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Faculty of Sciences
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Master of Statistics

Masterthesis

Spatial analysis of age-specific disease counts

Bonaventure Neba Ngwa
Thesis presented in fulfillment of the requirements for the degree of Master of Statistics, specialization Epidemiology & Public Health Methodology

SUPERVISOR :
Prof. dr. Christel FAES

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Abstract

Spatial epidemiology involves the analysis of geographical health data in which the framework of disease mapping can be applied to map the incidence or mortality rates over areas. The aim of this study, is to obtain reliable estimates by applying a modeling framework which takes into account over-dispersion, non-linear age effect and spatial correlation using Bayesian hierarchical models. The health data consist of the incidence of Lung and Kidney cancer for each gender over different age groups in the states of Germany. The generalized linear mixed modeling (GLMM) framework was used to statistically analyze the data. Several models were fitted to the data and the Deviance Information Criterion (DIC) was used to select the best model. The Markov chain Monte Carlo (MCMC) methods were used to obtain parameter estimates, and based on the best model selected, the spatial relative risk and spatial age-specific relative risk for a given gender based on each organ's cancer incidence data was obtained.

Keywords; *Bayesian hierarchical spatial model; Disease mapping; Generalized linear mixed model (GLMM); MCMC method*

1 Introduction

Spatial epidemiology is the description and analysis of geographically indexed health data with respect to demographic, environmental, behavioral, socioeconomic, genetic and infectious risk factors (Elliott and Wartenberg, 2004). When interest is in modeling and mapping of small-area disease incidence or prevalence, it is termed disease mapping. The main focus in spatial modeling is to obtain reliable statistical estimates of the disease risk over each region based on the number of observed cases for each region. Bayesian hierarchical models has mostly been used in disease mapping whereby the number of cases is assumed to be Poisson distributed, and modeling is done by aggregating the number of disease cases over the age groups in each area. It is known as the traditional method, but when comparing several areas that are different based on age distribution, standardization is employed because age mostly influences the risk of diseases. In the traditional method, a single estimate is obtained for each area hence assuming all age groups are affected by the disease similarly but this may not always be true because children and the elderly may not be similarly affected by a disease hence models which include age groups, area by age interactions have been considered by some researchers. From literature, Silva and Dean (2012) made used of splines in modeling disease incidence rates by age groups over regions and explained that it is flexible and advantageous because it allows less number of parameters in the model, but concluded that a model with dummy age group is preferred when there are many age groups. Nandram et al (2000), studied the mortality rates for chronic obstructive pulmonary disease in local health areas and modeled the age effects as independent random effects. Goicoa et al (2016), analyzed prostate cancer mortality rate in 50 Spanish provinces by time period, age group and considered space–time, space–age and age–time interactions. They made used of a CAR prior for space and a first order random walk process for the time period and also for age group. Sun et al (2000), in their study considered age-space-time interaction and age was modeled as fixed effect. Dean et al (2001), made used of unstructured random effects for area by age interaction and also considered a CAR prior for spatial effects. The Poisson regression is often used in spatial analysis, but it is usually faced with short comings of over-dispersion since counts data often display over-dispersion (Faes, 2016-2017). The aim of this study is to model disease incidence rates by age-groups over regions taking into account (i) over-dispersion, (ii) spatial correlation, (iii) non-linear age-specific effect and using hierarchical Bayesian spatial models. The generalized linear mixed modeling framework, will be applied in estimating lung and kidney cancer rates in the states of Germany. Cancer is known as the uncontrolled growth of cells which can spread and invade other parts of our body leading to severe health consequences and is one of the most leading cause of death as stated by the World Health Organization (WHO). In Germany, lung cancer is one of the most common type of cancer among both men and women, accounting for 25% of deaths due to cancer, while it is the third most common among women (14%) (Kaatsch et al, 2016). Among all types of kidney tumors in adults, renal cell carcinomas (hypernephromas) occur most frequently, accounting for 90% of all cases (Kaatsch et al, 2016) hence the need for obtaining reliable risk estimates. This report consists of the following sections, in section 2 an exploration of the data set that was performed will be presented and the method to be used in modeling the count data will be explained. In section 3 the results obtained will be shown and discussed. Finally, section 4 contains the conclusion from the analysis.

1.1 Objectives of the study

The objective of this project is to model Lung/Kidney cancer incidence rates by age groups over the states of Germany instead of applying the traditional method which involves aggregating counts over the age groups in an area, and the method used should take into account the following;

- Overdispersion
- spatial correlation
- Non-linear age-specific effect, using hierarchical Bayesian spatial models

2 Methodology

2.1 Case study

The health data consist of Kidney and Lung cancer incidence from Germany obtained during the period 1998-2007. The data is made of 16 states of Germany and for each state the number of cases (Lung or Kidney cancer) and the population at risk for a given gender in an age group was recorded. The study is focus on the most recent incidence data that was recorded in 2007 which is made of 18 age groups for each gender, the age groups are classified as follows; $\leq 4, 5-9, 10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, \geq 85$ years. Figure 1, presents a plot of the number of cancer cases over all the states and gender by age group for each organ. It was observed that the effect of age group is non-linear and each of the first 8 age groups had zero mean incidence over all state. On figure 2, the incidence for each state was plotted against the age groups and a zero (0) mean incidence over both gender for the aforementioned age groups (first 8 age groups) was observed. In preliminary studies, when fitting the model to be used in analyzing the data, it failed to update and each of the early age groups was then removed sequentially until the model finally updated. Hence the first eight (8) age group categories was removed from the study.

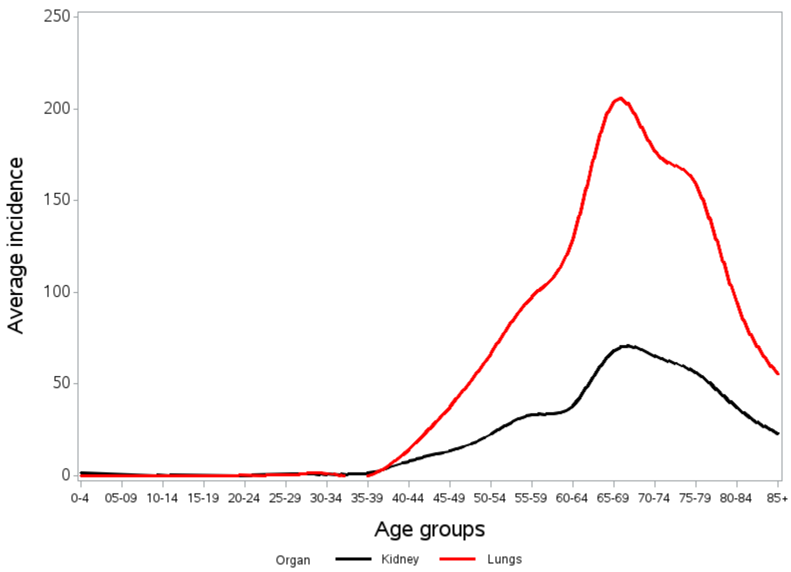

Figure 1: Average incidence for each organs' cancer by age groups over all states and gender.

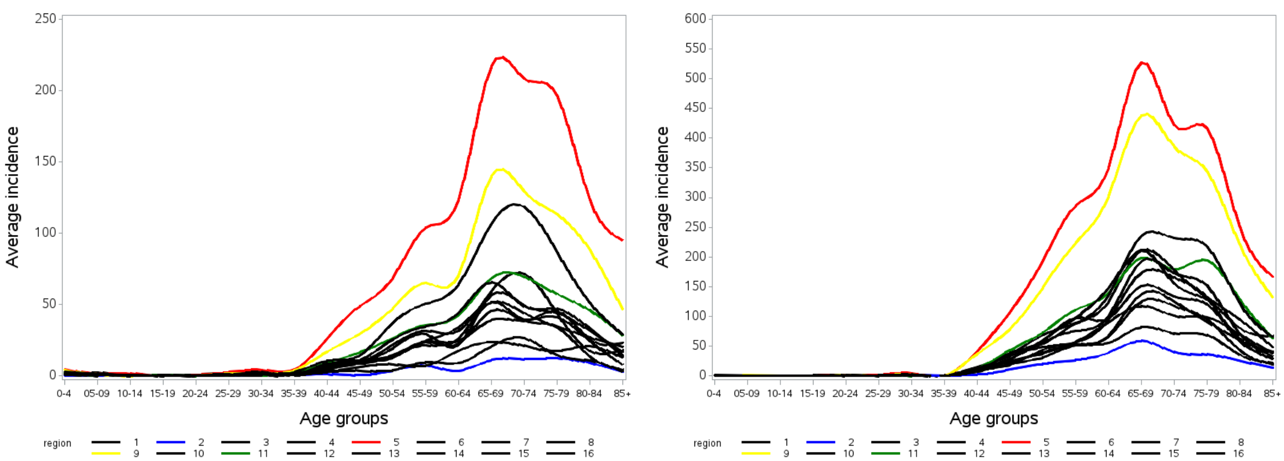

Figure 2: (a) Average Kidney cancer incidence for each state by age groups over both gender, (b) Average Lung cancer incidence for each state by age groups over both gender.

The following exploratory data analysis was performed on the incidence data based on the 7 variables described on table 1, that is, the response variable which is the number of cases for Kidney cancer and Lung cancer in 2007 (year) from Germany and four categorical variables which include age groups, states, gender and organs. The data set description on table 1, presents the 10 age group categories, 2 categories for gender (male and female) and 2 organs (Kidney and Lung). The population at risk given a gender for each age group belonging in each state was recorded.

Variables	description
Incidence (response variables)	Count
Age group(Age in years)	Categorical, 10 levels
40-44	1
45-49	2
50-54	3
55-59	4
60-64	5
65-69	6
70-74	7
75-79	8
80-84	9
85-85+	10
Time (years)	1 level 2007
Gender	Categorical, 2 levels
Female	1
Male	2
Organ	Categorical, 2 levels
Kidney	1
Lungs	2
Population	People at risk during the period

Table 1: Data set description

The description of each state can be seen on table 2, which presents the overall population of each state and the total number of cases over all age groups in a state for each gender. From table 2, states with id, 5 (Bavaria) and 9 (Niedersachsen) are those with most population and highest number of cases (summed over all 10 age groups) for each organ cancer given a gender. State 3 (Bremen), had the lowest overall population with the lowest counts for each organ's cancer given a gender while states 4 and 7 had no data. The data set for this study is made of, 16 states, 10 age group categories and 2 genders, giving a total of 320 observations for kidney cancer incidence data and also, Lung cancer incidence data. Two states had no data, hence there are 280 observations with data and 40 observations with no data. Incidence rate which is defined as the number of new cases per population at risk for a particular period was obtained. The mean incidence rates (the rates were multiplied by 10000) over all states for each gender by age group was obtained as shown on table 3. It was observed that the overall mean incidence rates of Kidney/Lung cancer for males were greater than that for females for each age group.

The plots of figure 3(a) and 4(a), represents the average log kidney/lung cancer incidence rate trend for each state by age group over both genders from which it was observed that state 10 (Nordrhein-Westfalen) has a lower average log cancer incidence rate trend from the other states while figure 3(b) and 4(b) represents the average log kidney/lung cancer incidence rate for each age group given a gender over all states. From these plots, it was observed that the effect of age group is non-linear, and males were observed to have higher rates than females. Also, it could be seen that as the age groups extend to higher age groups the incidence rate was also increasing which starts to decrease after age group 75-79.

State id	States	Population	Incidence (Kidney), Female	Incidence (Kidney), Male	Incidence (Lung), Female	Incidence (Lung), Male
1	Berlin	3,491,788	215	318	752	1158
2	Bremen	683,346	46	78	189	351
3	Brandenburg	2,600,077	237	385	420	1214
4	Baden-Wurttemberg	930,168	NA	NA	NA	NA
5	Bavaria(Bayern)	11,750,370	946	1480	1747	3782
6	Hamburg	1,690,974	110	163	517	770
7	Hessen	5,914,858	NA	NA	NA	NA
8	Mecklenburg-Vorpommern	1,933,738	146	271	300	885
9	Niedersachsen	7,574,522	563	932	1358	3269
10	Nordrhein-Westfalen(NRW)	3,084,474	185	281	464	1132
11	Rheinland-Pfalz	3,826,373	296	504	705	1580
12	Sachsen-Anhalt	2,887,746	223	341	423	1375
13	Sachsen(Saxony)	4,786,032	496	642	597	1828
14	Schleswig-Holstein	2,696,016	208	320	638	1387
15	Saarland	1,090,716	79	128	252	634
16	Thuringen	2,626,220	284	374	326	955

Table 2: Data set description of the states of Germany

	Age groups	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+
Kidney	Female	0.3551	0.4937	0.9975	1.7011	2.2076	4.2907	4.1286	5.6869	6.2294	4.2521
	Male	0.7777	1.1143	2.2002	3.6493	4.9386	10.0968	7.6992	9.3175	8.6416	8.113
Lung	Female	1.0529	2.2408	3.61599	5.43899	7.9544	11.2470	7.5678	11.0218	11.0144	8.9566
	Male	1.2669	3.0199	6.7829	11.3630	18.9749	36.2216	28.2118	37.9440	34.5333	31.1871

Table 3: The observed mean incidence rate (rates multiplied by 10000) over all regions for each age group by gender.

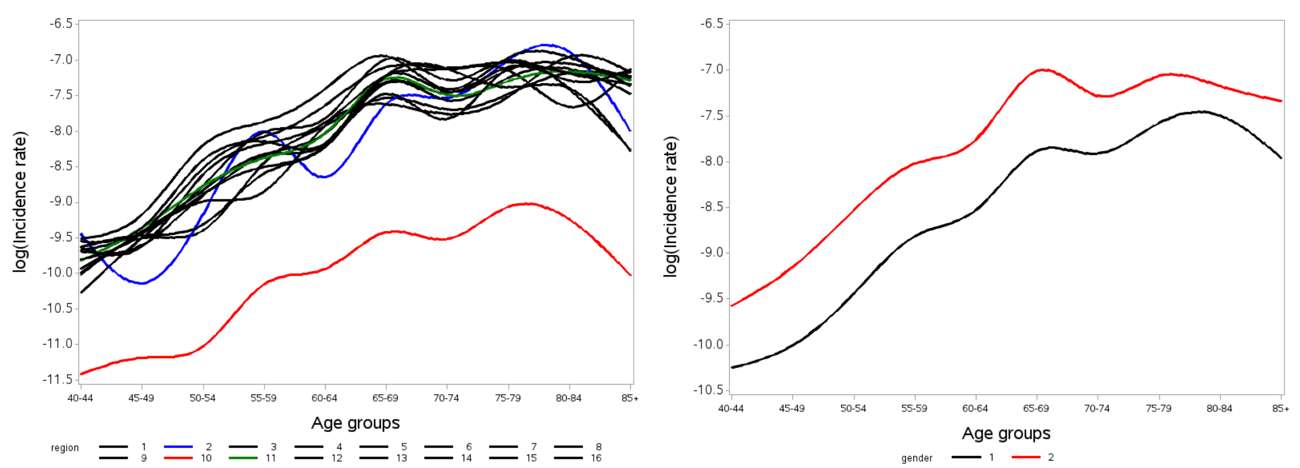

Figure 3: (a) Average log Kidney cancer incidence rate by age group for each state over both genders, (b) Average log Kidney cancer incidence rate by age group for each gender over all states.

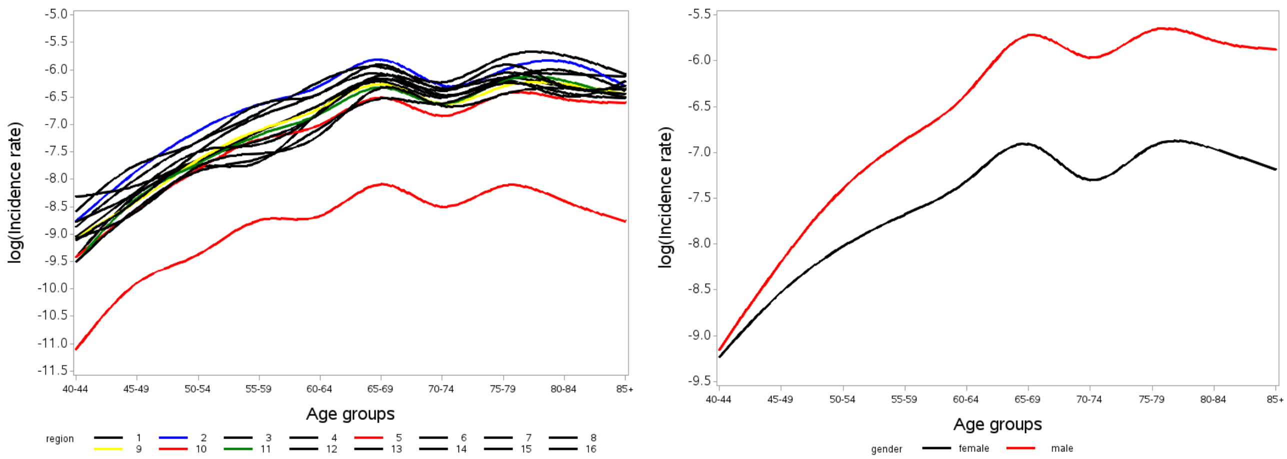

Figure 4: (a) Average log lung cancer incidence rate by age group for each state over both genders, (b) Average log lung cancer incidence rate by age group for each gender over all states.

2.2 Method

The traditional framework in which the number of disease cases is aggregated over all age groups for each state and modeled, assumes that, the observed number of cases is Poisson distributed. Standardization based on age is often applied, whereby the observed number of cases is compared with the expected number of cases from a standard population. The estimate of the small area effect is often obtained by taking the ratio of the observed and expected number of cases for each state (Faes, 2016-2017).

The spatial age-specific modeling of Kidney/Lungs cancer incidence rate given a gender described here and applied to the data is based on the generalized linear mixed modeling framework. Researchers agreed on the use of Poisson regression when the response variable is count. For example if we assume that Y is the number of disease cases observed, which is count and non-negative, the count is often assumed to be Poisson distributed as expressed in equation 1, with a parameter μ.

$$P(Y = y) = \frac{exp(-\mu)\mu^y}{y!} \tag{1}$$

where, $y = 0, 1, 2, ...$

and $\mu = E(Y)$, is the expected number of disease cases, which is positive.

Therefore, based on the data as described above, let Y_{ijk} be the observed number of cancer (Kidney/lung) cases, n_{ijk} the population at risk and r_{ijk} the incidence rate for a given gender k, within age group j, belonging in the i^{th} state. Where, i=state, with 16 states, j= age groups, made of 10 categories and k= gender, of 2 categories. Hence, conditioned on the incidence rate the expected number of cases μ_{ijk}, which is often modeled with a log link function was assumed to be Poisson distributed as shown below;

$$Y_{ijk}|r_{ijk} \sim poisson(\mu_{ijk} = n_{ijk} * r_{ijk}) \tag{2}$$

$$log(\mu_{ijk}) = log(n_{ijk}) + log(r_{ijk}) \tag{3}$$

Based on equation 3, the $log(n_{ijk})$ term is an offset and different models were fitted to the data depending on the specification of $log(r_{ijk})$. The Poisson distribution is often faced with the shortcoming of over-dispersion when used in modeling and also the effect of age group is non-linear, hence the following was considered in modeling the incidence rates.

1. **Non-linear age group effect**; From literature, age group has been modeled as an independent random effects and also a first order random walk process had been considered by some researchers in spatial analysis.

2. **Over-dispersion**; The Poisson distribution assumes that the mean should be equal to the variance. When the variance is larger than the mean, it is known as over-dispersion which may inflate the standard errors hence giving a poor fit of the model to the data. The inclusion of state-level random effects usually accounts for the extra variability in the data. Hence the covariate "states" was included into the model as random effects to account for unstructured and structured extra-Poisson variation.

3. **Unstructured heterogeneity**; The unstructured heterogeneity in disease mapping is modeled as random effects which is usually assign a prior distribution (explained in subsection 2.3) hence was assumed to be normally distributed, with mean zero (0) and a variance parameter. The random effects represent the residual relative risk for each state, and the variance parameter captures the extra variation present in the data. In understanding the effect of each age group by state and that of each gender by state, an unstructured interaction between the covariates "states" by "age group" and also "states" by "gender" was considered.

4. **Spatial correlated (structured) heterogeneity**; It is related to the location of the states. Spatial autocorrelation measures the dependency between states, that is, states that are closer (neighboring area) may have similar effects than states that are far apart (Faes, 2016-2017). Spatially structured random effects was included in the model to take into consideration that states which are closer could be correlated. It was assumed that the effect of the covariates for each state does not depend on its neighbors hence no structured interaction was employed to fit a less complex model with simple interpretation and also to avoid over modeling the data.

5. **Convolution model**; Including both structured and unstructured random effects explained above into the model is known as a convoluted model. Therefore, the ratio of the variance for the residual relative rate (spatial correlated random effect and unstructured) can be computed to allow the model to give an insight on which of the heterogeneity dominates more (Faes, 2016-2017).

The following models was then fitted to the data ;

$$Model \quad 1; \quad log(\mu_{ijk}) = \alpha_0 + \beta_j + \gamma_2 S_2 + h_i + b_i + log(n_{ijk}) \tag{4}$$
$$Model \quad 2; \quad log(\mu_{ijk}) = \alpha_0 + \beta_j + \gamma_2 S_2 + \lambda_{jk} + h_i + b_i + log(n_{ijk}) \tag{5}$$
$$Model \quad 3; \quad log(\mu_{ijk}) = \alpha_0 + \beta_j + \gamma_2 S_2 + \lambda_{jk} + \delta_{ij} + \psi_{ik} + h_i + b_i + log(n_{ijk}) \tag{6}$$
$$Model \quad 4; \quad log(\mu_{ijk}) = \alpha_0 + \beta_j^1 + \gamma_2 S_2 + \lambda_{jk} + \delta_{ij} + \psi_{ik} + h_i + b_i + log(n_{ijk}) \tag{7}$$

where,

- S_2 : is the dummy variable created for the k^{th} gender.

$$S_2 = \begin{cases} 0, & \text{if gender, } k = 1 \\ 1, & \text{if } k = 2 \end{cases} \tag{8}$$

- α_0 is the overall expected log cancer incidence rate for females (given that gender, $k = 1$, is the reference).
- γ_2 is the main effect of gender given that $k = 2$
- β_j represents age group effect which is modeled as independent random effects (for models 1, 2 and 3).

$$\beta_j \sim N(0, \sigma_\beta^2) \tag{9}$$

- h_i represents unstructured random effects for the states variable, assumed to be normally distributed with a mean of zero (0) and variance σ_h^2.

$$h_i \sim N(0, \sigma_h^2) \tag{10}$$

- The parameters λ_{jk}, δ_{ij} and ψ_{ik} are unstructured random effects which deals with $agegroup-gender$, $states-agegroup$ and $states-gender$ interaction respectively. They were assumed to be normally distributed.

$$\lambda_{j(k=1)} \sim N(0, \sigma_{\lambda 1}^2), \quad \lambda_{j(k=2)} \sim N(0, \sigma_{\lambda 2}^2) \tag{11}$$
$$\delta_{i(j=1)} \sim N(0, \sigma_{\delta 1}^2), \quad ..., \quad \delta_{i(j=10)} \sim N(0, \sigma_{\delta 10}^2) \tag{12}$$
$$\psi_{i(k=1)} \sim N(0, \sigma_{\psi 1}^2), \quad \psi_{i(k=2)} \sim N(0, \sigma_{\psi 2}^2) \tag{13}$$

  The variance parameter, $\sigma_{\lambda 1}^2, \sigma_{\lambda 2}^2$ captures the variability of the covariate age group for each gender k as shown on equation 11, while $\sigma_{\delta 1}^2, ..., \sigma_{\delta 10}^2$ captures the variability of the states for a given age group (equation 12) and $\sigma_{\psi 1}^2, \sigma_{\psi 2}^2$ captures the variability of the states for a given gender (equation 13).

- b_i represent the spatially correlated random effect for each state. b_i was assigned a conditional autoregressive (CAR) prior with precision τ_b and variance σ_b^2 (explained in subsection 2.3).
- In model 4, β_j^1 represents the age group effect which is model as a first order random walk process as explained in subsection 2.3.

2.3 Bayesian hierarchical modeling

Bayesian hierarchical modeling approach was applied to make inference on the cancer rates based on the spatial age-specific model. In the Bayesian framework, inference is based on the posterior distribution which reflects a compromise between a prior distribution assumption and the likelihood (data information) (Silva and Dean, 2012). It is known as hierarchical Bayesian model because the information for each observational unit (state) in the data are presented at different levels and parameter estimates are obtained using Bayesian method. The fixed (γ_2) and random effects (β_j, β_j^1, h_i, b_i, λ_{jk}, δ_{ij} and ψ_{ik}) as explain above are assumed to be random parameters which are given a prior distribution. The prior distribution could reflect our prior knowledge or beliefs on the parameters, but in practice when Markov chain Monte Carlo (MCMC) methods are employed in estimation of complex models the priors are usually specified as "non-informative" (Molenbergh and Verbeke, 2005). Non-informative priors express no knowledge about the parameters of interest to minimize their effect on statistical inference and examples of such priors include flat prior, vague/weak prior etcetera (Lesaffre and Lawson, 2012), hence these priors were used to allow learning from the data. More information on Bayesian hierarchical model, Bayesian inference and method can be read in the book of Lesaffre and Lawson, (2012) where they provide a good and comprehensive review of the Bayesian modeling framework.

2.3.1 Prior assumptions

In Bayesian modeling the variance is modeled as a precision parameter (τ) which is $1/variance$, hence the following prior distributions were assumed for each parameter;

- α_0 is assigned a flat prior
- γ_2 is assign a vague prior and assumed to be normally distributed, with $mean = 0$ and $precision = 1.0 * 10^{-6}$.
- λ_{jk} (with precision $\tau_{\lambda 1}$ and $\tau_{\lambda 2}$), δ_{ij} (with precision $\tau_{\delta 1}, ..., \tau_{\delta 10}$) and ψ_{ik} (with precision $\tau_{\psi 1}$ and $\tau_{\psi 2}$) were each assumed to be normally distributed and independent of each other and also, independent of the random effects β_j (β_j^1 for model 4), h_i and b_i. That is, all the random effects were assumed to be independent of each other. The corresponding variance parameter for each of the random effects can be seen on subsection 2.2.
- h_i and β_j was assumed to be normally distributed, with precision τ_h and τ_β
- b_i is assigned a conditional autoregressive (CAR) prior with precision τ_b. A conditional autoregressive (CAR) prior was assigned to the spatial correlated effects, that is the relative risk for state i is obtained as the average relative risk of the neighboring states ($\bar{b}_i$) to the i^{th} state with precision τ_b and variance σ_b^2, expressed as,

$$b_i | b_{l \neq i} \sim N(mean = \bar{b}_i, variance = \sigma_b^2), \quad where \quad l = neighboring \quad state \tag{14}$$

  The neighborhood structure was based on sharing boundary using the Queen's definition, in which a state (i) that shares a point or more than one point with another state is given a weight of 1 and zero if otherwise (Faes, 2016-2017).

- In model 4, β^1_j was assigned a first order random walk prior which reflect the prior belief that age group effect could be correlated expressed as;

$$\beta^1_j|\beta^1_{-j} \sim N(mean = \beta^1_{j+1}, \quad variance = \sigma^2_{\beta^1}) \quad for \quad j = 1 \tag{15}$$

$$\beta^1_j|\beta^1_{-j} \sim N(mean = (\beta^1_{j-1} + \beta^1_{j+1})/2, \quad variance = \sigma^2_{\beta^1}/2) \quad for \quad j = 2, ..., j = 9 \tag{16}$$

$$\beta^1_j|\beta^1_{-j} \sim N(mean = \beta^1_{j-1}, \quad variance = \sigma^2_{\beta^1}) \quad for \quad j = 10 \tag{17}$$

  where, β^1_{-j} represents all the parameters of β^1 ($\beta^1 = \beta^1_1, ..., \beta^1_{10}$) except β^1_j itself, hence the age group effect for age group j is obtained as the average of the neighboring age groups. The prior was specified in $WinBUGS$ with a CAR normal distribution, with precision τ_{β^1} and the neighboring age groups to a particular age group, j was either $j-1$ or $j+1$ or both. More on the random walk prior can be read in the work of Shaddick and Wakefield (2002) and implementation in $WinBUGS$ can be found in the pollution examples in *OpenBUGS* manual.

- The hyper-parameters ($\tau_{\delta 1}, ..., \tau_{\delta 10}, \tau_{\psi 1}, \tau_{\psi 2}, \tau_{\lambda 1}, \tau_{\lambda 2}, \tau_b, \tau_h, \tau_\beta, \tau_{\beta^1}$) were each assigned an inverse gamma prior, $IG(c, d)$ with scale parameter c and shape parameter d. Lesaffre and Lawson, (2012) explained that a gamma prior for the random effects *precision* is proper and non-informative when c and d is small hence giving a posterior which is proper. Kelsall and Wakefield (1999) suggested that a gamma distribution with scale parameter, 0.5 and shape parameter, 0.0005 should be used for modeling the precision of the spatial random effects in a CAR model and argue that this prior is a reasonable choice for the estimation of relative risks within the class of gamma priors (Silva et al, 2008). Hence the precision parameters was each assigned an inverse gamma prior, $IG(0.5, 0.0005)$.

- Two MCMC chains were used for the Kidney incidence data with each having 80,000 samples, and a burn-in of 40000 iterations was applied to each chain. (for models 1, 2 and 3)

- Two MCMC chains were used for the Lung incidence data with each having 100,000 samples, and a burn-in of 75000 iterations was applied to each chain. (for models 1, 2 and 3)

- In model 4, two MCMC chains were used for both data with each having 40,000 samples, and a burn-in of 20000 iterations was applied to each chain.

- The Brooks-Gelman-Rubin (BGR) diagnostic was used to assess convergence of the chains (Lesaffre and Lawson, 2012)

Based on the joint posterior distribution of each model, sampling using MCMC methods was employed, the mostly used method is the Gibbs sampler, which works by drawing samples from the full conditional distribution of each random variable given the other random variables (more on Gibbs sampling can be found in Lesaffre and Lawson, (2012)).
The several models shown above were fitted to both data and model comparison was based on Deviance Information Criterion (DIC) proposed by Spielgelhalter et al (2002). It is computed as the difference of the expected posterior deviance and the effective number of parameters hence measuring the goodness of fit and complexity of the model, respectively (Silva and Dean, 2012). Model 1 was fitted with fixed effects of gender, independent random effects for age group without

any interactions and also including random effects for unstructured heterogeneity (h_i) and spatially correlated random effects (b_i). The interaction between age group and gender was added as random effects in model 1 to obtain model 2. Model 2 was then extended by including interaction of state by age group and state by gender (as unstructured random effects) which gave rise to model 3. Model 4 is similar to model 3 but the only difference is, the effect of age group was modeled using a first order random walk process.

2.4 Interpretation of model parameters

The fixed and random effects combine gives the expected log cancer incidence rate for each gender, within an age group in a state. Therefore, the regression coefficient γ_2 (the fixed effect) can only be interpreted conditioned on the random effects. The random effects $(b_i + h_i)$ represents the unobserved variation (structured and unstructured variation) for each state that was not captured by covariates in the model. Silva and Dean (2012) explained that the relative risk for each state can be obtain by taking the exponent of these effect ($\exp^{b_i+h_i}$), hence the spatial relative risks for a given gender (RRf for female and RRm for male) in a state can be obtained by using the following equation;

$$RRf_{i|k=1} = \exp^{\psi_{i1}+b_i+h_i} \tag{18}$$

$$RRm_{i|k=2} = \exp^{\psi_{i2}+b_i+h_i} \tag{19}$$

Another parameter of interest is the interaction between each state and each level of the covariates, that is age group (δ_{ij}) and gender (ψ_{ik}) in order to understand their effect on each state. Since the log link function was used in modeling, the spatial age-specific relative risk (SA) for each state given a gender (either male, SAM or female, SAF) was obtained using the following equation;

$$SA_{i|jk} = \exp^{\delta_{ij}+\psi_{ik}+b_i+h_i} \tag{20}$$

Hence, based on equation 20 the spatial age-specific relative risk for male and female in age group 7 for each state was obtained that is $RR7m$ and $RR7f$ respectively.

$$RR7f_{(i|j=7,k=1)} = \exp^{\delta_{i7}+\psi_{i1}+b_i+h_i} \tag{21}$$

$$RR7m_{(i|j=7,k=2)} = \exp^{\delta_{i7}+\psi_{i2}+b_i+h_i} \tag{22}$$

Therefore, depending on an age group and gender of interest, the relative risk for each state can be obtained. The relative spatial variation contribution between the structured and unstructured heterogeneity was obtained using the following expression,

$$fraction = \frac{\sigma_b}{\sigma_b + \sigma_h} \tag{23}$$

If the $fraction$ is close to 1 then the structured variation contribution dominates and if it is close to zero then it is small.

2.5 Sensitivity analysis

After selecting the best model for each cancer incidence data, a simple sensitivity analysis was made to observe the influence of the hyper-priors' assumptions by varying the scale parameter c and shape parameter d of the prior distribution, $IG(c, d)$. The following 3 sets of the prior specification was used for c and d, $A = (0.5, 0.0005), B = (0.001, 0.001), C = (0.1, 0.1)$. All hyper-parameters were given the same set, that is set A, was given to all hyper-parameters of the inverse gamma prior and the variance of each hyper-parameter obtained (same with the other sets). Silva et al, (2008) pointed out that it is important to look at the sensitivity of model selection based on DIC with respect to the assumed prior for the hyper-parameters, to see if the model selected changed also, therefore this was also performed.

2.6 Software

- The Bayesian statistical analysis was performed using the software $WinBUGS$, dataset exploration was performed using SAS and *RStudio* was used to produce maps.

3 Results and discussion

The DIC of each model fitted to the data can be seen on table 4. DIC was used to select amongst these models that which fits the data better than the others. The model with smallest DIC is consider better than those with higher DIC (Spielgelhalter et al, 2002). Based on DIC, it can be observed that the model with lowest DIC for both cancer incidence data is model 3 and inference was based on this preferred model.

Organ	Models	DIC
Kidney	Model 1; $log(\mu_{ijk}) = \alpha_0 + \beta_j + \gamma_2 S_2 + h_i + b_i + log(n_{ijk})$	1767.57
	Model 2; $log(\mu_{ijk}) = \alpha_0 + \beta_j + \gamma_2 S_2 + \lambda_{jk} + h_i + b_i + log(n_{ijk})$	1743.79
	Model 3; $log(\mu_{ijk}) = \alpha_0 + \beta_j + \gamma_2 S_2 + \lambda_{jk} + \delta_{ij} + \psi_{ik} + h_i + b_i + log(n_{ijk})$	**1706.79**
	Model 4; $log(\mu_{ijk}) = \alpha_0 + \beta_j^1 + \gamma_2 S_2 + \lambda_{jk} + \delta_{ij} + \psi_{ik} + h_i + b_i + log(n_{ijk})$	1707.60
Lung	Model 1; $log(\mu_{ijk}) = \alpha_0 + \beta_j + \gamma_2 S_2 + h_i + b_i + log(n_{ijk})$	2933.11
	Model 2; $log(\mu_{ijk}) = \alpha_0 + \beta_j + \gamma_2 S_2 + \lambda_{jk} + h_i + b_i + log(n_{ijk})$	2428.06
	Model 3; $log(\mu_{ijk}) = \alpha_0 + \beta_j + \gamma_2 S_2 + \lambda_{jk} + \delta_{ij} + \psi_{ik} + h_i + b_i + log(n_{ijk})$	**2088.88**
	Model 4; $log(\mu_{ijk}) = \alpha_0 + \beta_j^1 + \gamma_2 S_2 + \lambda_{jk} + \delta_{ij} + \psi_{ik} + h_i + b_i + log(n_{ijk})$	2089.34

Table 4: DIC of the various models fitted to the Kidney and Lung cancer incidence data

After assessing the convergence of the preferred model, the following results was obtained as shown below and the spatial relative risk for each gender (based on the equations in subsection 2.4) was obtained and mapped. The spatial age-specific relative risk for kidney cancer incidence rate and lung cancer incidence rate for each gender belonging in age group 7 was mapped as shown on the figures below.

3.1 Kidney cancer incidence rate results

The results of the fixed effect (for gender), random effects for age group and interaction effect between age group and gender can be seen on table 5. The MC error gives the variability of the parameter estimates due to the Markov chain variability. Researchers agreed that it should be less than 5% of the standard deviation (sd) for the parameter estimate. Molenberghs G. and Verbeke G. (2005) explained that in a generalized linear mixed modeling framework the fixed effects in the model are interpreted conditioned on the random effects. Based on the Bayesian confidence interval (known as credible interval) of the results obtained, the effect of gender is significantly different from zero (it is worth mentioning that the log link function was used in modeling, had it been that the exponent was taken then the parameter estimates will be observed if it is different from 1). The parameter γ_2 can be interpreted as, conditioned on the random effects the expected log kidney cancer incidence rate for males is 0.6699 higher than females. The parameter estimates of the age group and the interaction effects between age group and gender was presented using box plot on figure 5, which shows that the effect of age group is non-linear.

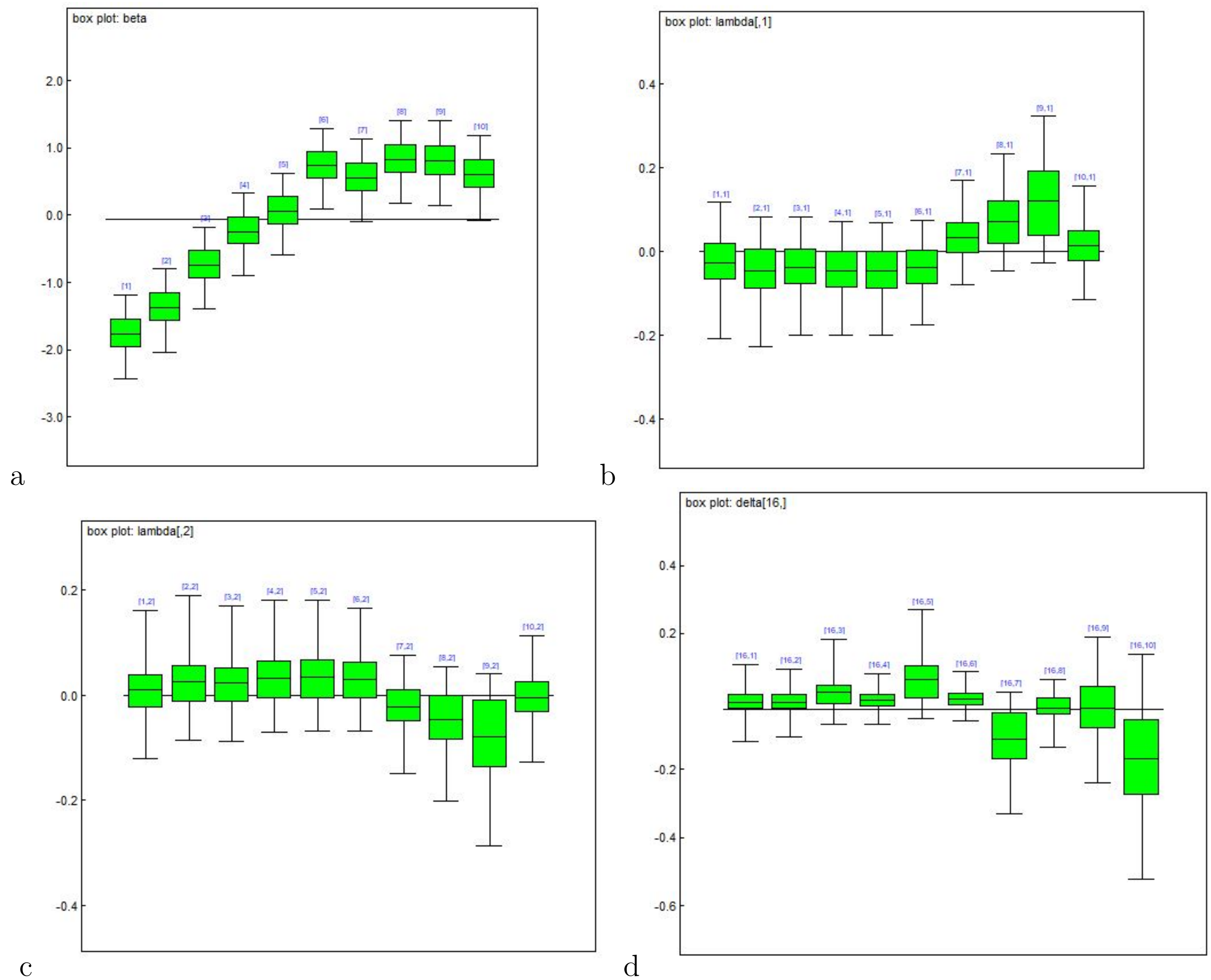

Figure 5: Box plot of the parameter estimates for (a) the global age group trend (b) the global age group trend for females (c) the global age group trend for males (d) the age group effect for state 16 over both genders (interaction between age group and state 16).

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
alpha0	-8.4720	0.3273	0.0157	-9.0410	-8.4960	-7.7700
beta[1]	-1.7590	0.3177	0.0145	-2.4240	-1.7430	-1.1860
beta[2]	-1.3680	0.3157	0.0146	-2.0290	-1.3530	-0.8011
beta[3]	-0.7388	0.3137	0.0146	-1.3960	-0.7245	-0.1786
beta[4]	-0.2405	0.3129	0.0146	-0.8864	-0.2248	0.3208
beta[5]	0.0632	0.3127	0.0146	-0.5823	0.0794	0.6237
beta[6]	0.7377	0.3109	0.0146	0.0896	0.7529	1.2900
beta[7]	0.5547	0.3121	0.0146	-0.0918	0.5659	1.1290
beta[8]	0.8292	0.3122	0.0146	0.1814	0.8418	1.4030
beta[9]	0.8052	0.3212	0.0146	0.1398	0.8149	1.4100
beta[10]	0.6035	0.3198	0.0144	-0.0686	0.6174	1.1870
gamma[2]	0.6699	0.0493	0.0009	0.5740	0.6692	0.7696
lambda[1,1]	-0.0277	0.0785	0.0007	-0.2080	-0.0176	0.1165
lambda[1,2]	0.0098	0.0655	0.0005	-0.1199	0.0052	0.1613
lambda[2,1]	-0.0471	0.0778	0.0009	-0.2273	-0.0332	0.0825
lambda[2,2]	0.0263	0.0665	0.0009	-0.0860	0.0148	0.1892
lambda[3,1]	-0.0398	0.0707	0.0008	-0.2014	-0.0293	0.0829
lambda[3,2]	0.0234	0.0616	0.0008	-0.0864	0.0141	0.1703
lambda[4,1]	-0.0465	0.0694	0.0010	-0.2008	-0.0362	0.0721
lambda[4,2]	0.0323	0.0625	0.0010	-0.0703	0.0204	0.1809
lambda[5,1]	-0.0475	0.0684	0.0010	-0.1996	-0.0374	0.0686
lambda[5,2]	0.0337	0.0619	0.0010	-0.0684	0.0219	0.1806
lambda[6,1]	-0.0394	0.0631	0.0011	-0.1764	-0.0320	0.0737
lambda[6,2]	0.0312	0.0582	0.0010	-0.0670	0.0212	0.1656
lambda[7,1]	0.0324	0.0620	0.0010	-0.0791	0.0253	0.1684
lambda[7,2]	-0.0224	0.0553	0.0009	-0.1500	-0.0146	0.0765
lambda[8,1]	0.0719	0.0740	0.0015	-0.0464	0.0632	0.2322
lambda[8,2]	-0.0473	0.0667	0.0013	-0.2024	-0.0324	0.0540
lambda[9,1]	0.1197	0.0984	0.0022	-0.0278	0.1121	0.3216
lambda[9,2]	-0.0798	0.0904	0.0021	-0.2878	-0.0544	0.0402
lambda[10,1]	0.0126	0.0652	0.0007	-0.1149	0.0083	0.1551
lambda[10,2]	-0.0040	0.0567	0.0005	-0.1270	-0.0024	0.1131

Table 5: Parameter estimates of age group, gender and age group by gender interaction effects with its standard deviation, MC error, lower and upper credible interval(Lower CI and Upper CI respectively)

The spatial relative risk for each gender and the spatial age-specific relative risk for each gender belonging in age group 7 as explained in subsection 2.4 was obtained (table 6 and 7) and mapped as presented below. Based on the spatial relative risk for females, it was observed that the states in which the relative risk is significantly different from 1 (base on their credible interval) and higher than 1 include state 13 (Sachsen) and 16 (Thuringen) while the state with low risk (relative risk significantly lower than 1) is state 10 (Nordrhein-Westfalen). For males the states with higher risk include state 8 (Mecklenburg-Vorpommern), 13 (Sachsen) and 16 (Thuringen) while state 10 (Nordrhein-Westfalen) had lower risk. For females within age group 7, the states with high risk include Brandenburg, Sachsen and Thuringen while Nordrhein-Westfalen had lower risk. For males in age group 7, Brandenburg, Mecklenburg-Vorpommern and Sachsen had high risk while state 10 (Nordrhein-Westfalen) had lower risk. An independent interval scheme as explained by Faes, (2016-2017) was used to classify the relative risk for each state into category and colors were used for each category and represented on a map. The color changes from light green (small risk) to dark red (higher risk) as the relative risk increases as seen on figure 6 and 7. The relative structured variance contribution between the structured and unstructured variation shows that both are important as seen on table 8 (from the $fraction$ estimate).

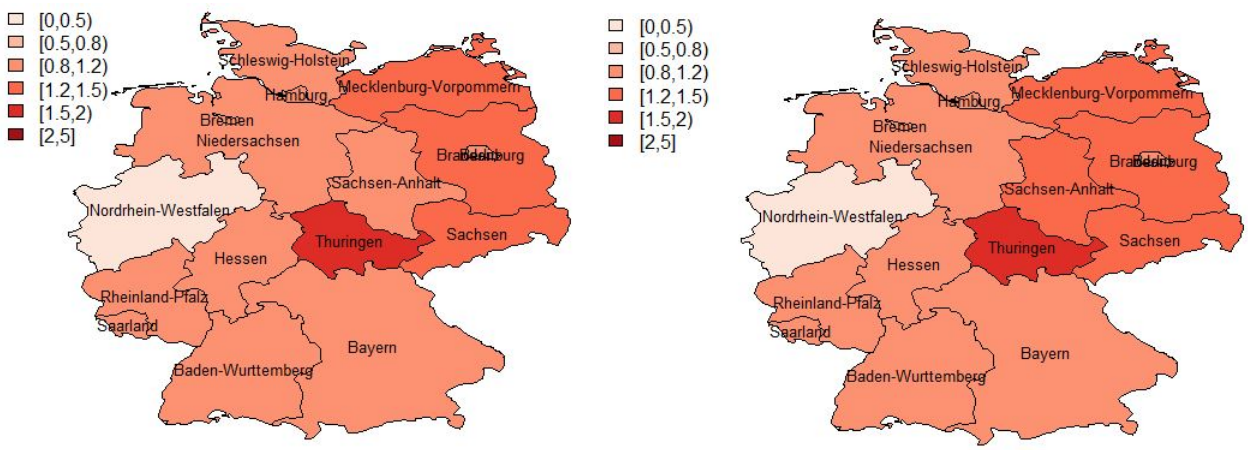

Figure 6: Plot of the spatial relative risk of Kidney Cancer incidence rate for females (a) and males (b).

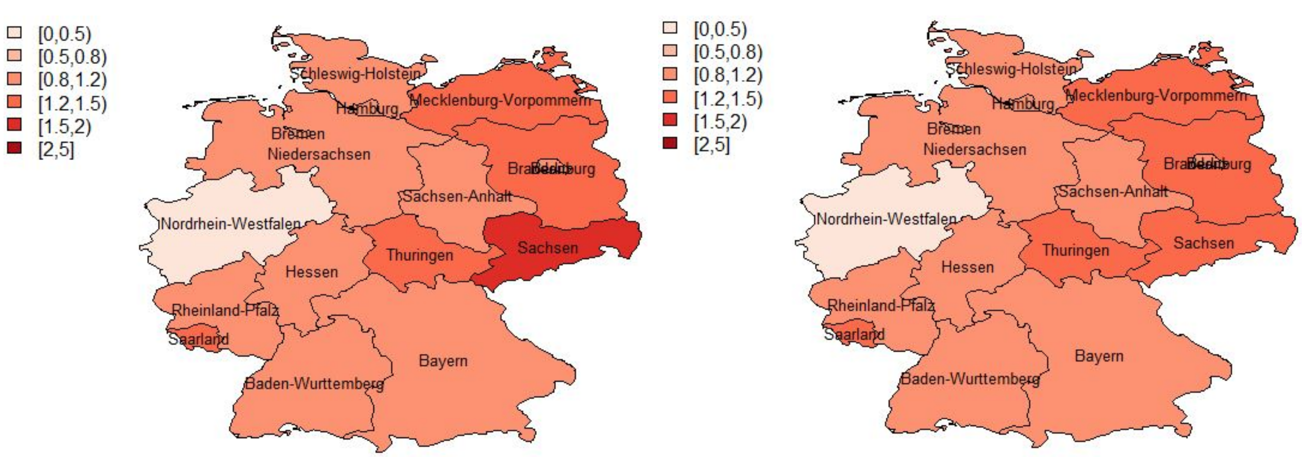

Figure 7: Plot of the spatial age-specific relative risk of Kidney Cancer incidence rate for females (a) and males (b) in age group 7 (70-74 years of age).

Table 6: Spatial relative risk of Kidney cancer incidence rate for females (RRf) and males (RRm).

States	Parameters	mean	sd	MC error	Lower CI	median	Upper CI
Berlin	RRf[1]	0.9483	0.1310	0.0050	0.6982	0.9463	1.2360
Bremen	RRf[2]	1.0530	0.1681	0.0055	0.7491	1.0430	1.4170
Brandenburg	RRf[3]	1.2670	0.1751	0.0067	0.9372	1.2620	1.6500
Baden-Wurttemberg	RRf[4]	1.1770	0.7877	0.0032	0.3213	0.9977	3.0930
Bavaria(Bayern)	RRf[5]	1.1160	0.1479	0.0060	0.8336	1.1150	1.4400
Hamburg	RRf[6]	0.9443	0.1389	0.0050	0.6859	0.9393	1.2470
Hessen	RRf[7]	1.0840	0.6912	0.0066	0.3366	0.9228	2.8080
Mecklenburg-Vorpommern	RRf[8]	1.3520	0.1906	0.0071	0.9960	1.3470	1.7670
Nierdersachsen	RRf[9]	1.0410	0.1394	0.0055	0.7757	1.0390	1.3480
Nordrhein-Westfalen(NRW)	RRf[10]	0.1578	0.0220	0.0008	0.1160	0.1573	0.2055
Rheinland-pfalz	RRf[11]	1.0770	0.1467	0.0057	0.8009	1.0720	1.4010
Sachsen-Anhalt	RRf[12]	1.1910	0.1649	0.0063	0.8777	1.1880	1.5480
Sachsen (Saxony)	RRf[13]	1.4490	0.1971	0.0077	1.0740	1.4440	1.8810
Schleswig-Holstein	RRf[14]	1.0100	0.1414	0.0053	0.7433	1.0060	1.3190
Saarland	RRf[15]	1.0670	0.1601	0.0056	0.7724	1.0610	1.4140
Thuringen	RRf[16]	1.5900	0.2202	0.0084	1.1730	1.5840	2.0730
Berlin	RRm[1]	0.9397	0.1277	0.0050	0.6948	0.9383	1.2240
Bremen	RRm[2]	1.0670	0.1679	0.0055	0.7622	1.0580	1.4320
Brandenburg	RRm[3]	1.2810	0.1745	0.0068	0.9515	1.2770	1.6640
Baden-Wurttemberg	RRm[4]	1.1770	0.7884	0.0031	0.3222	0.9972	3.0980
Bavaria(Bayern)	RRm[5]	1.1210	0.1469	0.0060	0.8395	1.1200	1.4430
Hamburg	RRm[6]	0.9443	0.1366	0.0050	0.6887	0.9398	1.2410
Hessen	RRm[7]	1.0840	0.6922	0.0067	0.3355	0.9229	2.8050
Mecklenburg-Vorpommern	RRm[8]	1.4090	0.1947	0.0074	1.0440	1.4030	1.8340
Nierdersachsen	RRm[9]	1.0700	0.1411	0.0057	0.7979	1.0680	1.3790
Nordrhein-Westfalen(NRW)	RRm[10]	0.1563	0.0215	0.0008	0.1155	0.1559	0.2031
Rheinland-pfalz	RRm[11]	1.1120	0.1491	0.0059	0.8289	1.1090	1.4370
Sachsen-Anhalt	RRm[12]	1.2040	0.1644	0.0064	0.8919	1.2020	1.5640
Sachsen (Saxony)	RRm[13]	1.3480	0.1801	0.0071	1.0070	1.3450	1.7470
Schleswig-Holstein	RRm[14]	1.0040	0.1382	0.0053	0.7416	1.0010	1.3060
Saarland	RRm[15]	1.0730	0.1585	0.0056	0.7800	1.0670	1.4170
Thuringen	RRm[16]	1.5100	0.2055	0.0079	1.1200	1.5050	1.9630

Table 7: Spatial relative risk of Kidney cancer incidence rate for females ($RR7f$) and males ($RR7m$) in age group 7.

States	Parameters	mean	sd	MC error	Lower CI	median	Upper CI
Berlin	RR7f[1]	0.9311	0.1411	0.0049	0.6705	0.9263	1.2370
Bremen	RR7f[2]	1.0650	0.1886	0.0056	0.7339	1.0520	1.4820
Brandenburg	RR7f[3]	1.4050	0.2169	0.0075	1.0150	1.3920	1.8840
Baden-Wurttemberg	RR7f[4]	1.1830	0.8135	0.0032	0.3145	0.9990	3.1650
Bavaria(Bayern)	RR7f[5]	1.1310	0.1571	0.0060	0.8358	1.1270	1.4720
Hamburg	RR7f[6]	0.9226	0.1495	0.0049	0.6519	0.9153	1.2490
Hessen	RR7f[7]	1.0900	0.7064	0.0067	0.3285	0.9240	2.8670
Mecklenburg-Vorpommern	RR7f[8]	1.3410	0.2058	0.0071	0.9642	1.3320	1.7880
Nierdersachsen	RR7f[9]	1.0340	0.1467	0.0055	0.7599	1.0300	1.3550
Nordrhein-Westfalen(NRW)	RR7f[10]	0.1523	0.0233	0.0008	0.1092	0.1514	0.2026
Rheinland-pfalz	RR7f[11]	1.0880	0.1598	0.0058	0.7950	1.0810	1.4380
Sachsen-Anhalt	RR7f[12]	1.1710	0.1755	0.0062	0.8484	1.1640	1.5520
Sachsen (Saxony)	RR7f[13]	1.5680	0.2303	0.0084	1.1440	1.5580	2.0700
Schleswig-Holstein	RR7f[14]	0.9285	0.1448	0.0050	0.6612	0.9239	1.2400
Saarland	RR7f[15]	1.2000	0.2150	0.0064	0.8336	1.1790	1.6880
Thuringen	RR7f[16]	1.4270	0.2242	0.0077	1.0150	1.4190	1.9100
Berlin	RR7m[1]	0.9228	0.1382	0.0049	0.6665	0.9181	1.2240
Bremen	RR7m[2]	1.0790	0.1889	0.0056	0.7476	1.0660	1.4950
Brandenburg	RR7m[3]	1.4210	0.2171	0.0076	1.0270	1.4080	1.8960
Baden-Wurttemberg	RR7m[4]	1.1840	0.8144	0.0032	0.3136	0.9989	3.1580
Bavaria(Bayern)	RR7m[5]	1.1350	0.1562	0.0060	0.8418	1.1310	1.4750
Hamburg	RR7m[6]	0.9226	0.1477	0.0049	0.6543	0.9152	1.2430
Hessen	RR7m[7]	1.0900	0.7079	0.0067	0.3283	0.9238	2.8540
Mecklenburg-Vorpommern	RR7m[8]	1.3970	0.2109	0.0074	1.0060	1.3890	1.8540
Nierdersachsen	RR7m[9]	1.0620	0.1491	0.0056	0.7823	1.0590	1.3900
Nordrhein-Westfalen(NRW)	RR7m[10]	0.1508	0.0228	0.0008	0.1088	0.1500	0.2000
Rheinland-pfalz	RR7m[11]	1.1230	0.1629	0.0059	0.8228	1.1180	1.4770
Sachsen-Anhalt	RR7m[12]	1.1840	0.1754	0.0063	0.8603	1.1790	1.5670
Sachsen (Saxony)	RR7m[13]	1.4590	0.2117	0.0078	1.0710	1.4500	1.9200
Schleswig-Holstein	RR7m[14]	0.9227	0.1421	0.0049	0.6599	0.9187	1.2280
Saarland	RR7m[15]	1.2070	0.2135	0.0065	0.8421	1.1860	1.6920
Thuringen	RR7m[16]	1.3550	0.2102	0.0073	0.9670	1.3480	1.8080

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
$\sigma^2_{\lambda 1}$	0.0093	0.0105	0.0002	0.0003	0.0063	0.0364
$\sigma^2_{\lambda 2}$	0.0064	0.0083	0.0002	0.0002	0.0032	0.0285
σ^2_{β}	1.0060	0.5725	0.0087	0.3891	0.8635	2.4690
$\sigma^2_{\delta 1}$	0.0034	0.0066	0.0001	0.0002	0.0013	0.0209
$\sigma^2_{\delta 2}$	0.0027	0.0048	0.0001	0.0002	0.0012	0.0154
$\sigma^2_{\delta 3}$	0.0035	0.0058	0.0001	0.0002	0.0015	0.0193
$\sigma^2_{\delta 4}$	0.0016	0.0021	0.0001	0.0002	0.0009	0.0073
$\sigma^2_{\delta 5}$	0.0075	0.0109	0.0001	0.0002	0.0036	0.0372
$\sigma^2_{\delta 6}$	0.0015	0.0020	0.0001	0.0002	0.0009	0.0068
$\sigma^2_{\delta 7}$	0.0116	0.0124	0.0002	0.0003	0.0079	0.0445
$\sigma^2_{\delta 8}$	0.0029	0.0040	0.0001	0.0002	0.0015	0.0136
$\sigma^2_{\delta 9}$	0.0313	0.0293	0.0004	0.0007	0.0240	0.1061
$\sigma^2_{\delta 10}$	0.0834	0.0643	0.0006	0.0099	0.0679	0.2474
$\sigma^2_{\psi 1}$	0.0020	0.0024	0.0001	0.0002	0.0011	0.0086
$\sigma^2_{\psi 2}$	0.0020	0.0026	0.0001	0.0002	0.0011	0.0089
σ^2_{b}	0.2178	0.4283	0.0189	0.0002	0.0043	1.4030
σ^2_{h}	0.2532	0.1820	0.0066	0.0004	0.2518	0.6530
$fraction$	0.3860	0.3854	0.0187	0.0249	0.1538	0.9812

Table 8: Variance components of the Kidney cancer incidence data.

3.2 Lung cancer incidence rate results

From the results obtained, the fixed effect parameter γ_2 is interpreted conditioned on the random effects, that is the expected log lung cancer incidence rate for males is 0.8996 higher than females. Box plot was used to show the parameter estimates of age group, gender and the interaction effect of both covariate age group and gender (figure 8). From the plots, the effect of age group is non-linear. The spatial relative risk for females and males can be seen on table 10, where it was observed that for females, states 1 (Berlin), 2 (Bremen), 6 (Hamburg) and 15 (Saarland) are those with higher risk (significantly greater than 1 based on the credible interval) while state 10 (Nordrhein-Westfalen) had lower risk. For males, states 2 (Bremen), 12 (Sachsen-Anhalt) and 15 (Saarland) had higher risk while Nordrhein-Westfalen was observed to have lower risk. On table 11, the spatial age-specific relative risk of lung cancer incidence rate for a given gender in age group 7 was presented. For females, the states Berlin, Bremen, Hamburg and Saarland are those with higher risk while Nordrhein-Westfalen had lower risk. For males in age group 7, the state Bremen, Mecklenburg-Vorpommern, Sachsen-Anhalt and Saarland had higher risk while states 5 (Bayern) and 10 (Nordrhein-Westfalen) had lower risk. The results of the spatial risk were mapped and shown on figure 9 and 10. The complete results of the random effects for the interaction terms and the spatial age-specific relative risk for each gender (for both data) can be seen in the appendix. The results of the relative variance components also show that both structured and unstructured heterogeneity are important.

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
alpha0	-7.5480	0.2186	0.0119	-8.0230	-7.5510	-7.1250
beta[1]	-1.7160	0.2314	0.0111	-2.2240	-1.7070	-1.2770
beta[2]	-1.0200	0.2200	0.0110	-1.5000	-1.0120	-0.6025
beta[3]	-0.4423	0.2139	0.0109	-0.9050	-0.4376	-0.0215
beta[4]	-0.1071	0.2198	0.0111	-0.5960	-0.1015	0.3153
beta[5]	0.2891	0.2145	0.0112	-0.1803	0.2976	0.6956
beta[6]	0.6641	0.2112	0.0111	0.2253	0.6643	1.0780
beta[7]	0.2781	0.2154	0.0113	-0.1978	0.2841	0.6800
beta[8]	0.6309	0.2160	0.0113	0.1568	0.6342	1.0640
beta[9]	0.6109	0.2144	0.0109	0.1529	0.6162	1.0270
beta[10]	0.4299	0.2178	0.0109	-0.0343	0.4346	0.8523
gamma[2]	0.8996	0.1467	0.0077	0.6213	0.8965	1.2040
lambda[1,1]	0.0111	0.0742	0.0015	-0.1155	0.0038	0.1909
lambda[1,2]	-0.7362	0.1797	0.0071	-1.1170	-0.7311	-0.3967
lambda[2,1]	0.0085	0.0690	0.0016	-0.1183	0.0032	0.1749
lambda[2,2]	-0.4874	0.1583	0.0070	-0.8171	-0.4834	-0.1865
lambda[3,1]	0.0088	0.0665	0.0017	-0.1114	0.0035	0.1671
lambda[3,2]	-0.3091	0.1536	0.0071	-0.6331	-0.3065	-0.0187
lambda[4,1]	0.0041	0.0693	0.0021	-0.1239	0.0012	0.1501
lambda[4,2]	-0.0964	0.1525	0.0073	-0.4036	-0.0933	0.1912
lambda[5,1]	0.0028	0.0663	0.0022	-0.1303	0.0011	0.1513
lambda[5,2]	0.0090	0.1534	0.0075	-0.3125	0.0114	0.3063
lambda[6,1]	-0.0086	0.0620	0.0020	-0.1687	-0.0024	0.1001
lambda[6,2]	0.2710	0.1518	0.0076	-0.0501	0.2736	0.5605
lambda[7,1]	-0.0060	0.0705	0.0027	-0.1666	-0.0037	0.1390
lambda[7,2]	0.4225	0.1526	0.0076	0.0807	0.4287	0.7156
lambda[8,1]	-0.0058	0.0728	0.0027	-0.1604	-0.0030	0.1244
lambda[8,2]	0.3937	0.1524	0.0075	0.0714	0.3977	0.6894
lambda[9,1]	-0.0036	0.0693	0.0024	-0.1492	-0.0010	0.1298
lambda[9,2]	0.2889	0.1592	0.0077	-0.0642	0.2948	0.5870
lambda[10,1]	-0.0039	0.0720	0.0021	-0.1643	-0.0022	0.1352
lambda[10,2]	0.3755	0.1579	0.0072	0.0511	0.3788	0.6863

Table 9: Parameter estimates of age group and gender effects with interaction for both.

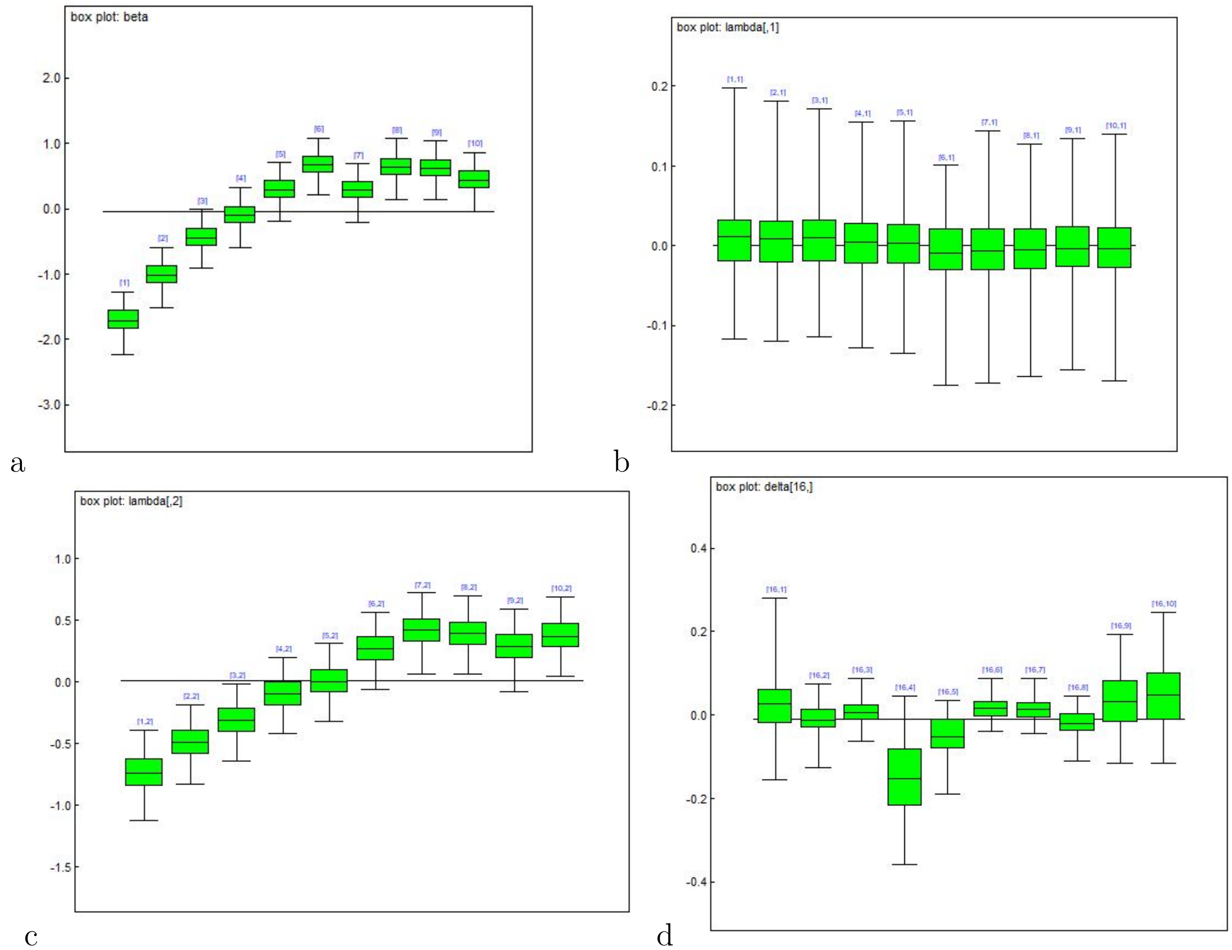

Figure 8: Box plot of the parameter estimates for (a) the global age group trend (b) global age group trend for females (c) the global age group trend for males (d) the age group effect for state 16 over both genders (interaction between age group and state 16).

Table 10: Spatial relative risk of Lung cancer incidence rate for females (RRf) and males (RRm).

States	Parameters	mean	sd	MC error	Lower CI	median	Upper CI
Berlin	RRf[1]	1.4150	0.1989	0.0097	1.0340	1.4200	1.8300
Bremen	RRf[2]	1.6750	0.2575	0.0115	1.1980	1.6690	2.2160
Brandenburg	RRf[3]	0.9892	0.1436	0.0068	0.7180	0.9892	1.2890
Baden-Wurttemberg	RRf[4]	1.1280	0.7912	0.0065	0.2932	0.9406	3.0550
Bavaria(Bayern)	RRf[5]	0.8798	0.1221	0.0060	0.6473	0.8820	1.1340
Hamburg	RRf[6]	1.9210	0.2750	0.0131	1.4010	1.9200	2.4910
Hessen	RRf[7]	1.0410	0.7363	0.0115	0.3056	0.8548	2.8700
Mecklenburg-Vorpommern	RRf[8]	1.1050	0.1625	0.0076	0.8002	1.1040	1.4420
Nierdersachsen	RRf[9]	1.0460	0.1459	0.0072	0.7687	1.0480	1.3500
Nordrhein-Westfalen(NRW)	RRf[10]	0.1626	0.0236	0.0011	0.1180	0.1628	0.2114
Rheinland-pfalz	RRf[11]	1.0570	0.1499	0.0072	0.7738	1.0570	1.3690
Sachsen-Anhalt	RRf[12]	0.9987	0.1443	0.0068	0.7271	0.9979	1.2960
Sachsen (Saxony)	RRf[13]	0.7964	0.1134	0.0054	0.5813	0.7973	1.0310
Schleswig-Holstein	RRf[14]	1.3160	0.1875	0.0090	0.9624	1.3170	1.7020
Saarland	RRf[15]	1.4150	0.2121	0.0097	1.0180	1.4120	1.8610
Thuringen	RRf[16]	0.8243	0.1207	0.0056	0.5974	0.8240	1.0760
Berlin	RRm[1]	0.9524	0.1285	0.0064	0.7047	0.9568	1.2200
Bremen	RRm[2]	1.3990	0.1999	0.0094	1.0220	1.3980	1.8130
Brandenburg	RRm[3]	1.1790	0.1615	0.0080	0.8716	1.1810	1.5150
Baden-Wurttemberg	RRm[4]	1.1130	0.7498	0.0063	0.3067	0.9385	2.9480
Bavaria(Bayern)	RRm[5]	0.7987	0.1075	0.0054	0.5921	0.8015	1.0210
Hamburg	RRm[6]	1.2680	0.1756	0.0086	0.9318	1.2700	1.6310
Hessen	RRm[7]	1.0260	0.6891	0.0111	0.3205	0.8562	2.7520
Mecklenburg-Vorpommern	RRm[8]	1.3450	0.1853	0.0091	0.9957	1.3460	1.7330
Nierdersachsen	RRm[9]	1.0410	0.1401	0.0070	0.7752	1.0450	1.3320
Nordrhein-Westfalen(NRW)	RRm[10]	0.1675	0.0229	0.0011	0.1240	0.1678	0.2149
Rheinland-pfalz	RRm[11]	0.9859	0.1338	0.0066	0.7304	0.9874	1.2640
Sachsen-Anhalt	RRm[12]	1.3760	0.1876	0.0093	1.0190	1.3780	1.7650
Sachsen (Saxony)	RRm[13]	1.0340	0.1402	0.0070	0.7648	1.0360	1.3230
Schleswig-Holstein	RRm[14]	1.1740	0.1605	0.0079	0.8692	1.1770	1.5060
Saarland	RRm[15]	1.4910	0.2075	0.0100	1.0980	1.4930	1.9190
Thuringen	RRm[16]	1.0190	0.1398	0.0068	0.7515	1.0200	1.3080

Table 11: Spatial age-specific relative risk of Lung cancer incidence for females ($RR7f$) and males ($RR7m$) in age group 7.

States	Parameters	mean	sd	MC error	Lower CI	median	Upper CI
Berlin	RR7f[1]	1.4140	0.2025	0.0097	1.0310	1.4160	1.8360
Bremen	RR7f[2]	1.6570	0.2589	0.0114	1.1820	1.6500	2.1990
Brandenburg	RR7f[3]	1.0070	0.1480	0.0069	0.7281	1.0060	1.3120
Baden-Wurttemberg	RR7f[4]	1.1290	0.7924	0.0065	0.2926	0.9418	3.0510
Bavaria(Bayern)	RR7f[5]	0.8539	0.1196	0.0058	0.6269	0.8555	1.1030
Hamburg	RR7f[6]	1.9110	0.2774	0.0130	1.3920	1.9090	2.4900
Hessen	RR7f[7]	1.0420	0.7394	0.0115	0.3051	0.8560	2.8770
Mecklenburg-Vorpommern	RR7f[8]	1.1210	0.1674	0.0077	0.8075	1.1180	1.4690
Nierdersachsen	RR7f[9]	1.0420	0.1463	0.0071	0.7637	1.0430	1.3470
Nordrhein-Westfalen(NRW)	RR7f[10]	0.1622	0.0238	0.0011	0.1172	0.1622	0.2112
Rheinland-pfalz	RR7f[11]	1.0430	0.1500	0.0072	0.7617	1.0430	1.3550
Sachsen-Anhalt	RR7f[12]	1.0120	0.1481	0.0069	0.7341	1.0100	1.3160
Sachsen (Saxony)	RR7f[13]	0.8118	0.1171	0.0056	0.5909	0.8121	1.0540
Schleswig-Holstein	RR7f[14]	1.3160	0.1895	0.0090	0.9577	1.3150	1.7080
Saarland	RR7f[15]	1.4080	0.2142	0.0097	1.0100	1.4040	1.8600
Thuringen	RR7f[16]	0.8356	0.1243	0.0057	0.6038	0.8344	1.0960
Berlin	RR7m[1]	0.9516	0.1309	0.0064	0.7016	0.9534	1.2250
Bremen	RR7m[2]	1.3830	0.2012	0.0093	1.0050	1.3820	1.8000
Brandenburg	RR7m[3]	1.2000	0.1664	0.0081	0.8834	1.2020	1.5490
Baden-Wurttemberg	RR7m[4]	1.1130	0.7507	0.0063	0.3058	0.9397	2.9590
Bavaria(Bayern)	RR7m[5]	0.7751	0.1053	0.0052	0.5744	0.7776	0.9938
Hamburg	RR7m[6]	1.2620	0.1772	0.0085	0.9258	1.2620	1.6320
Hessen	RR7m[7]	1.0270	0.6925	0.0111	0.3202	0.8560	2.7520
Mecklenburg-Vorpommern	RR7m[8]	1.3650	0.1908	0.0092	1.0040	1.3650	1.7630
Nierdersachsen	RR7m[9]	1.0370	0.1405	0.0070	0.7685	1.0390	1.3270
Nordrhein-Westfalen(NRW)	RR7m[10]	0.1671	0.0231	0.0011	0.1234	0.1673	0.2152
Rheinland-pfalz	RR7m[11]	0.9732	0.1337	0.0066	0.7195	0.9741	1.2510
Sachsen-Anhalt	RR7m[12]	1.3940	0.1922	0.0094	1.0280	1.3950	1.7930
Sachsen (Saxony)	RR7m[13]	1.0540	0.1447	0.0071	0.7767	1.0550	1.3540
Schleswig-Holstein	RR7m[14]	1.1740	0.1620	0.0079	0.8653	1.1750	1.5110
Saarland	RR7m[15]	1.4840	0.2098	0.0100	1.0880	1.4840	1.9200
Thuringen	RR7m[16]	1.0330	0.1437	0.0070	0.7594	1.0330	1.3310

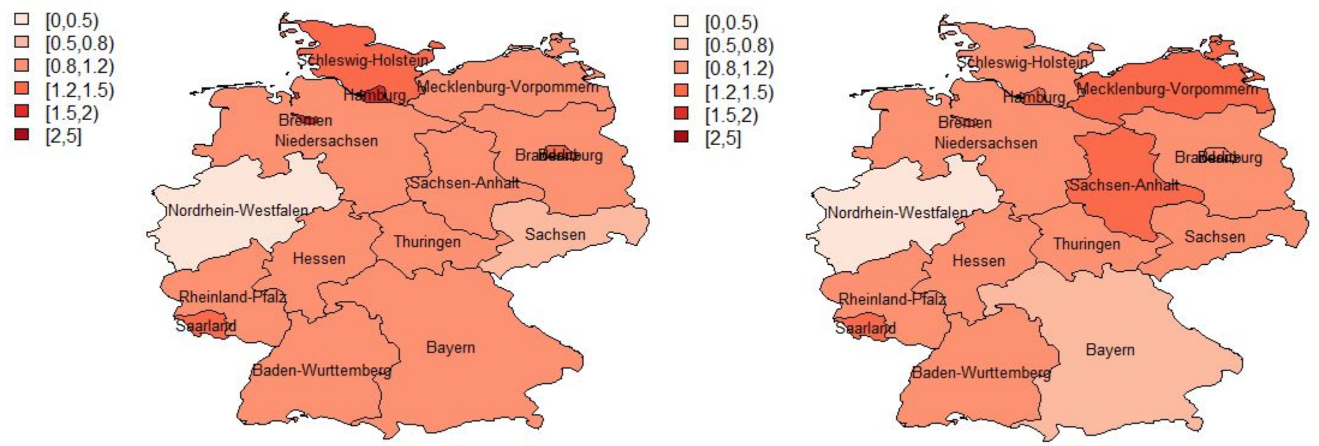

Figure 9: Plot of the spatial relative risk of Lung Cancer incidence rate for females (a) and males (b)

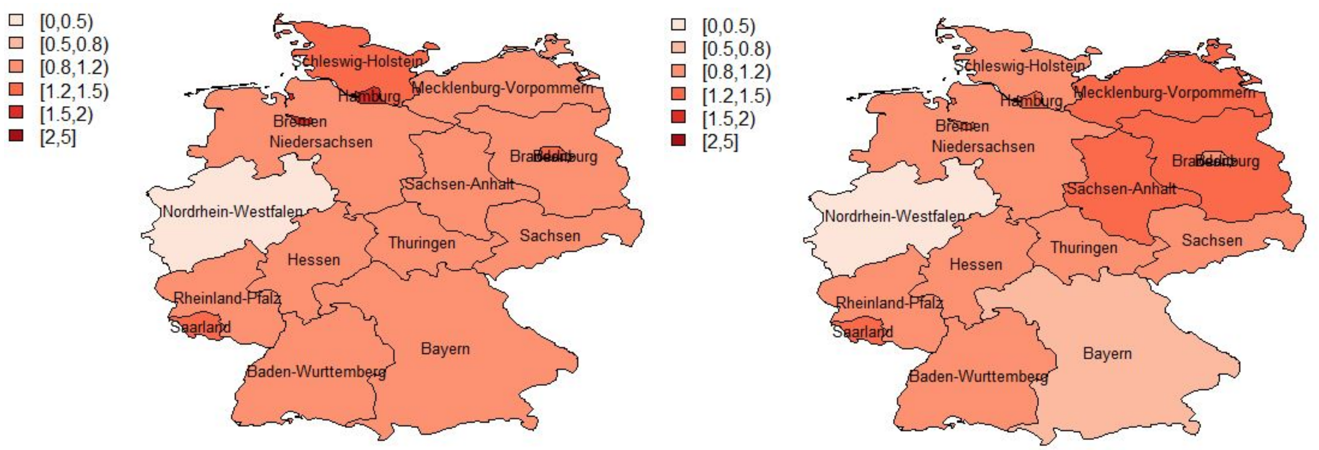

Figure 10: Plot of the spatial relative risk of Lung Cancer incidence rate for females (a) and males (b) in age group 7 (70-74 years of age).

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
$\sigma^2_{\lambda 1}$	0.0058	0.0138	0.0006	0.0002	0.0015	0.0432
$\sigma^2_{\lambda 2}$	0.1971	0.1227	0.0024	0.0701	0.1669	0.4990
σ^2_{β}	0.6940	0.3876	0.0051	0.2700	0.5993	1.6790
$\sigma^2_{\delta 1}$	0.0151	0.0266	0.0006	0.0002	0.0042	0.0890
$\sigma^2_{\delta 2}$	0.0026	0.0041	0.0001	0.0002	0.0012	0.0137
$\sigma^2_{\delta 3}$	0.0016	0.0020	0.0001	0.0002	0.0009	0.0069
$\sigma^2_{\delta 4}$	0.0404	0.0219	0.0002	0.0141	0.0354	0.0951
$\sigma^2_{\delta 5}$	0.0036	0.0039	0.0001	0.0002	0.0023	0.0140
$\sigma^2_{\delta 6}$	0.0011	0.0012	0.0001	0.0002	0.0007	0.0045
$\sigma^2_{\delta 7}$	0.0014	0.0015	0.0001	0.0002	0.0009	0.0052
$\sigma^2_{\delta 8}$	0.0019	0.0022	0.0001	0.0002	0.0012	0.0076
$\sigma^2_{\delta 9}$	0.0155	0.0114	0.0001	0.0017	0.0130	0.0446
$\sigma^2_{\delta 10}$	0.0156	0.0144	0.0002	0.0005	0.0120	0.0528
$\sigma^2_{\psi 1}$	0.0424	0.0323	0.0012	0.0004	0.0402	0.1166
$\sigma^2_{\psi 2}$	0.0170	0.0256	0.0012	0.0002	0.0040	0.0853
σ^2_{b}	0.3140	0.4477	0.0217	0.0002	0.0111	1.4110
σ^2_{h}	0.2039	0.1905	0.0087	0.0004	0.2053	0.6204
$fraction$	0.4259	0.4011	0.0220	0.0256	0.1711	0.9797

Table 12: Variance component of Lung cancer incidence data.

3.3 Sensitivity analysis

The choice of hyper-prior is important to allow learning from the data by using non-informative prior. As explained by Lesaffre and Lawson (2012), the inverse gamma prior is weakly informative when the shape and scale parameter is small, hence the need for sensitivity analysis. The results of the variance components show that as the hyper-prior changes the hyper-parameter estimates changes also. The variance estimate obtained for hyper-prior set A ($IG(0.5, 0.0005)$), B ($IG(0.001, 0.001)$) and C ($IG(0.1, 0.1)$) increases as the hyper-prior scale and shape parameter was increased (table 13). Hence, the hyper-parameter estimates changes with the choice of hyper-prior. The sensitivity analysis based on DIC in selecting the preferred model, showed that model 3 with hyper-prior $IG(0.5, 0.0005)$ for the random effects precision had the lowest DIC and this was the preferred model in which inference was based on. Also with respect to each of the hyper-prior, model 3 seems to have better fit than the others. Since the shape and scale parameter of hyper-prior set B is small, the magnitude of the difference in DIC with respect to hyper-prior A is small.

Organ	parameter	$IG(0.5, 0.0005)$ mean (sd)	$IG(0.001, 0.001)$ mean (sd)	$IG(0.1, 0.1)$ mean (sd)
Kidney	$\sigma^2_{\lambda 1}$	0.0093 (0.0105)	0.0133 (0.0152)	0.0841 (0.0723)
	$\sigma^2_{\lambda 2}$	0.0064 (0.0083)	0.0105 (0.0126)	0.0748 (0.0607)
	σ^2_{β}	1.006 (0.5725)	1.148 (0.7093)	1.599 (1.924)
	$\sigma^2_{\delta 1}$	0.0034 (0.0066)	0.0096 (0.0144)	0.0645 (0.0425)
	$\sigma^2_{\delta 2}$	0.0027 (0.0048)	0.0069 (0.0099)	0.0562(0.0362)
	$\sigma^2_{\delta 3}$	0.0035 (0.0058)	0.0089 (0.0113)	0.0544 (0.0325)
	$\sigma^2_{\delta 4}$	0.0016 (0.0021)	0.0036 (0.0044)	0.0421 (0.0247)
	$\sigma^2_{\delta 5}$	0.0075 (0.0109)	0.0157 (0.0171)	0.0590 (0.0357)
	$\sigma^2_{\delta 6}$	0.0015 (0.0020)	0.0033 (0.0038)	0.0375 (0.0202)
	$\sigma^2_{\delta 7}$	0.0116 (0.0124)	0.0185 (0.0167)	0.0554 (0.0311)
	$\sigma^2_{\delta 8}$	0.0029 (0.0040)	0.0058 (0.0063)	0.0396 (0.0218)
	$\sigma^2_{\delta 9}$	0.0313 (0.0293)	0.0442 (0.0366)	0.0814 (0.0478)
	$\sigma^2_{\delta 10}$	0.0834 (0.0643)	0.1093 (0.0799)	0.1459 (0.0951)
	$\sigma^2_{\psi 1}$	0.0020 (0.0024)	0.0039 (0.0041)	0.0476 (0.0291)
	$\sigma^2_{\psi 2}$	0.0020 (0.0026)	0.0040 (0.0042)	0.0479 (0.0292)
	σ^2_{b}	0.2178 (0.4283)	0.3843 (0.5041)	0.4122 (0.416)
	σ^2_{h}	0.2532 (0.1820)	0.2388 (0.1993)	0.2682 (0.1949)
Lung	$\sigma^2_{\lambda 1}$	0.0058 (0.0138)	0.033 (0.063)	0.1244 (0.1125)
	$\sigma^2_{\lambda 2}$	0.1971 (0.1227)	0.2219 (0.1635)	0.2886 (0.2368)
	σ^2_{β}	0.6940 (0.3876)	1.023 (0.7379)	0.975 (0.6667)
	$\sigma^2_{\delta 1}$	0.0151 (0.0266)	0.0375 (0.0427)	0.1011 (0.0646)
	$\sigma^2_{\delta 2}$	0.0026 (0.0041)	0.0058 (0.0071)	0.0428 (0.0230)
	$\sigma^2_{\delta 3}$	0.0016 (0.0020)	0.0033 (0.0035)	0.0335 (0.0173)
	$\sigma^2_{\delta 4}$	0.0404 (0.0219)	0.0453 (0.0256)	0.0662 (0.0353)
	$\sigma^2_{\delta 5}$	0.0036 (0.0039)	0.0060 (0.0054)	0.0330 (0.0168)
	$\sigma^2_{\delta 6}$	0.0011 (0.0012)	0.0022 (0.0021)	0.0283 (0.0142)
	$\sigma^2_{\delta 7}$	0.0014 (0.0015)	0.0025 (0.0023)	0.0288 (0.0144)
	$\sigma^2_{\delta 8}$	0.0019 (0.0022)	0.0034 (0.0033)	0.0302 (0.0149)
	$\sigma^2_{\delta 9}$	0.0155 (0.0114)	0.0196 (0.0138)	0.0477 (0.0254)
	$\sigma^2_{\delta 10}$	0.0156 (0.0144)	0.0220 (0.0174)	0.0571 (0.0309)
	$\sigma^2_{\psi 1}$	0.0424 (0.0323)	0.0424 (0.0349)	0.0809 (0.0504)
	$\sigma^2_{\psi 2}$	0.0170 (0.0256)	0.0279 (0.0300)	0.0703 (0.0446)
	σ^2_{b}	0.3140 (0.4477)	0.6194 (0.5088)	0.1394 (0.2837)
	σ^2_{h}	0.2039 (0.1905)	0.1153 (0.1483)	0.3009 (0.1798)

Table 13: Sensitivity analysis of the variance component, mean (sd).

Organ	model	$IG(0.5, 0.0005)$	$IG(0.001, 0.001)$	$IG(0.1, 0.1)$
Kidney	1	1767.57	1767.7	1767.96
	2	1743.79	1743.9	1745.35
	3	**1706.79**	1707.3	1744.6
	4	1707.6	1707.73	1745.33
Lung	1	2933.11	2933.18	2933.47
	2	2428.06	2428.68	2428.93
	3	**2088.88**	2089.45	2111.86
	4	2089.34	2089.67	2112.44

Table 14: Sensitivity analysis of model selection

4 Conclusion

In concluding, based on the results obtained, it was observed that the spatial relative risk for each gender varies with age group but the state, Nordrhein-Westfalen (state 10) was the state in which the relative risk was low for both data and all age groups. Kaatsh et al, (2016), in their book titled "Cancer in Germany" explained that the most important risk factors for Kidney cancer include smoking and passive smoking, as well as hypertension and obesity. They also stated that lack of physical activity seems to increase the risk of developing kidney cancer. For Lung cancer they explained that exposure to tobacco smoke has long been recognized as the main risk factor for lung cancer with up to nine out of ten cases of lung cancer in men and at least six out of ten cases in women which are attributable to active smoking (Kaatsh et al, 2016). In the traditional method counts are aggregated in a region over all age groups and age standardized rates are modeled. Hence, based on some of the factors listed above and from the different spatial age-specific relative risk obtained for each age group for some of the states it is preferable to include age as a covariate in spatial analysis because a disease may not affect all age groups equally. The Bayesian modeling framework as stated above makes use of prior assumptions on parameter of interest and the data information hence to allow learning from the data non-informative priors were used. For a gamma distribution to be used as a non-informative hyper-prior its shape and scale parameter are required to be small (Lesaffre and Lawson, 2012) hence a sensitivity analysis was carried out which shows that the hyper-parameter estimates changes with a change in the value of the scale and shape parameter but the selected model in which inferences was based on, was still the preferred model based on DIC. The method applied to analyze the data took into account (i) over-dispersion, (ii) spatial correlation, (iii) non-linear age-specific effect and also made use of Bayesian hierarchical spatial modeling framework, with DIC being used to select the model with best fit to the data, hence the objective of the study was met. Further research can be performed on the data by including spatially structured interaction random effects between states and the covariates, and also modeling age group to depend on neighboring age groups hence increasing the model complexity leading to complex interpretation but the data may be over-modeled and computational time may increased. Therefore, the model fitted to the data provides a simple and informative interpretation and the results obtained and presented here is of great importance to health administrators in identifying areas with high risk and in policies decision making based on the information gotten from the spatial age-specific data analysis.

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6 Appendix

6.1 Kidney cancer incidence results continuation

6.1.1 Parameter estimates of interaction effects between states i and age groups j, δ_{ij}

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
delta[1,1]	-0.0026	0.0544	0.0002	-0.1202	-0.0012	0.1055
delta[1,2]	0.0023	0.0480	0.0002	-0.0946	0.0010	0.1062
delta[1,3]	-0.0150	0.0571	0.0003	-0.1555	-0.0082	0.0840
delta[1,4]	0.0035	0.0371	0.0001	-0.0694	0.0022	0.0835
delta[1,5]	0.0478	0.0786	0.0008	-0.0690	0.0294	0.2467
delta[1,6]	-0.0111	0.0362	0.0002	-0.0958	-0.0075	0.0532
delta[1,7]	-0.0200	0.0767	0.0004	-0.1905	-0.0137	0.1280
delta[1,8]	-0.0131	0.0486	0.0003	-0.1270	-0.0084	0.0760
delta[1,9]	0.1151	0.1246	0.0012	-0.0952	0.1016	0.3895
delta[1,10]	0.2361	0.1741	0.0017	-0.0751	0.2280	0.5979
delta[2,1]	-0.0027	0.0567	0.0002	-0.1258	-0.0012	0.1097
delta[2,2]	-0.0086	0.0526	0.0003	-0.1304	-0.0043	0.0853
delta[2,3]	-0.0008	0.0588	0.0002	-0.1270	-0.0003	0.1223
delta[2,4]	0.0056	0.0392	0.0002	-0.0680	0.0034	0.0922
delta[2,5]	-0.0410	0.0917	0.0008	-0.2819	-0.0205	0.0950
delta[2,6]	-0.0016	0.0369	0.0001	-0.0794	-0.0011	0.0734
delta[2,7]	0.0092	0.0917	0.0004	-0.1788	0.0056	0.2081
delta[2,8]	0.0141	0.0539	0.0003	-0.0817	0.0082	0.1450
delta[2,9]	0.1069	0.1566	0.0013	-0.1563	0.0828	0.4694
delta[2,10]	-0.1559	0.2355	0.0012	-0.6774	-0.1351	0.2642
delta[3,1]	0.0016	0.0547	0.0002	-0.1109	0.0009	0.1182
delta[3,2]	-0.0095	0.0495	0.0003	-0.1257	-0.0052	0.0793
delta[3,3]	0.0061	0.0531	0.0002	-0.0992	0.0035	0.1268
delta[3,4]	0.0002	0.0362	0.0001	-0.0746	0.0003	0.0753
delta[3,5]	0.0166	0.0675	0.0004	-0.1106	0.0096	0.1766
delta[3,6]	0.0007	0.0343	0.0002	-0.0690	0.0004	0.0727
delta[3,7]	0.1008	0.0902	0.0012	-0.0312	0.0868	0.3029
delta[3,8]	-0.0149	0.0476	0.0003	-0.1271	-0.0099	0.0701
delta[3,9]	-0.2485	0.1628	0.0023	-0.5967	-0.2366	0.0089
delta[3,10]	0.1539	0.1682	0.0015	-0.1568	0.1456	0.5044
delta[4,1]	0.0000	0.0577	0.0002	-0.1174	-0.0000	0.1170
delta[4,2]	0.0000	0.0518	0.0002	-0.1074	0.0001	0.1058
delta[4,3]	0.0003	0.0612	0.0002	-0.1266	0.0002	0.1292
delta[4,4]	-0.0001	0.0391	0.0001	-0.0802	-0.0002	0.0811
delta[4,5]	0.0003	0.0853	0.0003	-0.1825	-0.0001	0.1843
delta[4,6]	-0.0001	0.0383	0.0001	-0.0783	-0.0002	0.0773
delta[4,7]	-0.0001	0.1064	0.0004	-0.2277	-0.0000	0.2262
delta[4,8]	-0.0000	0.0538	0.0002	-0.1135	0.0000	0.1127
delta[4,9]	0.0006	0.1765	0.0006	-0.3693	0.0005	0.3670
delta[4,10]	-0.0009	0.2898	0.0010	-0.5956	-0.0012	0.5955
delta[5,1]	-0.0169	0.0531	0.0004	-0.1508	-0.0093	0.0702
delta[5,2]	0.0060	0.0432	0.0002	-0.0772	0.0037	0.1036
delta[5,3]	-0.0318	0.0531	0.0005	-0.1671	-0.0211	0.0481
delta[5,4]	-0.0046	0.0333	0.0002	-0.0770	-0.0033	0.0605
delta[5,5]	-0.0284	0.0552	0.0004	-0.1566	-0.0207	0.0690
delta[5,6]	-0.0033	0.0303	0.0002	-0.0679	-0.0026	0.0565
delta[5,7]	0.0121	0.0559	0.0004	-0.0986	0.0099	0.1301
delta[5,8]	0.0444	0.0482	0.0005	-0.0266	0.0347	0.1617
delta[5,9]	0.0226	0.0813	0.0007	-0.1374	0.0196	0.1913
delta[5,10]	0.2466	0.1237	0.0015	0.0170	0.2416	0.5039
delta[6,1]	-0.0062	0.0567	0.0003	-0.1338	-0.0029	0.1003
delta[6,2]	0.0039	0.0501	0.0002	-0.0939	0.0020	0.1135
delta[6,3]	0.0019	0.0567	0.0002	-0.1157	0.0011	0.1250
delta[6,4]	-0.0115	0.0409	0.0002	-0.1081	-0.0071	0.0583
delta[6,5]	0.0378	0.0816	0.0007	-0.0880	0.0206	0.2451
delta[6,6]	-0.0071	0.0367	0.0002	-0.0896	-0.0048	0.0610
delta[6,7]	-0.0254	0.0853	0.0005	-0.2199	-0.0163	0.1364
delta[6,8]	-0.0096	0.0504	0.0002	-0.1269	-0.0057	0.0853
delta[6,9]	0.2012	0.1607	0.0020	-0.0439	0.1852	0.5525
delta[6,10]	0.2573	0.1990	0.0018	-0.0923	0.2449	0.6753
delta[7,1]	-0.0000	0.0581	0.0002	-0.1186	-0.0000	0.1190
delta[7,2]	0.0002	0.0519	0.0002	-0.1043	0.0000	0.1071
delta[7,3]	0.0002	0.0615	0.0002	-0.1288	-0.0002	0.1290
delta[7,4]	0.0000	0.0393	0.0001	-0.0814	-0.0000	0.0811
delta[7,5]	-0.0002	0.0869	0.0003	-0.1859	-0.0004	0.1847
delta[7,6]	0.0000	0.0379	0.0001	-0.0788	0.0002	0.0783
delta[7,7]	-0.0003	0.1072	0.0004	-0.2302	0.0001	0.2258
delta[7,8]	-0.0001	0.0543	0.0002	-0.1141	0.0001	0.1141
delta[7,9]	-0.0002	0.1770	0.0007	-0.3721	-0.0006	0.3740
delta[7,10]	-0.0009	0.2889	0.0010	-0.5899	-0.0016	0.5897
delta[8,1]	-0.0003	0.0551	0.0002	-0.1158	-0.0000	0.1137
delta[8,2]	0.0084	0.0497	0.0003	-0.0818	0.0043	0.1246
delta[8,3]	-0.0134	0.0570	0.0003	-0.1511	-0.0072	0.0879
delta[8,4]	0.0023	0.0367	0.0001	-0.0708	0.0015	0.0810
delta[8,5]	0.0110	0.0698	0.0003	-0.1291	0.0066	0.1701
delta[8,6]	0.0159	0.0384	0.0003	-0.0465	0.0107	0.1093
delta[8,7]	-0.0101	0.0762	0.0004	-0.1749	-0.0070	0.1438
delta[8,8]	-0.0030	0.0467	0.0002	-0.1039	-0.0019	0.0928
delta[8,9]	-0.1689	0.1491	0.0017	-0.5050	-0.1506	0.0582
delta[8,10]	-0.2483	0.2193	0.0014	-0.7283	-0.2284	0.1257

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
delta[9,1]	-0.0026	0.0505	0.0002	-0.1140	-0.0014	0.0998
delta[9,2]	0.0042	0.0447	0.0002	-0.0852	0.0026	0.1031
delta[9,3]	0.0052	0.0486	0.0002	-0.0930	0.0036	0.1119
delta[9,4]	0.0001	0.0343	0.0001	-0.0703	0.0001	0.0709
delta[9,5]	-0.0478	0.0659	0.0007	-0.2064	-0.0341	0.0530
delta[9,6]	0.0039	0.0317	0.0001	-0.0590	0.0030	0.0717
delta[9,7]	-0.0079	0.0607	0.0004	-0.1359	-0.0059	0.1137
delta[9,8]	0.0018	0.0412	0.0002	-0.0822	0.0012	0.0899
delta[9,9]	0.1060	0.0935	0.0010	-0.0567	0.0993	0.3041
delta[9,10]	0.0074	0.1286	0.0012	-0.2396	0.0042	0.2713
delta[10,1]	0.0123	0.0570	0.0004	-0.0848	0.0059	0.1502
delta[10,2]	0.0072	0.0489	0.0002	-0.0838	0.0037	0.1197
delta[10,3]	-0.0062	0.0543	0.0002	-0.1303	-0.0034	0.1013
delta[10,4]	0.0055	0.0372	0.0001	-0.0659	0.0036	0.0876
delta[10,5]	-0.0092	0.0684	0.0003	-0.1658	-0.0051	0.1269
delta[10,6]	-0.0097	0.0360	0.0002	-0.0930	-0.0066	0.0556
delta[10,7]	-0.0377	0.0794	0.0006	-0.2206	-0.0267	0.1038
delta[10,8]	0.0134	0.0481	0.0003	-0.0740	0.0086	0.1269
delta[10,9]	-0.0336	0.1125	0.0007	-0.2747	-0.0260	0.1824
delta[10,10]	-0.3398	0.2049	0.0017	-0.7790	-0.3253	0.0124
delta[11,1]	-0.0009	0.0527	0.0002	-0.1135	-0.0002	0.1084
delta[11,2]	0.0055	0.0475	0.0002	-0.0857	0.0030	0.1123
delta[11,3]	0.0032	0.0518	0.0002	-0.1038	0.0019	0.1165
delta[11,4]	-0.0048	0.0363	0.0001	-0.0846	-0.0033	0.0660
delta[11,5]	-0.0054	0.0623	0.0003	-0.1427	-0.0033	0.1231
delta[11,6]	0.0036	0.0337	0.0001	-0.0640	0.0027	0.0762
delta[11,7]	0.0086	0.0686	0.0004	-0.1298	0.0063	0.1543
delta[11,8]	-0.0140	0.0458	0.0002	-0.1200	-0.0096	0.0699
delta[11,9]	0.0506	0.1008	0.0008	-0.1391	0.0429	0.2663
delta[11,10]	0.1196	0.1479	0.0014	-0.1566	0.1136	0.4266
delta[12,1]	-0.0018	0.0545	0.0002	-0.1191	-0.0008	0.1082
delta[12,2]	-0.0022	0.0480	0.0002	-0.1056	-0.0011	0.0955
delta[12,3]	0.0159	0.0568	0.0003	-0.0825	0.0088	0.1553
delta[12,4]	0.0039	0.0366	0.0001	-0.0683	0.0028	0.0838
delta[12,5]	-0.0556	0.0838	0.0009	-0.2696	-0.0339	0.0593
delta[12,6]	0.0057	0.0346	0.0002	-0.0606	0.0039	0.0828
delta[12,7]	-0.0183	0.0734	0.0004	-0.1802	-0.0130	0.1252
delta[12,8]	-0.0022	0.0454	0.0002	-0.0997	-0.0014	0.0914
delta[12,9]	0.0466	0.1096	0.0008	-0.1612	0.0374	0.2818
delta[12,10]	0.0521	0.1634	0.0012	-0.2644	0.0471	0.3870
delta[13,1]	0.0006	0.0524	0.0002	-0.1097	0.0005	0.1117
delta[13,2]	-0.0144	0.0495	0.0003	-0.1365	-0.0081	0.0680
delta[13,3]	0.0275	0.0576	0.0005	-0.0604	0.0168	0.1758
delta[13,4]	-0.0032	0.0353	0.0001	-0.0796	-0.0020	0.0666
delta[13,5]	0.0502	0.0700	0.0008	-0.0532	0.0347	0.2221
delta[13,6]	-0.0078	0.0332	0.0002	-0.0822	-0.0056	0.0547
delta[13,7]	0.0778	0.0735	0.0008	-0.0377	0.0680	0.2412
delta[13,8]	-0.0165	0.0441	0.0003	-0.1197	-0.0115	0.0623
delta[13,9]	-0.1231	0.1052	0.0011	-0.3494	-0.1146	0.0513
delta[13,10]	-0.1192	0.1407	0.0011	-0.4052	-0.1160	0.1539
delta[14,1]	0.0132	0.0576	0.0004	-0.0828	0.0063	0.1558
delta[14,2]	-0.0056	0.0490	0.0002	-0.1158	-0.0031	0.0882
delta[14,3]	-0.0058	0.0548	0.0002	-0.1308	-0.0030	0.1018
delta[14,4]	-0.0006	0.0368	0.0001	-0.0781	-0.0004	0.0745
delta[14,5]	-0.0154	0.0683	0.0004	-0.1762	-0.0087	0.1135
delta[14,6]	-0.0041	0.0348	0.0002	-0.0805	-0.0027	0.0633
delta[14,7]	-0.0868	0.0916	0.0010	-0.3003	-0.0691	0.0480
delta[14,8]	0.0284	0.0537	0.0005	-0.0539	0.0182	0.1652
delta[14,9]	0.0174	0.1118	0.0007	-0.2071	0.0134	0.2512
delta[14,10]	0.2900	0.1745	0.0018	-0.0232	0.2829	0.6515
delta[15,1]	0.0027	0.0570	0.0002	-0.1097	0.0012	0.1252
delta[15,2]	-0.0010	0.0504	0.0002	-0.1075	-0.0006	0.1013
delta[15,3]	-0.0179	0.0624	0.0004	-0.1748	-0.0090	0.0839
delta[15,4]	-0.0004	0.0380	0.0001	-0.0794	-0.0003	0.0783
delta[15,5]	-0.0232	0.0788	0.0005	-0.2174	-0.0119	0.1164
delta[15,6]	0.0080	0.0376	0.0002	-0.0603	0.0051	0.0944
delta[15,7]	0.1128	0.1184	0.0015	-0.0460	0.0859	0.3972
delta[15,8]	-0.0103	0.0512	0.0002	-0.1311	-0.0061	0.0849
delta[15,9]	-0.0306	0.1330	0.0007	-0.3195	-0.0209	0.2272
delta[15,10]	-0.2693	0.2392	0.0017	-0.8064	-0.2451	0.1278
delta[16,1]	-0.0018	0.0540	0.0002	-0.1182	-0.0008	0.1076
delta[16,2]	-0.0016	0.0479	0.0002	-0.1039	-0.0009	0.0967
delta[16,3]	0.0258	0.0599	0.0005	-0.0665	0.0146	0.1806
delta[16,4]	0.0034	0.0361	0.0001	-0.0686	0.0023	0.0821
delta[16,5]	0.0628	0.0820	0.0010	-0.0492	0.0411	0.2688
delta[16,6]	0.0083	0.0348	0.0002	-0.0563	0.0056	0.0874
delta[16,7]	-0.1107	0.0966	0.0012	-0.3314	-0.0948	0.0269
delta[16,8]	-0.0186	0.0481	0.0003	-0.1344	-0.0123	0.0649
delta[16,9]	-0.0194	0.1058	0.0006	-0.2394	-0.0155	0.1903
delta[16,10]	-0.1699	0.1676	0.0011	-0.5210	-0.1617	0.1400

6.1.2 Parameter estimates of interaction effects between states i and gender k, ψ_{ik}

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
psi[1,1]	0.0041	0.0387	0.0002	-0.0726	0.0028	0.0878
psi[1,2]	-0.0046	0.0390	0.0002	-0.0891	-0.0032	0.0729
psi[2,1]	-0.0067	0.0431	0.0002	-0.1038	-0.0043	0.0760
psi[2,2]	0.0069	0.0433	0.0002	-0.0755	0.0042	0.1045
psi[3,1]	-0.0047	0.0379	0.0002	-0.0871	-0.0033	0.0706
psi[3,2]	0.0067	0.0382	0.0002	-0.0670	0.0046	0.0912
psi[4,1]	-0.0001	0.0449	0.0002	-0.0931	-0.0002	0.0940
psi[4,2]	-0.0001	0.0455	0.0002	-0.0965	-0.0001	0.0953
psi[5,1]	-0.0017	0.0335	0.0003	-0.0703	-0.0016	0.0678
psi[5,2]	0.0024	0.0336	0.0003	-0.0648	0.0018	0.0736
psi[6,1]	-0.0003	0.0407	0.0002	-0.0862	-0.0002	0.0849
psi[6,2]	0.0001	0.0406	0.0002	-0.0842	-0.0001	0.0859
psi[7,1]	-0.0000	0.0450	0.0002	-0.0932	-0.0003	0.0946
psi[7,2]	-0.0001	0.0450	0.0002	-0.0941	-0.0001	0.0935
psi[8,1]	-0.0197	0.0429	0.0003	-0.1248	-0.0134	0.0510
psi[8,2]	0.0217	0.0439	0.0004	-0.0484	0.0147	0.1307
psi[9,1]	-0.0131	0.0359	0.0003	-0.0937	-0.0101	0.0530
psi[9,2]	0.0140	0.0360	0.0003	-0.0514	0.0107	0.0964
psi[10,1]	-0.0010	0.0387	0.0002	-0.0827	-0.0007	0.0783
psi[10,2]	-0.0101	0.0397	0.0003	-0.1015	-0.0069	0.0639
psi[11,1]	-0.0155	0.0389	0.0003	-0.1055	-0.0115	0.0533
psi[11,2]	0.0172	0.0394	0.0003	-0.0512	0.0124	0.1109
psi[12,1]	-0.0056	0.0382	0.0002	-0.0889	-0.0040	0.0703
psi[12,2]	0.0063	0.0383	0.0002	-0.0689	0.0046	0.0908
psi[13,1]	0.0366	0.0452	0.0005	-0.0309	0.0279	0.1475
psi[13,2]	-0.0351	0.0446	0.0005	-0.1449	-0.0265	0.0313
psi[14,1]	0.0030	0.0385	0.0002	-0.0743	0.0019	0.0861
psi[14,2]	-0.0030	0.0382	0.0002	-0.0861	-0.0019	0.0741
psi[15,1]	-0.0029	0.0414	0.0002	-0.0931	-0.0018	0.0804
psi[15,2]	0.0032	0.0416	0.0002	-0.0811	0.0021	0.0929
psi[16,1]	0.0272	0.0435	0.0004	-0.0404	0.0196	0.1355
psi[16,2]	-0.0244	0.0429	0.0004	-0.1301	-0.0174	0.0438

6.1.3 Spatial relative risk of Kidney cancer incidence for females given each age group.

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
SAf[1,1]	0.9504	0.1402	0.0051	0.6874	0.9459	1.2590
SAf[1,2]	0.9547	0.1388	0.0051	0.6934	0.9502	1.2600
SAf[1,3]	0.9386	0.1385	0.0050	0.6777	0.9346	1.2410
SAf[1,4]	0.9554	0.1355	0.0051	0.6989	0.9514	1.2540
SAf[1,5]	1.0000	0.1544	0.0053	0.7217	0.9894	1.3470
SAf[1,6]	0.9413	0.1316	0.0050	0.6901	0.9381	1.2310
SAf[1,7]	0.9344	0.1413	0.0050	0.6721	0.9291	1.2420
SAf[1,8]	0.9399	0.1347	0.0050	0.6853	0.9361	1.2340
SAf[1,9]	1.0740	0.1897	0.0057	0.7475	1.0560	1.5010
SAf[1,10]	1.2210	0.2634	0.0068	0.7934	1.1890	1.8230
SAf[2,1]	1.0550	0.1782	0.0055	0.7370	1.0430	1.4430
SAf[2,2]	1.0480	0.1752	0.0055	0.7337	1.0380	1.4290
SAf[2,3]	1.0570	0.1784	0.0055	0.7404	1.0450	1.4460
SAf[2,4]	1.0630	0.1738	0.0056	0.7522	1.0520	1.4420
SAf[2,5]	1.0170	0.1809	0.0054	0.6840	1.0080	1.4040
SAf[2,6]	1.0550	0.1711	0.0055	0.7469	1.0450	1.4280
SAf[2,7]	1.0690	0.1889	0.0056	0.7367	1.0550	1.4860
SAf[2,8]	1.0720	0.1772	0.0056	0.7559	1.0610	1.4580
SAf[2,9]	1.1860	0.2536	0.0063	0.7760	1.1550	1.7790
SAf[2,10]	0.9251	0.2472	0.0049	0.5019	0.9046	1.4720
SAf[3,1]	1.2750	0.1890	0.0068	0.9278	1.2670	1.6880
SAf[3,2]	1.2610	0.1831	0.0067	0.9168	1.2550	1.6590
SAf[3,3]	1.2810	0.1875	0.0068	0.9328	1.2720	1.6910
SAf[3,4]	1.2720	0.1796	0.0067	0.9352	1.2660	1.6660
SAf[3,5]	1.2950	0.1933	0.0068	0.9396	1.2860	1.7190
SAf[3,6]	1.2730	0.1780	0.0067	0.9384	1.2660	1.6630
SAf[3,7]	1.4090	0.2170	0.0075	1.0200	1.3960	1.8920
SAf[3,8]	1.2530	0.1785	0.0066	0.9174	1.2470	1.6440
SAf[3,9]	1.0020	0.2007	0.0058	0.6451	0.9900	1.4270
SAf[3,10]	1.5010	0.3163	0.0082	0.9793	1.4660	2.2170
SAf[4,1]	1.1780	0.8004	0.0033	0.3193	0.9964	3.1150
SAf[4,2]	1.1770	0.7925	0.0032	0.3204	0.9974	3.1080
SAf[4,3]	1.1780	0.7968	0.0032	0.3203	0.9972	3.1150
SAf[4,4]	1.1770	0.7941	0.0032	0.3204	0.9960	3.1020
SAf[4,5]	1.1800	0.8004	0.0032	0.3184	0.9967	3.1420
SAf[4,6]	1.1760	0.7891	0.0032	0.3203	0.9959	3.1030
SAf[4,7]	1.1820	0.8141	0.0033	0.3144	0.9978	3.1600
SAf[4,8]	1.1770	0.7924	0.0032	0.3195	0.9975	3.1120
SAf[4,9]	1.1950	0.8408	0.0035	0.3064	0.9980	3.2620
SAf[4,10]	1.2240	0.9403	0.0035	0.2816	0.9973	3.5580
SAf[5,1]	1.1030	0.1548	0.0059	0.8078	1.1000	1.4370
SAf[5,2]	1.1280	0.1557	0.0060	0.8327	1.1230	1.4700
SAf[5,3]	1.0860	0.1516	0.0058	0.7993	1.0830	1.4170
SAf[5,4]	1.1150	0.1503	0.0060	0.8273	1.1120	1.4480
SAf[5,5]	1.0900	0.1516	0.0058	0.8005	1.0870	1.4210
SAf[5,6]	1.1160	0.1487	0.0060	0.8300	1.1140	1.4440
SAf[5,7]	1.1350	0.1571	0.0061	0.8378	1.1300	1.4760
SAf[5,8]	1.1710	0.1589	0.0062	0.8703	1.1660	1.5210
SAf[5,9]	1.1480	0.1714	0.0062	0.8307	1.1400	1.5250
SAf[5,10]	1.4420	0.2525	0.0080	1.0050	1.4220	2.0060
SAf[6,1]	0.9430	0.1472	0.0050	0.6729	0.9363	1.2620
SAf[6,2]	0.9522	0.1470	0.0051	0.6843	0.9447	1.2760
SAf[6,3]	0.9506	0.1481	0.0050	0.6795	0.9430	1.2710
SAf[6,4]	0.9373	0.1415	0.0050	0.6755	0.9313	1.2470
SAf[6,5]	0.9865	0.1620	0.0052	0.7007	0.9747	1.3470
SAf[6,6]	0.9411	0.1403	0.0050	0.6813	0.9349	1.2460
SAf[6,7]	0.9258	0.1497	0.0050	0.6547	0.9185	1.2520
SAf[6,8]	0.9392	0.1430	0.0050	0.6758	0.9324	1.2500
SAf[6,9]	1.1690	0.2359	0.0063	0.7865	1.1400	1.7140
SAf[6,10]	1.2460	0.2975	0.0069	0.7752	1.2070	1.9360
SAf[7,1]	1.0880	0.6985	0.0067	0.3341	0.9238	2.8310
SAf[7,2]	1.0870	0.6960	0.0067	0.3339	0.9242	2.8160
SAf[7,3]	1.0880	0.6983	0.0067	0.3336	0.9244	2.8400
SAf[7,4]	1.0870	0.6960	0.0067	0.3360	0.9249	2.8120
SAf[7,5]	1.0900	0.7058	0.0067	0.3305	0.9241	2.8460
SAf[7,6]	1.0870	0.6954	0.0067	0.3354	0.9244	2.8190
SAf[7,7]	1.0920	0.7085	0.0068	0.3283	0.9252	2.8680
SAf[7,8]	1.0870	0.6965	0.0067	0.3343	0.9237	2.8220
SAf[7,9]	1.1040	0.7584	0.0069	0.3181	0.9246	2.9610
SAf[7,10]	1.1320	0.8282	0.0069	0.2900	0.9246	3.2140
SAf[8,1]	1.3580	0.2053	0.0072	0.9830	1.3490	1.8050
SAf[8,2]	1.3700	0.2033	0.0072	0.9973	1.3600	1.8160
SAf[8,3]	1.3410	0.2007	0.0070	0.9688	1.3320	1.7770
SAf[8,4]	1.3610	0.1960	0.0072	0.9968	1.3530	1.7890
SAf[8,5]	1.3740	0.2113	0.0072	0.9879	1.3630	1.8390
SAf[8,6]	1.3790	0.1987	0.0073	1.0130	1.3700	1.8160
SAf[8,7]	1.3460	0.2060	0.0071	0.9675	1.3360	1.7940
SAf[8,8]	1.3540	0.1964	0.0071	0.9887	1.3460	1.7830
SAf[8,9]	1.1570	0.2251	0.0065	0.7488	1.1480	1.6320
SAf[8,10]	1.0810	0.2678	0.0059	0.6132	1.0640	1.6610
SAf[9,1]	1.0440	0.1479	0.0055	0.7659	1.0390	1.3650
SAf[9,2]	1.0500	0.1471	0.0056	0.7726	1.0450	1.3750
SAf[9,3]	1.0520	0.1478	0.0056	0.7736	1.0470	1.3780
SAf[9,4]	1.0460	0.1427	0.0056	0.7740	1.0420	1.3580
SAf[9,5]	0.9979	0.1440	0.0053	0.7242	0.9943	1.3090
SAf[9,6]	1.0490	0.1418	0.0056	0.7791	1.0460	1.3640

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
SAf[9,7]	1.0380	0.1467	0.0056	0.7624	1.0330	1.3600
SAf[9,8]	1.0470	0.1433	0.0056	0.7746	1.0440	1.3620
SAf[9,9]	1.1650	0.1805	0.0062	0.8402	1.1530	1.5650
SAf[9,10]	1.0600	0.1907	0.0058	0.7278	1.0460	1.4850
SAf[10,1]	0.1606	0.0245	0.0009	0.1163	0.1592	0.2147
SAf[10,2]	0.1597	0.0235	0.0008	0.1161	0.1586	0.2111
SAf[10,3]	0.1576	0.0233	0.0008	0.1138	0.1567	0.2082
SAf[10,4]	0.1593	0.0228	0.0008	0.1164	0.1585	0.2086
SAf[10,5]	0.1572	0.0238	0.0008	0.1129	0.1562	0.2086
SAf[10,6]	0.1569	0.0223	0.0008	0.1145	0.1562	0.2052
SAf[10,7]	0.1528	0.0233	0.0008	0.1096	0.1519	0.2033
SAf[10,8]	0.1606	0.0232	0.0008	0.1171	0.1597	0.2111
SAf[10,9]	0.1539	0.0263	0.0008	0.1060	0.1525	0.2112
SAf[10,10]	0.1148	0.0267	0.0006	0.0679	0.1130	0.1720
SAf[11,1]	1.0810	0.1569	0.0057	0.7900	1.0740	1.4260
SAf[11,2]	1.0870	0.1556	0.0058	0.7983	1.0800	1.4310
SAf[11,3]	1.0850	0.1566	0.0058	0.7956	1.0780	1.4320
SAf[11,4]	1.0760	0.1498	0.0057	0.7948	1.0700	1.4060
SAf[11,5]	1.0760	0.1572	0.0057	0.7833	1.0690	1.4190
SAf[11,6]	1.0850	0.1499	0.0057	0.8036	1.0790	1.4190
SAf[11,7]	1.0910	0.1600	0.0058	0.7976	1.0840	1.4430
SAf[11,8]	1.0660	0.1497	0.0057	0.7847	1.0610	1.3950
SAf[11,9]	1.1410	0.1846	0.0061	0.8112	1.1280	1.5480
SAf[11,10]	1.2290	0.2399	0.0068	0.8265	1.2040	1.7690
SAf[12,1]	1.1940	0.1769	0.0063	0.8656	1.1880	1.5790
SAf[12,2]	1.1930	0.1740	0.0063	0.8684	1.1880	1.5740
SAf[12,3]	1.2150	0.1805	0.0065	0.8838	1.2070	1.6130
SAf[12,4]	1.2000	0.1698	0.0063	0.8809	1.1940	1.5710
SAf[12,5]	1.1330	0.1763	0.0061	0.8016	1.1290	1.5090
SAf[12,6]	1.2020	0.1685	0.0064	0.8838	1.1970	1.5710
SAf[12,7]	1.1750	0.1756	0.0062	0.8514	1.1680	1.5570
SAf[12,8]	1.1930	0.1699	0.0063	0.8732	1.1870	1.5650
SAf[12,9]	1.2570	0.2111	0.0067	0.8802	1.2420	1.7280
SAf[12,10]	1.2730	0.2640	0.0068	0.8299	1.2470	1.8670
SAf[13,1]	1.4560	0.2118	0.0078	1.0600	1.4470	1.9240
SAf[13,2]	1.4350	0.2055	0.0077	1.0420	1.4280	1.8780
SAf[13,3]	1.4960	0.2185	0.0080	1.0920	1.4850	1.9800
SAf[13,4]	1.4500	0.2013	0.0077	1.0680	1.4430	1.8910
SAf[13,5]	1.5310	0.2267	0.0082	1.1150	1.5170	2.0340
SAf[13,6]	1.4430	0.1979	0.0077	1.0640	1.4370	1.8760
SAf[13,7]	1.5740	0.2304	0.0084	1.1470	1.5620	2.0750
SAf[13,8]	1.4310	0.1992	0.0077	1.0520	1.4240	1.8680
SAf[13,9]	1.2910	0.2113	0.0071	0.9035	1.2820	1.7490
SAf[13,10]	1.3010	0.2430	0.0070	0.8747	1.2840	1.8310
SAf[14,1]	1.0290	0.1565	0.0055	0.7442	1.0200	1.3750
SAf[14,2]	1.0090	0.1485	0.0054	0.7314	1.0040	1.3350
SAf[14,3]	1.0090	0.1497	0.0054	0.7317	1.0030	1.3350
SAf[14,4]	1.0140	0.1453	0.0054	0.7413	1.0080	1.3330
SAf[14,5]	1.0000	0.1511	0.0053	0.7178	0.9944	1.3290
SAf[14,6]	1.0100	0.1428	0.0054	0.7412	1.0050	1.3210
SAf[14,7]	0.9318	0.1449	0.0050	0.6631	0.9271	1.2440
SAf[14,8]	1.0440	0.1516	0.0055	0.7621	1.0360	1.3770
SAf[14,9]	1.0360	0.1760	0.0055	0.7203	1.0260	1.4230
SAf[14,10]	1.3720	0.2955	0.0077	0.8885	1.3400	2.0430
SAf[15,1]	1.0750	0.1728	0.0057	0.7647	1.0650	1.4580
SAf[15,2]	1.0710	0.1684	0.0056	0.7634	1.0620	1.4370
SAf[15,3]	1.0540	0.1688	0.0056	0.7416	1.0460	1.4190
SAf[15,4]	1.0710	0.1645	0.0056	0.7689	1.0630	1.4300
SAf[15,5]	1.0490	0.1728	0.0056	0.7303	1.0410	1.4220
SAf[15,6]	1.0800	0.1650	0.0057	0.7781	1.0720	1.4400
SAf[15,7]	1.2040	0.2151	0.0065	0.8373	1.1830	1.6930
SAf[15,8]	1.0610	0.1644	0.0056	0.7570	1.0540	1.4170
SAf[15,9]	1.0460	0.1978	0.0056	0.6924	1.0330	1.4800
SAf[15,10]	0.8380	0.2193	0.0045	0.4516	0.8232	1.3060
SAf[16,1]	1.5950	0.2354	0.0084	1.1550	1.5850	2.1100
SAf[16,2]	1.5940	0.2313	0.0084	1.1610	1.5860	2.0980
SAf[16,3]	1.6400	0.2445	0.0087	1.1920	1.6250	2.1820
SAf[16,4]	1.6020	0.2266	0.0085	1.1730	1.5920	2.1000
SAf[16,5]	1.7030	0.2639	0.0090	1.2300	1.6830	2.2930
SAf[16,6]	1.6090	0.2259	0.0085	1.1810	1.6010	2.1060
SAf[16,7]	1.4320	0.2246	0.0078	1.0180	1.4230	1.9180
SAf[16,8]	1.5670	0.2237	0.0083	1.1460	1.5600	2.0560
SAf[16,9]	1.5720	0.2617	0.0085	1.0970	1.5570	2.1440
SAf[16,10]	1.3620	0.2825	0.0073	0.8702	1.3410	1.9760

6.1.4 Spatial relative risk of Kidney cancer incidence for males given each age group

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
SAm[1,1]	0.9418	0.1371	0.0050	0.6840	0.9377	1.2450
SAm[1,2]	0.9461	0.1357	0.0051	0.6907	0.9421	1.2460
SAm[1,3]	0.9302	0.1354	0.0050	0.6734	0.9266	1.2270
SAm[1,4]	0.9468	0.1322	0.0050	0.6959	0.9430	1.2390
SAm[1,5]	0.9913	0.1510	0.0053	0.7185	0.9807	1.3300
SAm[1,6]	0.9329	0.1283	0.0050	0.6868	0.9306	1.2150
SAm[1,7]	0.9261	0.1384	0.0050	0.6688	0.9208	1.2280
SAm[1,8]	0.9315	0.1318	0.0050	0.6816	0.9285	1.2220
SAm[1,9]	1.0640	0.1878	0.0057	0.7407	1.0460	1.4870
SAm[1,10]	1.2100	0.2628	0.0067	0.7868	1.1790	1.8160
SAm[2,1]	1.0690	0.1783	0.0056	0.7495	1.0580	1.4580
SAm[2,2]	1.0620	0.1752	0.0056	0.7458	1.0530	1.4440
SAm[2,3]	1.0710	0.1782	0.0056	0.7528	1.0600	1.4600
SAm[2,4]	1.0770	0.1737	0.0056	0.7648	1.0660	1.4570
SAm[2,5]	1.0300	0.1810	0.0055	0.6977	1.0230	1.4190
SAm[2,6]	1.0690	0.1708	0.0056	0.7599	1.0590	1.4430
SAm[2,7]	1.0830	0.1892	0.0057	0.7506	1.0700	1.5000
SAm[2,8]	1.0860	0.1773	0.0057	0.7673	1.0750	1.4750
SAm[2,9]	1.2020	0.2558	0.0064	0.7875	1.1710	1.8020
SAm[2,10]	0.9376	0.2501	0.0050	0.5076	0.9174	1.4910
SAm[3,1]	1.2890	0.1888	0.0069	0.9407	1.2820	1.7040
SAm[3,2]	1.2750	0.1828	0.0068	0.9303	1.2690	1.6720
SAm[3,3]	1.2950	0.1869	0.0069	0.9472	1.2870	1.7050
SAm[3,4]	1.2860	0.1789	0.0068	0.9494	1.2800	1.6800
SAm[3,5]	1.3090	0.1931	0.0069	0.9535	1.3010	1.7370
SAm[3,6]	1.2870	0.1774	0.0068	0.9520	1.2810	1.6790
SAm[3,7]	1.4250	0.2172	0.0076	1.0320	1.4120	1.9030
SAm[3,8]	1.2670	0.1783	0.0067	0.9314	1.2610	1.6570
SAm[3,9]	1.0140	0.2034	0.0059	0.6515	1.0020	1.4440
SAm[3,10]	1.5180	0.3209	0.0083	0.9930	1.4830	2.2500
SAm[4,1]	1.1780	0.8011	0.0033	0.3194	0.9962	3.1100
SAm[4,2]	1.1770	0.7930	0.0032	0.3208	0.9965	3.1010
SAm[4,3]	1.1790	0.7973	0.0032	0.3196	0.9959	3.1100
SAm[4,4]	1.1770	0.7947	0.0032	0.3206	0.9964	3.1050
SAm[4,5]	1.1810	0.8010	0.0032	0.3181	0.9964	3.1370
SAm[4,6]	1.1760	0.7895	0.0032	0.3212	0.9962	3.1040
SAm[4,7]	1.1820	0.8149	0.0033	0.3136	0.9971	3.1510
SAm[4,8]	1.1770	0.7930	0.0032	0.3189	0.9959	3.1170
SAm[4,9]	1.1950	0.8419	0.0034	0.3065	0.9968	3.2700
SAm[4,10]	1.2240	0.9399	0.0035	0.2812	0.9975	3.5490
SAm[5,1]	1.1070	0.1539	0.0059	0.8138	1.1050	1.4380
SAm[5,2]	1.1320	0.1546	0.0061	0.8384	1.1290	1.4730
SAm[5,3]	1.0900	0.1507	0.0058	0.8036	1.0880	1.4210
SAm[5,4]	1.1200	0.1492	0.0060	0.8332	1.1170	1.4490
SAm[5,5]	1.0940	0.1507	0.0058	0.8064	1.0910	1.4230
SAm[5,6]	1.1210	0.1476	0.0060	0.8366	1.1180	1.4490
SAm[5,7]	1.1390	0.1562	0.0061	0.8440	1.1350	1.4800
SAm[5,8]	1.1760	0.1584	0.0063	0.8746	1.1710	1.5280
SAm[5,9]	1.1530	0.1717	0.0062	0.8348	1.1440	1.5290
SAm[5,10]	1.4490	0.2545	0.0080	1.0080	1.4280	2.0160
SAm[6,1]	0.9431	0.1450	0.0050	0.6760	0.9367	1.2560
SAm[6,2]	0.9523	0.1447	0.0051	0.6857	0.9452	1.2690
SAm[6,3]	0.9506	0.1458	0.0050	0.6831	0.9439	1.2660
SAm[6,4]	0.9374	0.1392	0.0050	0.6775	0.9317	1.2400
SAm[6,5]	0.9865	0.1593	0.0052	0.7029	0.9755	1.3400
SAm[6,6]	0.9412	0.1380	0.0050	0.6832	0.9357	1.2400
SAm[6,7]	0.9259	0.1478	0.0050	0.6568	0.9184	1.2470
SAm[6,8]	0.9393	0.1407	0.0050	0.6788	0.9331	1.2440
SAm[6,9]	1.1690	0.2358	0.0064	0.7885	1.1390	1.7130
SAm[6,10]	1.2470	0.2986	0.0069	0.7774	1.2080	1.9390
SAm[7,1]	1.0880	0.6997	0.0067	0.3343	0.9240	2.8290
SAm[7,2]	1.0880	0.6972	0.0067	0.3337	0.9245	2.8200
SAm[7,3]	1.0880	0.6992	0.0067	0.3329	0.9244	2.8310
SAm[7,4]	1.0870	0.6973	0.0067	0.3355	0.9250	2.8170
SAm[7,5]	1.0900	0.7067	0.0067	0.3308	0.9242	2.8380
SAm[7,6]	1.0870	0.6966	0.0067	0.3363	0.9249	2.8200
SAm[7,7]	1.0920	0.7101	0.0068	0.3278	0.9252	2.8560
SAm[7,8]	1.0870	0.6978	0.0067	0.3340	0.9238	2.8230
SAm[7,9]	1.1040	0.7602	0.0069	0.3185	0.9243	2.9710
SAm[7,10]	1.1320	0.8294	0.0070	0.2895	0.9247	3.1970
SAm[8,1]	1.4150	0.2103	0.0075	1.0290	1.4060	1.8760
SAm[8,2]	1.4270	0.2082	0.0075	1.0430	1.4170	1.8830
SAm[8,3]	1.3970	0.2053	0.0074	1.0110	1.3890	1.8430
SAm[8,4]	1.4180	0.2003	0.0075	1.0440	1.4100	1.8550
SAm[8,5]	1.4320	0.2164	0.0076	1.0350	1.4200	1.9070
SAm[8,6]	1.4370	0.2032	0.0076	1.0600	1.4280	1.8840
SAm[8,7]	1.4020	0.2110	0.0074	1.0100	1.3930	1.8600
SAm[8,8]	1.4100	0.2012	0.0074	1.0350	1.4030	1.8510
SAm[8,9]	1.2060	0.2338	0.0068	0.7816	1.1960	1.7000
SAm[8,10]	1.1270	0.2786	0.0062	0.6379	1.1100	1.7250
SAm[9,1]	1.0720	0.1500	0.0057	0.7883	1.0680	1.3980
SAm[9,2]	1.0790	0.1491	0.0057	0.7964	1.0750	1.4080
SAm[9,3]	1.0800	0.1498	0.0058	0.7972	1.0750	1.4110
SAm[9,4]	1.0740	0.1446	0.0057	0.7963	1.0710	1.3910
SAm[9,5]	1.0250	0.1460	0.0055	0.7461	1.0230	1.3400
SAm[9,6]	1.0780	0.1435	0.0057	0.8028	1.0750	1.3960
SAm[9,7]	1.0660	0.1491	0.0057	0.7849	1.0620	1.3940
SAm[9,8]	1.0760	0.1455	0.0057	0.7975	1.0720	1.3960
SAm[9,9]	1.1970	0.1849	0.0064	0.8630	1.1850	1.6060
SAm[9,10]	1.0890	0.1962	0.0060	0.7479	1.0740	1.5270

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
SAm[10,1]	0.1591	0.0239	0.0008	0.1157	0.1579	0.2119
SAm[10,2]	0.1582	0.0229	0.0008	0.1156	0.1572	0.2084
SAm[10,3]	0.1561	0.0227	0.0008	0.1136	0.1553	0.2058
SAm[10,4]	0.1578	0.0222	0.0008	0.1159	0.1571	0.2061
SAm[10,5]	0.1557	0.0232	0.0008	0.1122	0.1548	0.2062
SAm[10,6]	0.1554	0.0217	0.0008	0.1142	0.1548	0.2028
SAm[10,7]	0.1514	0.0228	0.0008	0.1092	0.1505	0.2007
SAm[10,8]	0.1591	0.0226	0.0008	0.1167	0.1583	0.2086
SAm[10,9]	0.1525	0.0259	0.0008	0.1053	0.1511	0.2090
SAm[10,10]	0.1137	0.0266	0.0006	0.0672	0.1120	0.1706
SAm[11,1]	1.1170	0.1596	0.0059	0.8181	1.1110	1.4650
SAm[11,2]	1.1230	0.1584	0.0059	0.8267	1.1180	1.4720
SAm[11,3]	1.1210	0.1592	0.0059	0.8230	1.1150	1.4690
SAm[11,4]	1.1110	0.1523	0.0059	0.8227	1.1060	1.4440
SAm[11,5]	1.1120	0.1599	0.0059	0.8109	1.1060	1.4610
SAm[11,6]	1.1200	0.1523	0.0059	0.8322	1.1160	1.4570
SAm[11,7]	1.1270	0.1630	0.0060	0.8262	1.1210	1.4820
SAm[11,8]	1.1010	0.1524	0.0058	0.8127	1.0970	1.4330
SAm[11,9]	1.1790	0.1897	0.0063	0.8387	1.1660	1.5960
SAm[11,10]	1.2700	0.2482	0.0070	0.8524	1.2450	1.8290
SAm[12,1]	1.2080	0.1768	0.0064	0.8782	1.2020	1.5950
SAm[12,2]	1.2070	0.1737	0.0064	0.8820	1.2020	1.5870
SAm[12,3]	1.2300	0.1801	0.0065	0.8974	1.2220	1.6240
SAm[12,4]	1.2140	0.1694	0.0064	0.8935	1.2080	1.5860
SAm[12,5]	1.1460	0.1761	0.0062	0.8112	1.1430	1.5240
SAm[12,6]	1.2160	0.1681	0.0064	0.8975	1.2110	1.5850
SAm[12,7]	1.1890	0.1755	0.0063	0.8632	1.1820	1.5730
SAm[12,8]	1.2070	0.1697	0.0064	0.8869	1.2010	1.5780
SAm[12,9]	1.2720	0.2128	0.0068	0.8940	1.2570	1.7470
SAm[12,10]	1.2880	0.2679	0.0069	0.8392	1.2620	1.8950
SAm[13,1]	1.3550	0.1940	0.0072	0.9931	1.3480	1.7830
SAm[13,2]	1.3350	0.1882	0.0071	0.9779	1.3300	1.7470
SAm[13,3]	1.3920	0.2003	0.0074	1.0240	1.3820	1.8340
SAm[13,4]	1.3490	0.1840	0.0072	1.0010	1.3430	1.7530
SAm[13,5]	1.4250	0.2076	0.0076	1.0460	1.4120	1.8850
SAm[13,6]	1.3430	0.1809	0.0071	0.9976	1.3370	1.7410
SAm[13,7]	1.4640	0.2118	0.0078	1.0750	1.4530	1.9250
SAm[13,8]	1.3310	0.1828	0.0071	0.9862	1.3270	1.7360
SAm[13,9]	1.2010	0.1963	0.0066	0.8430	1.1930	1.6240
SAm[13,10]	1.2110	0.2272	0.0065	0.8123	1.1940	1.7070
SAm[14,1]	1.0230	0.1534	0.0055	0.7435	1.0150	1.3630
SAm[14,2]	1.0030	0.1454	0.0053	0.7303	0.9984	1.3210
SAm[14,3]	1.0030	0.1466	0.0053	0.7289	0.9976	1.3220
SAm[14,4]	1.0070	0.1421	0.0053	0.7406	1.0030	1.3190
SAm[14,5]	0.9938	0.1479	0.0053	0.7175	0.9886	1.3140
SAm[14,6]	1.0040	0.1396	0.0053	0.7393	0.9996	1.3080
SAm[14,7]	0.9261	0.1423	0.0050	0.6622	0.9216	1.2320
SAm[14,8]	1.0370	0.1487	0.0055	0.7603	1.0310	1.3650
SAm[14,9]	1.0300	0.1744	0.0055	0.7172	1.0200	1.4140
SAm[14,10]	1.3640	0.2947	0.0076	0.8822	1.3310	2.0380
SAm[15,1]	1.0820	0.1714	0.0057	0.7717	1.0720	1.4610
SAm[15,2]	1.0770	0.1668	0.0057	0.7717	1.0690	1.4400
SAm[15,3]	1.0600	0.1674	0.0056	0.7496	1.0530	1.4200
SAm[15,4]	1.0770	0.1629	0.0057	0.7787	1.0690	1.4340
SAm[15,5]	1.0550	0.1714	0.0056	0.7377	1.0470	1.4250
SAm[15,6]	1.0860	0.1635	0.0057	0.7860	1.0780	1.4450
SAm[15,7]	1.2110	0.2136	0.0065	0.8462	1.1900	1.6970
SAm[15,8]	1.0670	0.1630	0.0056	0.7666	1.0600	1.4210
SAm[15,9]	1.0520	0.1975	0.0056	0.6990	1.0400	1.4860
SAm[15,10]	0.8431	0.2204	0.0046	0.4549	0.8287	1.3130
SAm[16,1]	1.5140	0.2202	0.0080	1.1030	1.5060	1.9950
SAm[16,2]	1.5140	0.2164	0.0080	1.1070	1.5060	1.9880
SAm[16,3]	1.5570	0.2290	0.0083	1.1370	1.5430	2.0660
SAm[16,4]	1.5200	0.2116	0.0080	1.1210	1.5130	1.9870
SAm[16,5]	1.6160	0.2469	0.0086	1.1760	1.5990	2.1690
SAm[16,6]	1.5280	0.2109	0.0081	1.1290	1.5220	1.9940
SAm[16,7]	1.3600	0.2106	0.0074	0.9705	1.3520	1.8140
SAm[16,8]	1.4880	0.2096	0.0079	1.0930	1.4820	1.9460
SAm[16,9]	1.4920	0.2479	0.0080	1.0430	1.4780	2.0350
SAm[16,10]	1.2940	0.2691	0.0070	0.8268	1.2740	1.8800

6.2 Lung cancer incidence results continuation

6.2.1 Parameter estimates of interaction effects between states i and age groups j, δ_{ij}

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
delta[1,1]	-0.0692	0.1190	0.0022	-0.3923	-0.0314	0.0785
delta[1,2]	-0.0049	0.0441	0.0002	-0.1042	-0.0029	0.0813
delta[1,3]	-0.0160	0.0377	0.0002	-0.1059	-0.0114	0.0486
delta[1,4]	0.0232	0.0937	0.0010	-0.1630	0.0233	0.2078
delta[1,5]	0.0152	0.0454	0.0003	-0.0701	0.0115	0.1170
delta[1,6]	-0.0004	0.0295	0.0002	-0.0616	-0.0002	0.0598
delta[1,7]	-0.0012	0.0319	0.0002	-0.0682	-0.0009	0.0635
delta[1,8]	-0.0100	0.0362	0.0002	-0.0895	-0.0078	0.0596
delta[1,9]	0.0858	0.0801	0.0007	-0.0598	0.0812	0.2561
delta[1,10]	0.1698	0.1082	0.0017	-0.0065	0.1638	0.3972
delta[2,1]	-0.0440	0.1244	0.0017	-0.3828	-0.0152	0.1397
delta[2,2]	0.0037	0.0487	0.0002	-0.0941	0.0020	0.1120
delta[2,3]	0.0100	0.0392	0.0002	-0.0605	0.0064	0.1001
delta[2,4]	0.1034	0.1239	0.0009	-0.1375	0.1015	0.3508
delta[2,5]	0.0160	0.0522	0.0003	-0.0808	0.0108	0.1361
delta[2,6]	0.0113	0.0329	0.0002	-0.0475	0.0083	0.0874
delta[2,7]	-0.0115	0.0355	0.0002	-0.0935	-0.0082	0.0523
delta[2,8]	-0.0179	0.0419	0.0003	-0.1176	-0.0126	0.0537
delta[2,9]	0.0266	0.0942	0.0005	-0.1573	0.0233	0.2229
delta[2,10]	-0.0583	0.1035	0.0008	-0.2912	-0.0442	0.1222
delta[3,1]	0.0719	0.1189	0.0022	-0.0773	0.0332	0.3924
delta[3,2]	0.0071	0.0446	0.0002	-0.0787	0.0046	0.1084
delta[3,3]	-0.0199	0.0389	0.0003	-0.1157	-0.0140	0.0425
delta[3,4]	-0.3443	0.1031	0.0010	-0.5567	-0.3406	-0.1521
delta[3,5]	-0.0029	0.0449	0.0003	-0.0974	-0.0022	0.0889
delta[3,6]	0.0039	0.0284	0.0002	-0.0526	0.0032	0.0640
delta[3,7]	0.0173	0.0327	0.0002	-0.0395	0.0138	0.0933
delta[3,8]	-0.0004	0.0347	0.0002	-0.0719	-0.0006	0.0719
delta[3,9]	-0.1348	0.0852	0.0007	-0.3145	-0.1301	0.0154
delta[3,10]	0.0936	0.0961	0.0011	-0.0644	0.0822	0.3071
delta[4,1]	-0.0006	0.1227	0.0005	-0.2711	-0.0000	0.2647
delta[4,2]	0.0002	0.0517	0.0002	-0.1067	0.0002	0.1082
delta[4,3]	0.0000	0.0395	0.0002	-0.0810	-0.0001	0.0820
delta[4,4]	0.0009	0.2013	0.0008	-0.4040	0.0009	0.4044
delta[4,5]	-0.0002	0.0602	0.0003	-0.1273	-0.0001	0.1256
delta[4,6]	-0.0000	0.0338	0.0001	-0.0696	-0.0001	0.0701
delta[4,7]	-0.0000	0.0369	0.0001	-0.0765	-0.0001	0.0762
delta[4,8]	-0.0005	0.0432	0.0002	-0.0904	-0.0003	0.0894
delta[4,9]	0.0002	0.1249	0.0005	-0.2559	0.0002	0.2578
delta[4,10]	-0.0005	0.1257	0.0005	-0.2630	-0.0006	0.2650
delta[5,1]	-0.0202	0.0764	0.0008	-0.2030	-0.0103	0.1202
delta[5,2]	0.0013	0.0386	0.0002	-0.0801	0.0012	0.0821
delta[5,3]	0.0151	0.0325	0.0002	-0.0421	0.0118	0.0901
delta[5,4]	0.1471	0.0718	0.0011	0.0060	0.1465	0.2887
delta[5,5]	-0.0076	0.0359	0.0003	-0.0823	-0.0066	0.0642
delta[5,6]	-0.0003	0.0249	0.0002	-0.0516	0.0001	0.0500
delta[5,7]	-0.0301	0.0307	0.0003	-0.1008	-0.0260	0.0202
delta[5,8]	0.0138	0.0305	0.0002	-0.0421	0.0115	0.0812
delta[5,9]	0.0110	0.0568	0.0006	-0.0991	0.0098	0.1260
delta[5,10]	0.0601	0.0659	0.0008	-0.0559	0.0545	0.2008
delta[6,1]	-0.0232	0.0964	0.0009	-0.2661	-0.0092	0.1484
delta[6,2]	-0.0049	0.0451	0.0002	-0.1069	-0.0027	0.0845
delta[6,3]	-0.0043	0.0363	0.0002	-0.0836	-0.0030	0.0674
delta[6,4]	0.0471	0.0999	0.0010	-0.1498	0.0465	0.2452
delta[6,5]	0.0435	0.0542	0.0006	-0.0402	0.0337	0.1738
delta[6,6]	-0.0213	0.0334	0.0003	-0.1024	-0.0162	0.0320
delta[6,7]	-0.0051	0.0323	0.0002	-0.0753	-0.0039	0.0578
delta[6,8]	0.0128	0.0374	0.0003	-0.0548	0.0094	0.0992
delta[6,9]	0.1254	0.0857	0.0009	-0.0254	0.1206	0.3064
delta[6,10]	-0.0089	0.0833	0.0005	-0.1811	-0.0074	0.1610
delta[7,1]	0.0011	0.1233	0.0005	-0.2624	0.0004	0.2733
delta[7,2]	0.0005	0.0514	0.0002	-0.1037	0.0001	0.1091
delta[7,3]	0.0000	0.0401	0.0002	-0.0836	-0.0001	0.0832
delta[7,4]	-0.0007	0.2003	0.0008	-0.4009	-0.0010	0.3974
delta[7,5]	0.0001	0.0598	0.0003	-0.1243	-0.0002	0.1264
delta[7,6]	-0.0000	0.0336	0.0001	-0.0691	0.0000	0.0686
delta[7,7]	0.0001	0.0367	0.0002	-0.0755	0.0000	0.0756
delta[7,8]	-0.0002	0.0435	0.0002	-0.0908	0.0000	0.0899
delta[7,9]	-0.0006	0.1244	0.0005	-0.2544	-0.0001	0.2535
delta[7,10]	-0.0002	0.1241	0.0005	-0.2609	0.0004	0.2585
delta[8,1]	0.1125	0.1587	0.0034	-0.0527	0.0505	0.5421
delta[8,2]	0.0016	0.0457	0.0002	-0.0923	0.0011	0.1007
delta[8,3]	-0.0084	0.0367	0.0002	-0.0917	-0.0056	0.0597
delta[8,4]	-0.1795	0.1028	0.0010	-0.3878	-0.1768	0.0143
delta[8,5]	-0.0245	0.0495	0.0004	-0.1400	-0.0180	0.0621
delta[8,6]	0.0121	0.0306	0.0002	-0.0424	0.0094	0.0815
delta[8,7]	0.0142	0.0335	0.0002	-0.0448	0.0108	0.0919
delta[8,8]	-0.0071	0.0362	0.0002	-0.0861	-0.0054	0.0622
delta[8,9]	-0.0927	0.0867	0.0006	-0.2759	-0.0869	0.0629
delta[8,10]	-0.0236	0.0942	0.0005	-0.2278	-0.0175	0.1588

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
delta[9,1]	0.0284	0.0789	0.0008	-0.1113	0.0160	0.2205
delta[9,2]	-0.0165	0.0425	0.0003	-0.1185	-0.0112	0.0564
delta[9,3]	0.0048	0.0319	0.0002	-0.0582	0.0037	0.0735
delta[9,4]	0.1048	0.0743	0.0011	-0.0392	0.1044	0.2525
delta[9,5]	0.0249	0.0387	0.0004	-0.0442	0.0210	0.1099
delta[9,6]	-0.0074	0.0257	0.0002	-0.0636	-0.0061	0.0413
delta[9,7]	-0.0047	0.0273	0.0002	-0.0622	-0.0038	0.0484
delta[9,8]	-0.0055	0.0303	0.0002	-0.0684	-0.0048	0.0549
delta[9,9]	0.0394	0.0590	0.0006	-0.0736	0.0377	0.1592
delta[9,10]	0.0196	0.0648	0.0006	-0.1053	0.0164	0.1560
delta[10,1]	-0.0175	0.0943	0.0007	-0.2522	-0.0069	0.1637
delta[10,2]	0.0335	0.0560	0.0006	-0.0425	0.0204	0.1844
delta[10,3]	0.0153	0.0373	0.0003	-0.0484	0.0108	0.1039
delta[10,4]	0.2536	0.0914	0.0010	0.0779	0.2524	0.4377
delta[10,5]	-0.0116	0.0451	0.0003	-0.1100	-0.0087	0.0759
delta[10,6]	0.0014	0.0288	0.0001	-0.0577	0.0012	0.0611
delta[10,7]	-0.0029	0.0313	0.0002	-0.0692	-0.0021	0.0596
delta[10,8]	-0.0082	0.0354	0.0002	-0.0853	-0.0063	0.0607
delta[10,9]	-0.1363	0.0846	0.0008	-0.3145	-0.1319	0.0132
delta[10,10]	-0.1812	0.1211	0.0018	-0.4429	-0.1705	0.0076
delta[11,1]	-0.0564	0.1086	0.0018	-0.3470	-0.0254	0.0898
delta[11,2]	0.0017	0.0432	0.0002	-0.0884	0.0014	0.0940
delta[11,3]	-0.0072	0.0345	0.0002	-0.0843	-0.0052	0.0592
delta[11,4]	0.0285	0.0852	0.0010	-0.1397	0.0283	0.1969
delta[11,5]	-0.0182	0.0430	0.0003	-0.1133	-0.0146	0.0615
delta[11,6]	-0.0030	0.0280	0.0002	-0.0624	-0.0022	0.0522
delta[11,7]	-0.0132	0.0312	0.0002	-0.0841	-0.0105	0.0426
delta[11,8]	0.0333	0.0394	0.0004	-0.0279	0.0266	0.1276
delta[11,9]	0.1229	0.0727	0.0007	-0.0095	0.1200	0.2736
delta[11,10]	-0.0127	0.0749	0.0005	-0.1678	-0.0111	0.1384
delta[12,1]	-0.0067	0.0942	0.0005	-0.2259	-0.0025	0.1891
delta[12,2]	-0.0030	0.0447	0.0002	-0.1019	-0.0018	0.0876
delta[12,3]	0.0032	0.0349	0.0002	-0.0661	0.0022	0.0787
delta[12,4]	-0.1470	0.0929	0.0010	-0.3340	-0.1453	0.0309
delta[12,5]	-0.0305	0.0474	0.0004	-0.1408	-0.0238	0.0498
delta[12,6]	0.0058	0.0283	0.0002	-0.0490	0.0046	0.0678
delta[12,7]	0.0126	0.0313	0.0002	-0.0437	0.0100	0.0832
delta[12,8]	0.0134	0.0356	0.0003	-0.0514	0.0102	0.0947
delta[12,9]	-0.0872	0.0769	0.0006	-0.2477	-0.0836	0.0528
delta[12,10]	-0.0185	0.0820	0.0005	-0.1906	-0.0148	0.1446
delta[13,1]	-0.0458	0.1052	0.0015	-0.3259	-0.0197	0.1096
delta[13,2]	-0.0041	0.0440	0.0002	-0.1023	-0.0024	0.0847
delta[13,3]	-0.0015	0.0344	0.0002	-0.0741	-0.0013	0.0693
delta[13,4]	-0.1974	0.0892	0.0010	-0.3772	-0.1959	-0.0274
delta[13,5]	-0.0192	0.0431	0.0003	-0.1148	-0.0153	0.0599
delta[13,6]	-0.0235	0.0314	0.0003	-0.0985	-0.0189	0.0263
delta[13,7]	0.0190	0.0314	0.0003	-0.0357	0.0157	0.0910
delta[13,8]	0.0327	0.0389	0.0004	-0.0280	0.0263	0.1251
delta[13,9]	0.0406	0.0675	0.0006	-0.0882	0.0385	0.1791
delta[13,10]	0.0364	0.0766	0.0007	-0.1058	0.0301	0.2016
delta[14,1]	-0.0293	0.0952	0.0010	-0.2720	-0.0124	0.1321
delta[14,2]	-0.0285	0.0533	0.0006	-0.1704	-0.0173	0.0470
delta[14,3]	-0.0010	0.0349	0.0002	-0.0741	-0.0008	0.0712
delta[14,4]	0.1550	0.0889	0.0010	-0.0174	0.1544	0.3332
delta[14,5]	0.0721	0.0597	0.0008	-0.0149	0.0619	0.2095
delta[14,6]	0.0009	0.0279	0.0002	-0.0567	0.0009	0.0581
delta[14,7]	-0.0006	0.0302	0.0002	-0.0630	-0.0006	0.0610
delta[14,8]	-0.0276	0.0384	0.0003	-0.1198	-0.0217	0.0340
delta[14,9]	0.0859	0.0746	0.0007	-0.0498	0.0822	0.2425
delta[14,10]	-0.0492	0.0805	0.0006	-0.2226	-0.0419	0.0974
delta[15,1]	0.0266	0.1054	0.0009	-0.1647	0.0110	0.2933
delta[15,2]	0.0193	0.0521	0.0004	-0.0638	0.0112	0.1517
delta[15,3]	0.0039	0.0369	0.0002	-0.0689	0.0026	0.0843
delta[15,4]	0.1618	0.1058	0.0010	-0.0423	0.1604	0.3732
delta[15,5]	-0.0034	0.0483	0.0003	-0.1055	-0.0026	0.0959
delta[15,6]	0.0058	0.0305	0.0001	-0.0531	0.0044	0.0725
delta[15,7]	-0.0052	0.0333	0.0002	-0.0774	-0.0037	0.0594
delta[15,8]	-0.0069	0.0376	0.0002	-0.0900	-0.0049	0.0658
delta[15,9]	-0.0991	0.0919	0.0007	-0.2989	-0.0920	0.0608
delta[15,10]	-0.0563	0.0961	0.0008	-0.2717	-0.0450	0.1152
delta[16,1]	0.0274	0.1011	0.0009	-0.1547	0.0114	0.2817
delta[16,2]	-0.0114	0.0480	0.0003	-0.1261	-0.0064	0.0747
delta[16,3]	0.0068	0.0362	0.0002	-0.0621	0.0048	0.0877
delta[16,4]	-0.1521	0.1020	0.0010	-0.3597	-0.1502	0.0437
delta[16,5]	-0.0510	0.0574	0.0006	-0.1896	-0.0396	0.0343
delta[16,6]	0.0153	0.0312	0.0002	-0.0385	0.0118	0.0882
delta[16,7]	0.0133	0.0325	0.0002	-0.0455	0.0103	0.0872
delta[16,8]	-0.0202	0.0385	0.0003	-0.1110	-0.0152	0.0457
delta[16,9]	0.0333	0.0784	0.0006	-0.1168	0.0303	0.1936
delta[16,10]	0.0471	0.0901	0.0008	-0.1160	0.0376	0.2460

6.2.2 Parameter estimates of interaction effects between states i and gender k, ψ_{ik}

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
psi[1,1]	0.2750	0.1745	0.0085	-0.0386	0.3221	0.5403
psi[1,2]	-0.1203	0.1641	0.0081	-0.4827	-0.0434	0.0636
psi[2,1]	0.1277	0.1237	0.0042	-0.0803	0.1229	0.3801
psi[2,2]	-0.0510	0.1022	0.0037	-0.3061	-0.0211	0.1016
psi[3,1]	-0.1169	0.1107	0.0041	-0.3285	-0.1176	0.0796
psi[3,2]	0.0598	0.1012	0.0041	-0.0846	0.0268	0.3013
psi[4,1]	0.0009	0.2030	0.0009	-0.4215	-0.0006	0.4322
psi[4,2]	-0.0010	0.1357	0.0006	-0.3078	-0.0005	0.3087
psi[5,1]	0.0662	0.0886	0.0034	-0.1021	0.0616	0.2428
psi[5,2]	-0.0300	0.0765	0.0029	-0.2066	-0.0167	0.1072
psi[6,1]	0.2915	0.1822	0.0088	-0.0321	0.3396	0.5751
psi[6,2]	-0.1227	0.1687	0.0083	-0.4930	-0.0412	0.0679
psi[7,1]	0.0013	0.2018	0.0009	-0.4226	0.0013	0.4222
psi[7,2]	0.0005	0.1355	0.0006	-0.3069	0.0001	0.3113
psi[8,1]	-0.1314	0.1178	0.0045	-0.3585	-0.1326	0.0710
psi[8,2]	0.0670	0.1070	0.0044	-0.0790	0.0302	0.3245
psi[9,1]	0.0092	0.0850	0.0029	-0.1542	0.0054	0.1903
psi[9,2]	0.0052	0.0693	0.0022	-0.1389	0.0024	0.1635
psi[10,1]	-0.0491	0.0953	0.0028	-0.2600	-0.0391	0.1251
psi[10,2]	-0.0182	0.0794	0.0022	-0.2075	-0.0103	0.1392
psi[11,1]	0.0508	0.0898	0.0028	-0.1197	0.0432	0.2389
psi[11,2]	-0.0178	0.0755	0.0023	-0.1900	-0.0090	0.1300
psi[12,1]	-0.2170	0.1493	0.0069	-0.4674	-0.2420	0.0447
psi[12,2]	0.1046	0.1439	0.0070	-0.0674	0.0421	0.4308
psi[13,1]	-0.1803	0.1318	0.0058	-0.4134	-0.1958	0.0510
psi[13,2]	0.0813	0.1235	0.0057	-0.0798	0.0329	0.3632
psi[14,1]	0.0828	0.0988	0.0035	-0.0919	0.0764	0.2850
psi[14,2]	-0.0306	0.0803	0.0028	-0.2197	-0.0144	0.1079
psi[15,1]	-0.0312	0.0961	0.0023	-0.2327	-0.0238	0.1565
psi[15,2]	0.0227	0.0794	0.0020	-0.1239	0.0110	0.2121
psi[16,1]	-0.1442	0.1207	0.0048	-0.3743	-0.1479	0.0614
psi[16,2]	0.0687	0.1096	0.0047	-0.0796	0.0297	0.3278

6.2.3 Spatial relative risk of Lung cancer incidence for females given each age group

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
SAf[1,1]	1.3290	0.2368	0.0097	0.8670	1.3360	1.7950
SAf[1,2]	1.4100	0.2072	0.0097	1.0160	1.4110	1.8410
SAf[1,3]	1.3940	0.2012	0.0096	1.0120	1.3950	1.8110
SAf[1,4]	1.4550	0.2440	0.0103	1.0140	1.4440	1.9630
SAf[1,5]	1.4380	0.2105	0.0099	1.0390	1.4370	1.8750
SAf[1,6]	1.4150	0.2020	0.0097	1.0320	1.4170	1.8370
SAf[1,7]	1.4140	0.2025	0.0097	1.0310	1.4160	1.8360
SAf[1,8]	1.4020	0.2021	0.0096	1.0190	1.4040	1.8210
SAf[1,9]	1.5460	0.2469	0.0107	1.0980	1.5360	2.0730
SAf[1,10]	1.6860	0.2930	0.0120	1.1750	1.6640	2.3260
SAf[2,1]	1.6140	0.3079	0.0115	1.0310	1.6120	2.2410
SAf[2,2]	1.6830	0.2707	0.0115	1.1900	1.6730	2.2560
SAf[2,3]	1.6930	0.2677	0.0116	1.2040	1.6850	2.2540
SAf[2,4]	1.8700	0.3587	0.0131	1.2440	1.8450	2.6540
SAf[2,5]	1.7040	0.2733	0.0117	1.2070	1.6930	2.2810
SAf[2,6]	1.6950	0.2641	0.0116	1.2080	1.6880	2.2500
SAf[2,7]	1.6570	0.2589	0.0114	1.1820	1.6500	2.1990
SAf[2,8]	1.6470	0.2595	0.0113	1.1680	1.6390	2.1920
SAf[2,9]	1.7260	0.3029	0.0118	1.1880	1.7100	2.3780
SAf[2,10]	1.5870	0.2850	0.0109	1.0710	1.5740	2.1890
SAf[3,1]	1.0700	0.2046	0.0075	0.7344	1.0500	1.5550
SAf[3,2]	0.9971	0.1503	0.0069	0.7167	0.9945	1.3080
SAf[3,3]	0.9702	0.1440	0.0067	0.7016	0.9687	1.2700
SAf[3,4]	0.7042	0.1221	0.0049	0.4823	0.6994	0.9577
SAf[3,5]	0.9869	0.1474	0.0068	0.7105	0.9853	1.2940
SAf[3,6]	0.9932	0.1452	0.0068	0.7210	0.9925	1.2970
SAf[3,7]	1.0070	0.1480	0.0069	0.7281	1.0060	1.3120
SAf[3,8]	0.9891	0.1459	0.0068	0.7153	0.9884	1.2930
SAf[3,9]	0.8668	0.1409	0.0060	0.6081	0.8626	1.1580
SAf[3,10]	1.0910	0.1869	0.0076	0.7611	1.0780	1.4950
SAf[4,1]	1.1350	0.8140	0.0066	0.2880	0.9404	3.1300
SAf[4,2]	1.1300	0.7978	0.0066	0.2930	0.9413	3.0590
SAf[4,3]	1.1280	0.7904	0.0065	0.2930	0.9414	3.0470
SAf[4,4]	1.1520	0.8577	0.0069	0.2757	0.9437	3.2720
SAf[4,5]	1.1300	0.7988	0.0066	0.2915	0.9406	3.0650
SAf[4,6]	1.1290	0.7928	0.0066	0.2924	0.9416	3.0610
SAf[4,7]	1.1290	0.7924	0.0065	0.2926	0.9418	3.0510
SAf[4,8]	1.1280	0.7949	0.0065	0.2929	0.9408	3.0630
SAf[4,9]	1.1370	0.8202	0.0067	0.2881	0.9411	3.1380
SAf[4,10]	1.1360	0.8140	0.0066	0.2851	0.9427	3.1300
SAf[5,1]	0.8646	0.1358	0.0060	0.6131	0.8632	1.1440
SAf[5,2]	0.8815	0.1263	0.0061	0.6429	0.8819	1.1430
SAf[5,3]	0.8936	0.1267	0.0061	0.6544	0.8943	1.1570
SAf[5,4]	1.0220	0.1581	0.0072	0.7264	1.0190	1.3470
SAf[5,5]	0.8734	0.1233	0.0060	0.6396	0.8742	1.1300
SAf[5,6]	0.8797	0.1229	0.0060	0.6461	0.8815	1.1360
SAf[5,7]	0.8539	0.1196	0.0058	0.6269	0.8555	1.1030
SAf[5,8]	0.8922	0.1252	0.0061	0.6546	0.8935	1.1520
SAf[5,9]	0.8906	0.1313	0.0061	0.6457	0.8890	1.1640
SAf[5,10]	0.9360	0.1421	0.0065	0.6726	0.9327	1.2340
SAf[6,1]	1.8850	0.3204	0.0131	1.2910	1.8780	2.5470
SAf[6,2]	1.9130	0.2855	0.0131	1.3790	1.9070	2.5090
SAf[6,3]	1.9130	0.2806	0.0130	1.3860	1.9110	2.4950
SAf[6,4]	2.0220	0.3441	0.0141	1.3970	2.0090	2.7400
SAf[6,5]	2.0080	0.3004	0.0136	1.4490	2.0010	2.6360
SAf[6,6]	1.8810	0.2725	0.0128	1.3680	1.8790	2.4470
SAf[6,7]	1.9110	0.2774	0.0130	1.3920	1.9090	2.4900
SAf[6,8]	1.9460	0.2845	0.0132	1.4120	1.9430	2.5340
SAf[6,9]	2.1830	0.3549	0.0151	1.5410	2.1660	2.9460
SAf[6,10]	1.9090	0.3099	0.0131	1.3400	1.8960	2.5640
SAf[7,1]	1.0500	0.7635	0.0117	0.2970	0.8564	2.9500
SAf[7,2]	1.0420	0.7395	0.0115	0.3052	0.8547	2.8900
SAf[7,3]	1.0410	0.7382	0.0115	0.3048	0.8555	2.8690
SAf[7,4]	1.0610	0.7964	0.0117	0.2840	0.8607	3.0320
SAf[7,5]	1.0430	0.7429	0.0115	0.3037	0.8551	2.8820
SAf[7,6]	1.0410	0.7381	0.0115	0.3055	0.8555	2.8790
SAf[7,7]	1.0420	0.7394	0.0115	0.3051	0.8560	2.8770
SAf[7,8]	1.0410	0.7398	0.0115	0.3036	0.8549	2.8770
SAf[7,9]	1.0480	0.7583	0.0116	0.2970	0.8562	2.9570
SAf[7,10]	1.0490	0.7612	0.0116	0.2974	0.8573	2.9410
SAf[8,1]	1.2520	0.2860	0.0094	0.8294	1.2050	1.9750
SAf[8,2]	1.1070	0.1700	0.0076	0.7912	1.1040	1.4630
SAf[8,3]	1.0960	0.1648	0.0075	0.7894	1.0930	1.4390
SAf[8,4]	0.9273	0.1621	0.0065	0.6335	0.9207	1.2670
SAf[8,5]	1.0790	0.1650	0.0074	0.7720	1.0750	1.4240
SAf[8,6]	1.1180	0.1665	0.0076	0.8066	1.1170	1.4650
SAf[8,7]	1.1210	0.1674	0.0077	0.8075	1.1180	1.4690
SAf[8,8]	1.0970	0.1642	0.0075	0.7903	1.0950	1.4380
SAf[8,9]	1.0100	0.1669	0.0069	0.7045	1.0030	1.3620
SAf[8,10]	1.0830	0.1860	0.0074	0.7467	1.0740	1.4770

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
SAf[9,1]	1.0790	0.1728	0.0074	0.7655	1.0730	1.4490
SAf[9,2]	1.0300	0.1492	0.0071	0.7477	1.0290	1.3380
SAf[9,3]	1.0520	0.1494	0.0072	0.7703	1.0520	1.3630
SAf[9,4]	1.1650	0.1827	0.0082	0.8236	1.1620	1.5380
SAf[9,5]	1.0730	0.1529	0.0074	0.7840	1.0740	1.3890
SAf[9,6]	1.0390	0.1458	0.0071	0.7623	1.0410	1.3430
SAf[9,7]	1.0420	0.1463	0.0071	0.7637	1.0430	1.3470
SAf[9,8]	1.0410	0.1471	0.0072	0.7615	1.0420	1.3460
SAf[9,9]	1.0900	0.1620	0.0075	0.7877	1.0870	1.4270
SAf[9,10]	1.0690	0.1625	0.0074	0.7688	1.0640	1.4090
SAf[10,1]	0.1605	0.0274	0.0011	0.1098	0.1602	0.2168
SAf[10,2]	0.1684	0.0259	0.0012	0.1209	0.1676	0.2230
SAf[10,3]	0.1652	0.0246	0.0011	0.1190	0.1651	0.2161
SAf[10,4]	0.2103	0.0351	0.0015	0.1460	0.2090	0.2827
SAf[10,5]	0.1608	0.0240	0.0011	0.1157	0.1608	0.2106
SAf[10,6]	0.1629	0.0238	0.0011	0.1177	0.1629	0.2122
SAf[10,7]	0.1622	0.0238	0.0011	0.1172	0.1622	0.2112
SAf[10,8]	0.1613	0.0237	0.0011	0.1165	0.1614	0.2105
SAf[10,9]	0.1423	0.0230	0.0010	0.0996	0.1417	0.1898
SAf[10,10]	0.1365	0.0247	0.0010	0.0911	0.1358	0.1879
SAf[11,1]	1.0040	0.1744	0.0072	0.6730	1.0050	1.3540
SAf[11,2]	1.0590	0.1563	0.0073	0.7664	1.0580	1.3850
SAf[11,3]	1.0500	0.1522	0.0072	0.7639	1.0490	1.3680
SAf[11,4]	1.0910	0.1779	0.0077	0.7646	1.0850	1.4610
SAf[11,5]	1.0380	0.1517	0.0071	0.7522	1.0370	1.3550
SAf[11,6]	1.0540	0.1507	0.0072	0.7704	1.0540	1.3680
SAf[11,7]	1.0430	0.1500	0.0072	0.7617	1.0430	1.3550
SAf[11,8]	1.0930	0.1586	0.0075	0.7944	1.0920	1.4210
SAf[11,9]	1.1970	0.1866	0.0083	0.8544	1.1910	1.5910
SAf[11,10]	1.0460	0.1649	0.0072	0.7409	1.0400	1.3930
SAf[12,1]	0.9963	0.1707	0.0069	0.6850	0.9922	1.3520
SAf[12,2]	0.9966	0.1500	0.0068	0.7173	0.9942	1.3040
SAf[12,3]	1.0020	0.1482	0.0069	0.7254	1.0010	1.3110
SAf[12,4]	0.8654	0.1458	0.0061	0.5990	0.8603	1.1690
SAf[12,5]	0.9694	0.1446	0.0066	0.6979	0.9677	1.2690
SAf[12,6]	1.0050	0.1465	0.0069	0.7302	1.0040	1.3090
SAf[12,7]	1.0120	0.1481	0.0069	0.7341	1.0100	1.3160
SAf[12,8]	1.0130	0.1489	0.0069	0.7329	1.0110	1.3200
SAf[12,9]	0.9174	0.1465	0.0063	0.6467	0.9124	1.2220
SAf[12,10]	0.9833	0.1611	0.0068	0.6885	0.9775	1.3220
SAf[13,1]	0.7647	0.1323	0.0054	0.5136	0.7646	1.0320
SAf[13,2]	0.7938	0.1177	0.0054	0.5718	0.7932	1.0370
SAf[13,3]	0.7956	0.1161	0.0055	0.5769	0.7955	1.0360
SAf[13,4]	0.6560	0.1084	0.0046	0.4570	0.6522	0.8836
SAf[13,5]	0.7817	0.1145	0.0053	0.5658	0.7811	1.0200
SAf[13,6]	0.7780	0.1119	0.0053	0.5673	0.7777	1.0100
SAf[13,7]	0.8118	0.1171	0.0056	0.5909	0.8121	1.0540
SAf[13,8]	0.8232	0.1197	0.0056	0.5978	0.8234	1.0700
SAf[13,9]	0.8308	0.1283	0.0057	0.5938	0.8277	1.1000
SAf[13,10]	0.8279	0.1318	0.0057	0.5867	0.8226	1.1070
SAf[14,1]	1.2840	0.2175	0.0091	0.8800	1.2830	1.7280
SAf[14,2]	1.2810	0.1931	0.0088	0.9163	1.2800	1.6810
SAf[14,3]	1.3160	0.1919	0.0090	0.9551	1.3150	1.7130
SAf[14,4]	1.5420	0.2541	0.0108	1.0780	1.5330	2.0770
SAf[14,5]	1.4160	0.2127	0.0097	1.0200	1.4120	1.8580
SAf[14,6]	1.3180	0.1893	0.0090	0.9602	1.3180	1.7110
SAf[14,7]	1.3160	0.1895	0.0090	0.9577	1.3150	1.7080
SAf[14,8]	1.2810	0.1861	0.0088	0.9305	1.2800	1.6680
SAf[14,9]	1.4370	0.2253	0.0099	1.0250	1.4290	1.9160
SAf[14,10]	1.2560	0.2011	0.0087	0.8851	1.2510	1.6790
SAf[15,1]	1.4610	0.2713	0.0101	0.9954	1.4430	2.0610
SAf[15,2]	1.4440	0.2280	0.0099	1.0280	1.4370	1.9280
SAf[15,3]	1.4210	0.2181	0.0098	1.0170	1.4170	1.8810
SAf[15,4]	1.6710	0.2982	0.0118	1.1400	1.6550	2.3070
SAf[15,5]	1.4120	0.2192	0.0097	1.0020	1.4060	1.8730
SAf[15,6]	1.4240	0.2161	0.0098	1.0210	1.4200	1.8750
SAf[15,7]	1.4080	0.2142	0.0097	1.0100	1.4040	1.8600
SAf[15,8]	1.4060	0.2147	0.0097	1.0070	1.4020	1.8570
SAf[15,9]	1.2860	0.2175	0.0088	0.8893	1.2780	1.7440
SAf[15,10]	1.3430	0.2335	0.0093	0.9192	1.3340	1.8380
SAf[16,1]	0.8515	0.1533	0.0059	0.5862	0.8420	1.1920
SAf[16,2]	0.8158	0.1249	0.0056	0.5817	0.8143	1.0770
SAf[16,3]	0.8304	0.1247	0.0057	0.5987	0.8285	1.0900
SAf[16,4]	0.7112	0.1242	0.0050	0.4864	0.7061	0.9711
SAf[16,5]	0.7842	0.1204	0.0054	0.5608	0.7823	1.0350
SAf[16,6]	0.8372	0.1241	0.0057	0.6046	0.8370	1.0960
SAf[16,7]	0.8356	0.1243	0.0057	0.6038	0.8344	1.0960
SAf[16,8]	0.8083	0.1210	0.0055	0.5836	0.8066	1.0600
SAf[16,9]	0.8543	0.1388	0.0059	0.6019	0.8488	1.1490
SAf[16,10]	0.8671	0.1475	0.0060	0.6036	0.8584	1.1850

6.2.4 Spatial relative risk of Lung cancer incidence for males given each age group

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
SAm[1,1]	0.8947	0.1562	0.0064	0.5894	0.8987	1.2080
SAm[1,2]	0.9486	0.1344	0.0064	0.6910	0.9501	1.2280
SAm[1,3]	0.9378	0.1304	0.0063	0.6875	0.9400	1.2110
SAm[1,4]	0.9790	0.1606	0.0068	0.6877	0.9711	1.3170
SAm[1,5]	0.9678	0.1364	0.0065	0.7085	0.9681	1.2520
SAm[1,6]	0.9523	0.1306	0.0064	0.7031	0.9545	1.2240
SAm[1,7]	0.9516	0.1309	0.0064	0.7016	0.9534	1.2250
SAm[1,8]	0.9434	0.1310	0.0064	0.6932	0.9447	1.2160
SAm[1,9]	1.0410	0.1622	0.0071	0.7472	1.0330	1.3870
SAm[1,10]	1.1350	0.1955	0.0079	0.7934	1.1200	1.5630
SAm[2,1]	1.3480	0.2459	0.0094	0.8706	1.3490	1.8450
SAm[2,2]	1.4060	0.2116	0.0095	1.0120	1.4010	1.8500
SAm[2,3]	1.4140	0.2091	0.0095	1.0250	1.4100	1.8510
SAm[2,4]	1.5610	0.2880	0.0107	1.0540	1.5440	2.1810
SAm[2,5]	1.4230	0.2130	0.0096	1.0250	1.4180	1.8680
SAm[2,6]	1.4150	0.2051	0.0095	1.0290	1.4140	1.8400
SAm[2,7]	1.3830	0.2012	0.0093	1.0050	1.3820	1.8000
SAm[2,8]	1.3750	0.2019	0.0092	0.9926	1.3720	1.7950
SAm[2,9]	1.4420	0.2408	0.0097	1.0070	1.4320	1.9580
SAm[2,10]	1.3260	0.2279	0.0090	0.9068	1.3180	1.8040
SAm[3,1]	1.2760	0.2375	0.0089	0.8868	1.2500	1.8390
SAm[3,2]	1.1890	0.1703	0.0080	0.8680	1.1870	1.5470
SAm[3,3]	1.1570	0.1626	0.0078	0.8473	1.1570	1.4950
SAm[3,4]	0.8394	0.1398	0.0058	0.5843	0.8342	1.1290
SAm[3,5]	1.1760	0.1665	0.0079	0.8608	1.1760	1.5230
SAm[3,6]	1.1840	0.1634	0.0080	0.8746	1.1850	1.5260
SAm[3,7]	1.2000	0.1664	0.0081	0.8834	1.2020	1.5490
SAm[3,8]	1.1790	0.1643	0.0080	0.8670	1.1800	1.5230
SAm[3,9]	1.0330	0.1614	0.0070	0.7320	1.0290	1.3690
SAm[3,10]	1.3000	0.2165	0.0089	0.9182	1.2860	1.7740
SAm[4,1]	1.1200	0.7716	0.0063	0.2980	0.9399	3.0110
SAm[4,2]	1.1140	0.7565	0.0063	0.3066	0.9405	2.9650
SAm[4,3]	1.1130	0.7491	0.0063	0.3054	0.9393	2.9630
SAm[4,4]	1.1360	0.8153	0.0066	0.2845	0.9420	3.1490
SAm[4,5]	1.1150	0.7573	0.0063	0.3053	0.9380	2.9540
SAm[4,6]	1.1130	0.7511	0.0063	0.3059	0.9399	2.9630
SAm[4,7]	1.1130	0.7507	0.0063	0.3058	0.9397	2.9590
SAm[4,8]	1.1130	0.7528	0.0063	0.3047	0.9390	2.9540
SAm[4,9]	1.1220	0.7767	0.0064	0.2991	0.9404	3.0290
SAm[4,10]	1.1210	0.7742	0.0064	0.2980	0.9402	3.0120
SAm[5,1]	0.7850	0.1207	0.0054	0.5598	0.7845	1.0370
SAm[5,2]	0.8003	0.1115	0.0054	0.5845	0.8011	1.0320
SAm[5,3]	0.8112	0.1118	0.0055	0.5983	0.8123	1.0450
SAm[5,4]	0.9275	0.1403	0.0064	0.6641	0.9250	1.2160
SAm[5,5]	0.7929	0.1087	0.0054	0.5840	0.7946	1.0190
SAm[5,6]	0.7986	0.1082	0.0054	0.5904	0.8012	1.0240
SAm[5,7]	0.7751	0.1053	0.0052	0.5744	0.7776	0.9938
SAm[5,8]	0.8099	0.1102	0.0055	0.5987	0.8125	1.0390
SAm[5,9]	0.8085	0.1162	0.0055	0.5900	0.8074	1.0510
SAm[5,10]	0.8498	0.1261	0.0058	0.6158	0.8472	1.1180
SAm[6,1]	1.2450	0.2076	0.0086	0.8590	1.2430	1.6740
SAm[6,2]	1.2630	0.1831	0.0085	0.9157	1.2610	1.6440
SAm[6,3]	1.2640	0.1799	0.0085	0.9200	1.2630	1.6380
SAm[6,4]	1.3350	0.2232	0.0092	0.9291	1.3260	1.8050
SAm[6,5]	1.3260	0.1925	0.0089	0.9646	1.3230	1.7310
SAm[6,6]	1.2420	0.1741	0.0084	0.9105	1.2420	1.6050
SAm[6,7]	1.2620	0.1772	0.0085	0.9258	1.2620	1.6320
SAm[6,8]	1.2850	0.1818	0.0087	0.9400	1.2860	1.6620
SAm[6,9]	1.4420	0.2292	0.0098	1.0270	1.4320	1.9320
SAm[6,10]	1.2610	0.2006	0.0086	0.8911	1.2540	1.6880
SAm[7,1]	1.0350	0.7135	0.0112	0.3105	0.8568	2.8350
SAm[7,2]	1.0280	0.6927	0.0111	0.3188	0.8567	2.7630
SAm[7,3]	1.0270	0.6915	0.0111	0.3185	0.8575	2.7630
SAm[7,4]	1.0460	0.7491	0.0113	0.2960	0.8595	2.9170
SAm[7,5]	1.0280	0.6953	0.0111	0.3180	0.8568	2.7710
SAm[7,6]	1.0270	0.6908	0.0111	0.3197	0.8572	2.7700
SAm[7,7]	1.0270	0.6925	0.0111	0.3202	0.8560	2.7520
SAm[7,8]	1.0270	0.6928	0.0111	0.3185	0.8558	2.7610
SAm[7,9]	1.0330	0.7103	0.0111	0.3111	0.8586	2.8280
SAm[7,10]	1.0340	0.7147	0.0112	0.3100	0.8560	2.8080
SAm[8,1]	1.5250	0.3412	0.0114	1.0270	1.4640	2.3990
SAm[8,2]	1.3490	0.1951	0.0091	0.9827	1.3460	1.7570
SAm[8,3]	1.3350	0.1888	0.0090	0.9804	1.3340	1.7320
SAm[8,4]	1.1290	0.1886	0.0078	0.7840	1.1220	1.5220
SAm[8,5]	1.3140	0.1888	0.0089	0.9574	1.3130	1.7080
SAm[8,6]	1.3620	0.1897	0.0092	1.0040	1.3620	1.7580
SAm[8,7]	1.3650	0.1908	0.0092	1.0040	1.3650	1.7630
SAm[8,8]	1.3360	0.1875	0.0090	0.9813	1.3360	1.7280
SAm[8,9]	1.2300	0.1946	0.0083	0.8702	1.2240	1.6360
SAm[8,10]	1.3190	0.2173	0.0089	0.9240	1.3100	1.7830

Parameters	mean	sd	MC error	Lower CI	median	Upper CI
SAm[9,1]	1.0750	0.1680	0.0073	0.7702	1.0680	1.4360
SAm[9,2]	1.0250	0.1436	0.0069	0.7516	1.0260	1.3230
SAm[9,3]	1.0470	0.1438	0.0071	0.7750	1.0480	1.3460
SAm[9,4]	1.1600	0.1773	0.0081	0.8285	1.1560	1.5220
SAm[9,5]	1.0680	0.1470	0.0072	0.7876	1.0700	1.3730
SAm[9,6]	1.0340	0.1400	0.0070	0.7670	1.0370	1.3240
SAm[9,7]	1.0370	0.1405	0.0070	0.7685	1.0390	1.3270
SAm[9,8]	1.0360	0.1413	0.0070	0.7651	1.0390	1.3300
SAm[9,9]	1.0850	0.1568	0.0074	0.7898	1.0830	1.4130
SAm[9,10]	1.0640	0.1576	0.0073	0.7714	1.0600	1.4000
SAm[10,1]	0.1653	0.0271	0.0011	0.1150	0.1652	0.2218
SAm[10,2]	0.1735	0.0255	0.0012	0.1267	0.1728	0.2276
SAm[10,3]	0.1702	0.0241	0.0012	0.1249	0.1701	0.2201
SAm[10,4]	0.2166	0.0348	0.0015	0.1529	0.2151	0.2898
SAm[10,5]	0.1657	0.0235	0.0011	0.1212	0.1657	0.2141
SAm[10,6]	0.1678	0.0232	0.0011	0.1238	0.1681	0.2162
SAm[10,7]	0.1671	0.0231	0.0011	0.1234	0.1673	0.2152
SAm[10,8]	0.1662	0.0232	0.0011	0.1224	0.1663	0.2145
SAm[10,9]	0.1466	0.0228	0.0010	0.1043	0.1461	0.1940
SAm[10,10]	0.1406	0.0249	0.0010	0.0952	0.1397	0.1922
SAm[11,1]	0.9370	0.1586	0.0066	0.6324	0.9395	1.2560
SAm[11,2]	0.9884	0.1403	0.0067	0.7229	0.9877	1.2820
SAm[11,3]	0.9793	0.1363	0.0066	0.7198	0.9798	1.2650
SAm[11,4]	1.0180	0.1609	0.0071	0.7214	1.0120	1.3530
SAm[11,5]	0.9687	0.1358	0.0065	0.7099	0.9692	1.2490
SAm[11,6]	0.9831	0.1346	0.0066	0.7257	0.9845	1.2640
SAm[11,7]	0.9732	0.1337	0.0066	0.7195	0.9741	1.2510
SAm[11,8]	1.0200	0.1416	0.0069	0.7502	1.0210	1.3120
SAm[11,9]	1.1170	0.1684	0.0076	0.8076	1.1130	1.4730
SAm[11,10]	0.9758	0.1491	0.0066	0.6988	0.9723	1.2910
SAm[12,1]	1.3730	0.2263	0.0093	0.9562	1.3680	1.8500
SAm[12,2]	1.3730	0.1964	0.0093	1.0020	1.3720	1.7800
SAm[12,3]	1.3810	0.1934	0.0093	1.0150	1.3810	1.7860
SAm[12,4]	1.1920	0.1924	0.0082	0.8360	1.1870	1.5960
SAm[12,5]	1.3360	0.1890	0.0090	0.9740	1.3360	1.7270
SAm[12,6]	1.3840	0.1904	0.0094	1.0220	1.3870	1.7790
SAm[12,7]	1.3940	0.1922	0.0094	1.0280	1.3950	1.7930
SAm[12,8]	1.3950	0.1936	0.0094	1.0290	1.3960	1.7970
SAm[12,9]	1.2640	0.1930	0.0086	0.9027	1.2590	1.6670
SAm[12,10]	1.3550	0.2135	0.0092	0.9614	1.3480	1.8070
SAm[13,1]	0.9925	0.1666	0.0069	0.6737	0.9937	1.3310
SAm[13,2]	1.0300	0.1462	0.0069	0.7514	1.0300	1.3320
SAm[13,3]	1.0330	0.1439	0.0070	0.7584	1.0330	1.3310
SAm[13,4]	0.8514	0.1357	0.0059	0.6001	0.8476	1.1320
SAm[13,5]	1.0140	0.1420	0.0068	0.7432	1.0160	1.3090
SAm[13,6]	1.0100	0.1385	0.0068	0.7471	1.0110	1.2980
SAm[13,7]	1.0540	0.1447	0.0071	0.7767	1.0550	1.3540
SAm[13,8]	1.0680	0.1481	0.0072	0.7885	1.0700	1.3750
SAm[13,9]	1.0780	0.1600	0.0073	0.7807	1.0750	1.4130
SAm[13,10]	1.0750	0.1658	0.0073	0.7684	1.0680	1.4280
SAm[14,1]	1.1450	0.1886	0.0079	0.7929	1.1450	1.5350
SAm[14,2]	1.1430	0.1661	0.0078	0.8245	1.1440	1.4880
SAm[14,3]	1.1740	0.1647	0.0079	0.8616	1.1740	1.5170
SAm[14,4]	1.3760	0.2202	0.0095	0.9713	1.3680	1.8380
SAm[14,5]	1.2630	0.1824	0.0085	0.9225	1.2610	1.6460
SAm[14,6]	1.1750	0.1618	0.0080	0.8670	1.1780	1.5120
SAm[14,7]	1.1740	0.1620	0.0079	0.8653	1.1750	1.5110
SAm[14,8]	1.1430	0.1595	0.0077	0.8387	1.1440	1.4770
SAm[14,9]	1.2820	0.1948	0.0087	0.9232	1.2770	1.6940
SAm[14,10]	1.1210	0.1742	0.0076	0.7953	1.1170	1.4870
SAm[15,1]	1.5400	0.2742	0.0104	1.0690	1.5220	2.1560
SAm[15,2]	1.5220	0.2255	0.0103	1.1050	1.5170	2.0000
SAm[15,3]	1.4980	0.2149	0.0101	1.0950	1.4970	1.9480
SAm[15,4]	1.7620	0.3002	0.0122	1.2190	1.7460	2.4020
SAm[15,5]	1.4870	0.2152	0.0100	1.0800	1.4870	1.9330
SAm[15,6]	1.5000	0.2116	0.0101	1.0990	1.5010	1.9420
SAm[15,7]	1.4840	0.2098	0.0100	1.0880	1.4840	1.9200
SAm[15,8]	1.4820	0.2106	0.0100	1.0840	1.4810	1.9190
SAm[15,9]	1.3550	0.2175	0.0091	0.9522	1.3490	1.8050
SAm[15,10]	1.4150	0.2344	0.0096	0.9826	1.4090	1.9070
SAm[16,1]	1.0520	0.1824	0.0071	0.7355	1.0410	1.4580
SAm[16,2]	1.0080	0.1456	0.0068	0.7312	1.0070	1.3110
SAm[16,3]	1.0260	0.1452	0.0069	0.7514	1.0260	1.3290
SAm[16,4]	0.8788	0.1467	0.0061	0.6110	0.8727	1.1860
SAm[16,5]	0.9690	0.1404	0.0065	0.7033	0.9690	1.2600
SAm[16,6]	1.0350	0.1436	0.0070	0.7609	1.0360	1.3310
SAm[16,7]	1.0330	0.1437	0.0070	0.7594	1.0330	1.3310
SAm[16,8]	0.9987	0.1403	0.0067	0.7329	0.9990	1.2910
SAm[16,9]	1.0560	0.1633	0.0072	0.7550	1.0500	1.4000
SAm[16,10]	1.0720	0.1752	0.0073	0.7571	1.0620	1.4490

Table 15: Parameter estimates of Lungs Cancer incidence, standard deviation and confidence interval for each estimate

Auteursrechtelijke overeenkomst

Ik/wij verlenen het wereldwijde auteursrecht voor de ingediende eindverhandeling:
Spatial analysis of age-specific disease counts

Richting: **Master of Statistics-Epidemiology & Public Health Methodology**
Jaar: **2018**

in alle mogelijke mediaformaten, - bestaande en in de toekomst te ontwikkelen - , aan de Universiteit Hasselt.

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Voor akkoord,

Ngwa, Bonaventure Neba

Datum: **23/01/2018**