

FITTING OF AGE-PERIOD-COHORT MODELS TO STUDY TIME TRENDS IN THE INCIDENCE OF CANCER OF THE LARYNX

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ABSTRACT: *In this paper, the data on incidence of cancer of the larynx for Scotland over the period 1960-1989 are used to fit age-period-cohort models presented by Clayton and Schiffers (1987), Decarli and La Vecchia (1987) and Robertson and Boyle (1986,1987) to study the temporal variation in the incidence of cancer in the larynx. For females any of the two factor models is sufficient to represent the grouped data but the age-cohort model is best. The method used by Robertson and Boyle suggest that full age-period-cohort model should be used to represent the male data with individual records on males and age-cohort sufficiently represents the female data in the form of 3 way table data with individual records on females. For all the three methods, the age-cohort model is found to represent the data on incidence of cancer of the larynx for Scottish females. The main conclusion is that while the incidence rates are higher in older people the increase over time is mainly a result of cohort effects.*

1. INTRODUCTION

Information on all cases of cancer of the larynx for Scotland for the period 1960-1989 is available in the office of the Registrar General for Scotland (1992)[1]. For each person with cancer of the larynx the sex, age in years, year of registration and year of birth are held as individual records. Data on mid period populations for 5-year age groups are also available. These data on the individual records are collapsed to form 3 way tables of age group by time period by birth cohort and 2 way tables of age group by time period for males and females separately. These data in the form of these tables are used to study the trend in cancer of the larynx. The 2-way tables represent 10 year overlapping cohorts and the 3 way tables represent 5 year non-overlapping cohorts. A number of different methods are available to estimate the separate effects of age, period and cohort. In this paper, the data on incidence of cancer of the larynx for Scotland over the period 1960-1989 are used to fit age-period-cohort models presented by Clayton and Schiffers (1987)[2][3], Decarli and La Vecchia (1987)[4] and Robertson and Boyle (1986,1987)[5],[6] to study the temporal variation in the incidence of cancer in the larynx.

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Age is considered a vital factor in studying the rate of increase of a particular disease. Due to ever going developments in the universe many factors influence the human body negatively. All these factors can be safely summed up into one factor called the time period. Time period may be called responsible for temporal variation in the spread and extent of a disease. Another factor, which is apparently hidden in age and time period, may also be responsible for the temporal variation in some particular disease. This factor is the birth cohort. In this paper an attempt has been made to find out if age, period or cohort can explain temporal variation, if any, in the incidence data mentioned earlier.

2. MATERIALS AND METHODS

The two-way tables by age group and calendar period are constructed for males and females separately. The data are classified into 11 age groups of 5 years length and 6 time periods of 5 years each. A cohort is a group or band united in some struggle. In demographic studies and analysis, cohort is used specifically for records of some particular group of persons at different dates (Barclay, 1962)[7]. The cohort to which the incidences of cancer in the larynx belong according to various age groups and time periods can be calculated. The total number of cohorts is 16. The patients registered during 1960-1964 having age between 80 and 84 years (i.e. those born between 1876 and 1884) belong to cohort one. This cohort is the oldest one. Those patients registered during 1960-1964 having age between 75 and 79 years belong to cohort two and were born in 1881 to 1889. But every cell of the two-way table does not contain the incidences belonging to some unique Cohort. The patients registered during 1965-1969 having age between 80 and 84 years, also, belong to cohort two. The cells of the two-way tables existing in the descending diagonals (from left/top down to right/bottom) have the same cohort number. Thus, the incidences in the top right cell belong to cohort number 16, born in 1951 to 1959.

With individual records it is possible to construct a three-way table of age group by period by birth cohort. For three way tables, each age, period cell has two cohorts associated with it. This table will increase the number of cohorts by one. The number of cohorts will be now 17. In this case overlapping still exists but this time the cohorts overlap for only one year. The effect of one year overlapping can quite safely be ignored (Robertson and Boyle, 1986)[5].

The standard errors for the incidences can be calculated on the assumption that the incidences have Poisson distribution with the same mean as the observed incidences. Let n_{ij} be the number of observed incidences for the i th age group and j th time period. Then the confidence

interval for mean incidence in the i th age group and j th time period, can be written as

$$n_{ij} + \frac{(Z_{\alpha/2})^2}{2} \pm Z_{\alpha/2} \sqrt{n_{ij} + \frac{(Z_{\alpha/2})^2}{4}}$$

where $Z_{\alpha/2}$ is the value of standardized normal variate for probability $\alpha/2$ on both side (Wetherill, 1982)[8]. The confidence limits for the incidence rates can be calculated from the confidence limits for the mean incidence rates after dividing them by the corresponding mid year population.

A naive but traditional approach to the data on incidence rates presented in two way tables is to plot the rates against age, joining all points on a corresponding cohort (Osmond and Gardner, 1982)[9]. Age specific rates vary greatly so logarithms of the incidence rates are preferred.

New approaches to the analysis of temporal variation in disease incidence lead to the generalization of indirect standardization to the estimation of parameters of the age-period-cohort model (Holford, 1983)[10]. The parameters of the age-period-cohort model can also be estimated through Poisson or logistic regression analysis. In the following these techniques are discussed. Additionally the implementation of age-period-cohort model approach in the well-known statistical package GLIM is considered (Decarli and La Vecchia, 1987)[4]:

The GLIM macro provided by Decarli and La Vecchia does not calculate standard errors of the estimates. There is no information in their paper about the calculation of the standard errors. The estimates of the age-period-cohort model by the method proposed by Decarli and La Vecchia are based on the minimisation of a penalty function. The derivative of the penalty function is not linear. So it is not easy to calculate the standard errors analytically. Hence a parametric bootstrap method is used to have provide Monte Carlo estimates.

The identifiability problem is only overcome by using extra information or constraints. The methods of Osmond and Gardner (1982)[9] and Decarli and La Vecchia (1987)[4] are conceptually similar. The method of Decarli and La Vecchia relies on the minimization of a penalty function. The parametric bootstrap method will be applied to provide Monte Carlo estimates of the standard errors (Section 3.2). The method of Robertson and Boyle (1986, 1987)[5],[6] uses extra information to form a 3-way table. One degree of freedom is increased by the addition of one cohort and there remains no need of additional constraint. The method of Clayton and Schifflers, (1987)[2][3] is mathematically correct but the curvatures and

drift are not easy to interpret. The method of Holford, (1983)[10] is similar to that of Clayton and Schifflers [2].

3. RESULTS

The data on incidence of cancer of the larynx for Scotland over the period 1960-1989 are used to fit age-period-cohort models presented by Clayton and Schifflers (1987)[2][3], Decarli and La Vecchia (1987)[4] and Robertson and Boyle (1986,1987)[5][6]. The first two models use two way table of incidences. The third model uses data with individual records. The detail exists in section 3.1, 3.2 and 3.3 respectively. Before proceeding with the fitting of the models described in the above paragraph, a graphical analysis was necessary to assess the validity of the assumptions involved.

3.1 Clayton and Schifflers Model

Table 1 gives the parameter estimates for the full age-period-cohort model for the incidences of cancer of the larynx among Scottish males. The model used is presented by Clayton and Schifflers (1987)[2][3]. Linear components, viz., of age-drift and cohort-drift are extracted separately. With the inclusion of nonlinear components of the factors age, period and cohort it is possible to derive the estimable curvatures.

It will be worth noting that the last nonlinear component of the factors age, period or cohort will be aliased i.e. it will have no value. This aliasing is due to the extraction of the linear component, which has earned one degree of freedom. The linear component for age, will alias the nonlinear component of age group 80-84. This age group can give no more information as it has become dependent due to the information obtained from the linear component. Similarly, the linear component for cohort or period will alias the nonlinear components of time period 1985-1989 and birth cohort 1950.

From the age effects the amount of curvature for age groups 40-44 to age group 75-79 has been calculated. The amount of curvature has also been calculated for time periods 1965-1969 to 1980-1984 from period effects and for cohorts 1885 to 1945 from cohort effects. The amount of curvature gives the distortion from the linear component at various intermediate groups. If the amount of curvature is zero, it indicates that the log risk is locally a straight line. The positive and negative values of the curvature indicate convex or concave relationships, respectively.

The standard errors of the curvatures are also calculated for various age groups, periods and cohorts for which the curvature was calculated. As the curvatures for a factor are linear combinations of the parameter

estimates, the standard errors of these curvatures needed the covariances of the effects involved in the calculation of the particular curvature. For example, since the curvature for age group 40-44 is calculated as

$$\alpha_1 - 2\alpha_2 + \alpha_3,$$

the variance of the curvature is

$$\text{var}(\alpha_1) + 4\text{var}(\alpha_2) + \text{var}(\alpha_3) - 4\text{cov}(\alpha_1, \alpha_2) + 2\text{cov}(\alpha_1, \alpha_3) - 4\text{cov}(\alpha_2, \alpha_3)$$

A design matrix was thus constructed in GLIM with the values of 0, 1, 2 and -4 relevant to variances for the curvatures for various age groups, periods and cohorts. The covariance vector was extracted after fitting of the model with GLIM and thereafter multiplied with the design matrix to get the covariances. The square roots were taken to get the respective standard errors.

The linear component is the same for period and cohort. So only one of the linear components for period and cohort, is to be included. The longitudinal age effect for cancer of the larynx among males is simply the Age drift parameter 0.4920. The cross-sectional age effect is the difference of age-linear parameter and cohort-linear parameter and is equal to 0.4374 (Table 1).

Table 2 gives similar parameter estimation for the full age-period-cohort model for incidences of cancer of the larynx among Scottish females. The longitudinal age effect for cancer of the larynx among females is the age-linear parameter 0.3773. The cross-sectional age effect is the difference of age-linear parameter and cohort-linear parameter and is equal to 0.34430. The longitudinal age effects for data on males and females in Table 1 and Table 2 can be used to test statistically whether there is any difference between the logarithms of linear components of age for males and females. For large samples the maximum likelihood estimators follow a normal distribution. Hence, the t-test can be applied to test the null hypothesis that there is no difference between longitudinal age effects for males and females. The longitudinal age effects for males and females are 0.4920 and 0.3773 with standard errors of 0.0243 and 0.0370 respectively. The value of the statistic is $t = 2.591$ with a 2-tailed p-value of 0.005. This means that the logarithm of incidence of cancer of the larynx for Scottish males rises more steeply with age for males compared to females.

The t test applied to the longitudinal age effect can be applied to test the difference between the drifts for males and females. The estimated values of drift for males and females are 0.0546 and 0.0330, with standard errors of 0.0384 and 0.0834 respectively. The t statistic is calculated as 0.2353 with a 2-tailed p-value of 0.407. This means that there is no difference between the drift parameters for data on incidence of cancer of the larynx for Scottish males and females.

From Table 1 and Table 2 the curvatures of the non linear effects can be studied for male and female data respectively. For the male data (Table 1), the values of curvatures for age are not significant at 5% level of significance as compared to their respective standard errors. However, there are two considerable values of curvature for age groups 50-54 and 70-74 with a p - value of 0.08. The curvatures for period are not significant. The value of curvature for cohort 1900 is significant at 5% level (p-value being 0.04).

Table 2 shows that the values of curvatures for the age group 70-74 is significant at 5% level of significance for female data (p - value being 0.02). Another value of curvature, which is quite close to significance, is for age group 60-64. The p - value for this group is 0.052. The values of curvatures are not significant for time periods and cohorts. This means that Age-Drift model can be used to represent the data for females. An interpretation of the curvature is given below.

The exponential of the values for curvature pertain to the ratio of the relative risks. For example, for the first value of curvature for nonlinear age for male data, $e^{-0.150}$ (= 0.86) is the ratio of the relative multiplicative risks of

age groups 45-49 and 40-44 with age groups 40-44 and 35-39 i.e. $\frac{(b_3/b_2)}{(b_2/b_1)}$,

where β_3 , β_2 and β_1 are the multiplicative risks for age group 45-49, 40-44 and 35-39 respectively (Table 1). For the sake of brevity the relative multiplicative risk can simply be called the relative risk. For finite non negative values of the ratio, the logarithm of values greater than one, equal to one and less than one will be positive, zero and negative respectively. We already established that there is a linear increase in logarithm of rates. This means that if curvature = 0 then the linear increase is fine. If curvature is greater than 0 then the increase is faster than simply the linear increase. If curvature is less than 0 then the increase is slower than the linear. Thus in the above example the curvature of -0.150 implies that the ratio is less than one (here 0.86). The concavity i.e. slowing down of the linear increase would be indicated by the decrease in the negative values of curvature and the convexity i.e. upward steeping by the increase in the positive values of curvature. All other curvatures can be interpreted in the same fashion.

3.2 Decarli and La Vecchia model

The GLIM macro of Decarli and La Vecchia was used to calculate the age, period and cohort effects. The age group 35-39, the birth cohort 1925 and time period 1960-1964 are taken as baseline. The standard errors of the

estimates were neither given by the GLIM macro of Decarli and La Vecchia nor given in their papers. In fact the standard errors are not easy to calculate.

To get the estimates of the standard errors the data for males was simulated 100 times. The incidences are assumed to have a Poisson distribution with mean equal to the observed number of incidences. Let us assume that λ is the mean of a variable following a Poisson distribution. The random variables can be generated with the help of generating random variables E , say, from exponential distribution $\lambda e^{(-\lambda x)}$.

The random variables from exponential distribution with parameter λ can be generated with the help of uniform random variable $U(0,1)$, say, and making the transformation

$$E = -\{\log_e (U)\}/\lambda$$

Let E_1, E_2, \dots be the generated exponential random variables. For $k \geq 1$, the addition of these variables, S_k , say, defined as

$$S_k = \sum_{i=1}^k E_i,$$

will present a gamma random variable with parameters k and λ , where k is any number. If we set $S_1 = E_1$, then the Poisson random variable k , say, will have a value of 0 if $S_1 > 1$. If $S_1 \leq 1$, then we proceed to define the next value of $S_2 = E_1 + E_2$. If $S_2 > 1$ then k takes value 1. This procedure can be continued to get various values of Poisson random variable. The easier way to simulate S_k is to define it as

$$S_k = -\frac{1}{\lambda} \log \prod_{i=1}^k U_i \quad (\text{Morgan, 1984})[11].$$

A program was developed in Pascal to generate these Poisson random variables. The Decarli and La Vecchia model was fitted to the sets of data got by generation of Poisson random variables. The means and standard deviations of the parameters were calculated from the 100 values for each parameter (Efron, 1993)[12]. Table 3 and Table 4 give the age, period and cohort estimates from the original data and the Monte Carlo estimates for males and females respectively without separating the linear components. The means matched up well for the male data but are not so good for the female data. Part of the reason is that in the cell for period 1985-89 and age group 35-39 there is only one case and in many simulations a zero will be generated. This leads to the large negative mean value of -3.518 for the cohort 1950 as compared to the value -1.380 estimated by the macro. The adverse effect of this small cell frequency, also, produced the deviated value of -0.061 for the mean estimated value of the effect for period 1985-1989 leading to bias.

The age effects for males are significant as compared to the standard errors and smoothly increasing by various age groups. This means that as age increases, the risk of cancer of the larynx increases in Scottish males. The pattern of age effects for the various age groups of Scottish females is almost the same as for males. The effects are significantly different from age group 35-39 except for the age group 40-44.

The cohort effects for males represent a general rising trend. The effects are not significantly different from cohort 1925 around the reference cohort 1925. The value of the Effect for 1885 is lower than the Cohort 1880 but within random variation. For Cohort 1945 there has been reported a slight reduction in the risk of cancer of the larynx among Scottish males compared to 1940 Cohort, however, the effect is significant at 5% level. There is considerable fluctuation at the last cohort where the effect for cohort 1950 is negative while the effect is positive for cohort 1945. The estimate of risk for cohort 1950 is not reliable as it is based on 5 observations only.

For the female data the values of the effects for cohort 1880 and 1950 are not reliable as these are based on 4 and 1 observations respectively. The cohort effects are significantly different from 1925 from 1885 to 1915 and show a rising pattern from cohort 1890 to 1915. The female cohort 1890 experienced a lower risk of cancer of the larynx than that of cohort 1885. Other younger cohort effects are not significant and show no pattern.

The period effects calculated for males and females are not significantly different from the reference period 1960-64 and do not exhibit any clear trend. The risk of cancer of the larynx among Scottish males does not seem to increase or decrease considerably with period.

3.3 Robertson and Boyle model

Tables 5 and Table 6 give the parameter estimates for age-period-cohort models for the data in 3 way tables with individual records on incidence of cancer of the larynx for Scottish males and females respectively. The method used is suggested by Robertson and Boyle (1986, 1987)[2][3]. The age effects for data of males show a steeply rising trend with increasing age groups. The standard errors are very small as compared to the estimates indicating significance of the age effects. The age effect for age group 40-44 of females is not significant. All other age groups show significant age effects rising by the higher age groups.

The period effects for the data on Scottish males show that, the risk of cancer of the larynx increased as the time went on from 1960 to 1989 (Table 5). There had not been a considerable increase in the risk of cancer of the

larynx for the periods 1965-1969 to 1975-1979. For the periods 1980-1984 and 1985-1989 the males experienced considerable increased risk of cancer of the larynx relative to the period 1960-64. The Scottish females suffered from higher and higher risk of cancer of the larynx during the time span of 1960 to 1989 (Table 6). The period effects are significant for all time periods.

The cohort effects for data on Scottish males do not show any pattern (Table 5). The effects are negative for cohorts 1885-1889 and 1950-1954 but not significant as they have high standard errors. All other cohort effects are positive. However they have high standard errors and are not significant at the 5% level. The cohort effects for females, also, do not present any pattern (Table 6). Having a high value of 1.183 for females born in 1880-1884, the cohort effect decreases up to the cohort 1895-1899 but are not significant. After having a slight rise for the cohort 1900-1904, the effects again rise slightly through to cohort 1925-1929 but still are not significant. The increase or decrease for the rest of the female cohorts is not considerable except the fact that the effects take negative values for the last two cohorts i.e. 1945-1949 and 1950-1954. As compared to the standard errors no cohort effect is statistically significant.

4 SUMMARY OF MODELS

All the three methods applied suggest that logarithm of risk increases with age with a generally negative curvature i.e. increase slows down in older ages.

The rates are increasing with time period in Robertson and Boyle method. The cohorts show no pattern. The rates are increasing with age and the first portion of the set of cohorts in Decarli and La Vecchia method. The time period does not show any pattern. With the method of Clayton and Schifflers it is observed that the drift (cohort/period linear component) is positive. This means that the rates are increasing by age, time period or cohort. The study of curvature suggests that nonlinear components are important.

TABLES AND DIAGRAMS

Table-1: Parameter estimates for the age-period-cohort model for the incidence of cancer of the larynx among Scottish males, 1960-1989, (Clayton and Schiffers model: Linear components extracted separately)

	Estimate	S.E.	Curvature	S.E.
Mean	2.7390	0.3403	-	
Age (Linear)	0.4920	0.0243	-	
Cohort (linear)	0.0546	0.0384	-	
Age (Non-Linear)				
35-39	0.000	-----	-----	---
40-44	0.609	0.1846	-0.150	0.2718
45-49	1.068	0.1592	-0.189	0.1766
50-54	1.338	0.1384	-0.220	0.1281
55-59	1.388	0.1197	-0.146	0.1020
60-64	1.292	0.1040	-0.118	0.0917
65-69	1.078	0.0921	-0.051	0.0922
70-74	0.813	0.0852	-0.178	0.1030
75-79	0.370	0.0881	0.073	0.1345
80-84	0.000	aliased	-----	-----
Period (Non-Linear)				
1960-1964	0.000	-----	-----	-----
1965-1969	-0.050	0.0561	0.075	0.1030
1970-1974	-0.025	0.0506	-0.073	0.0970
1975-1979	-0.073	0.0479	0.143	0.0927
1980-1984	0.022	0.0448	-0.029	0.0854
1985-1989	0.000	aliased	-----	-----
Cohort (Non-Linear)				
1880	0.000	-----	-----	-----
1885	-0.183	0.2432	0.464	0.3569
1890	0.098	0.2156	-0.179	0.2269
1895	0.200	0.2115	-0.123	0.1594
1900	0.179	0.2169	0.256	0.1253
1905	0.214	0.2294	-0.077	0.1044
1910	0.172	0.2498	0.140	0.0990
1915	0.270	0.2728	-0.088	0.1015
1920	0.280	0.2991	0.110	0.1095
1925	0.400	0.3268	-0.130	0.1241
1930	0.390	0.3581	0.051	0.1584
1935	0.431	0.3918	0.242	0.2102
1940	0.764	0.4258	-0.444	0.2941
1945	0.653	0.4707	-0.542	0.5957
1950	0.000	aliased	-----	-----

Table-2: Parameter estimates for the age-period-cohort model for the incidence of cancer of the larynx among Scottish females, 1960-1989 (Clayton and Schifflers model: Linear components extracted separately)

	Estimate	S.E.	Curvature	S.E.
Mean	1.5700	0.6686	-----	
Age(linear)	0.3773	0.0370	-----	
Cohort (Linear)	0.0330	0.0834	-----	
Age (Non-Linear)				
35-39	0.000	-----	-----	-----
40-44	0.035	0.2570	0.315	0.4186
45-49	0.385	0.2209	-0.035	0.3148
50-54	0.700	0.1913	-0.405	0.2387
55-59	0.610	0.1747	0.295	0.2083
60-64	0.805	0.1572	-0.430	0.1865
65-69	0.570	0.1524	-0.218	0.1921
70-74	0.553	0.1489	-0.409	0.2100
75-79	0.124	0.1616	0.305	0.2617
80-84	0.000	aliased	-----	-----
Period (Nonlinear)				
1960-1964	0.000	-----	-----	-----
1965-1969	0.230	0.1216	-0.215	0.2138
1970-1974	0.245	0.1048	-0.214	0.1895
1975-1979	0.046	0.0970	0.313	0.1811
1980-1984	0.160	0.0869	-0.274	0.1640
1985-1989	0.000	aliased	-----	-----
Cohort (Nonlinear)				
1880	0.000	-----	-----	-----
1885	0.487	0.5332	-0.778	0.7127
1890	0.196	0.5035	0.404	0.4617
1895	0.309	0.4889	0.169	0.3552
1900	0.591	0.4884	-0.272	0.2659
1905	0.601	0.5094	0.234	0.2274
1910	0.845	0.5444	0.106	0.2059
1915	1.195	0.5867	-0.189	0.1949
1920	1.356	0.6381	-0.005	0.2027
1925	1.512	0.6937	-0.175	0.2300
1930	1.493	0.7574	-0.096	0.2992
1935	1.378	0.8274	0.220	0.4110
1940	1.483	0.9044	-0.596	0.5659
1945	1.509	0.9871	-1.535	01.1992
1950	0.000	aliased	-----	-----

Table-3: Parameter estimates and Monte Carlo estimates for age-period-cohort model of incidence of cancer in the larynx for Scottish males, 1960-1989 (Decarli and La Vecchia model)

Age	Effect	Means	*Standard Error
35-39	0.000	0.000	-----
40-44	1.098	1.108	0.2333
45-49	2.046	2.068	0.2722
50-54	2.806	2.833	0.3329
55-59	3.345	3.367	0.3752
60-64	3.738	3.748	0.3991
65-69	4.013	4.019	0.4087
70-74	4.238	4.251	0.4098
75-79	4.284	4.297	0.3727
80-84	4.403	4.421	0.3479
Cohort			
1880	-0.867	-0.855	0.3198
1885	-0.999	-1.001	0.2120
1890	-0.665	-0.664	0.1631
1895	-0.511	-0.504	0.1338
1900	-0.480	-0.478	0.1037
1905	-0.393	-0.387	0.0909
1910	-0.384	-0.381	0.0804
1915	-0.233	-0.226	0.0762
1920	-0.172	-0.168	0.0641
1925	0.000	0.000	-----
1930	0.042	0.034	0.0750
1935	0.135	0.136	0.1109
1940	0.520	0.536	0.1268
1945	0.461	0.468	0.2292
1950	-0.140	-0.090	0.4921
Period			
1960-1964	0.000	0.000	-----
1965-1969	-0.048	-0.046	0.0650
1970-1974	-0.020	-0.019	0.0587
1975-1979	-0.065	-0.072	0.0557
1980-1984	0.033	0.030	0.0563
1985-1989	0.014	0.020	0.0427

*Monte Carlo simulation used.

Table-4: Parameter estimates and Monte Carlo estimates for various age, period and cohort models of incidence of cancer in the larynx for Scottish females, 1960-1989 (Decarli and La Vecchia model)

Age	Effect	Means	*Standard Error
35-39	0.000	0.000	-----
40-44	0.405	0.375	0.3032
45-49	1.126	1.120	0.2991
50-54	1.812	1.807	0.3287
55-59	2.092	2.127	0.3760
60-64	2.657	2.712	0.4185
65-69	2.792	2.862	0.4361
70-74	3.146	3.248	0.4734
75-79	3.087	3.204	0.4954
80-84	3.334	3.475	0.5444
Cohort			
1880	-1.749	-2.145	1.6120
1885	-1.235	-1.429	0.4673
1890	-1.501	-1.663	0.4328
1895	-1.360	-1.491	0.3101
1900	-1.053	-1.166	0.2646
1905	-1.016	-1.117	0.2200
1910	-0.746	-0.814	0.1749
1915	-0.370	-0.422	0.1470
1920	-0.182	-0.209	0.1298
1925	0.000	0.000	-----
1930	0.008	0.023	0.1613
1935	-0.081	-0.026	0.1849
1940	0.051	0.077	0.3038
1945	0.103	0.077	0.3785
1950	-1.380	-3.518	3.4170
Period	z	z	z
1960-1964	0.000	0.000	-----
1965-1969	0.236	0.229	0.1414
1970-1974	0.258	0.222	0.1437
1975-1979	0.066	0.016	0.1623
1980-1984	0.187	0.125	0.1824
1985-1989	0.034	-0.061	0.2001

*Monte Carlo simulation used.

Table-5: Parameter estimates for the age-period-cohort model for the incidence of cancer in the larynx among Scottish males, 1960-1989 (Robertson and Boyle model)

	Estimate	Standard error
Mean	3.889	0.4604
Age group		
35-39	0.000	-----
40-44	1.057	0.1972
45-49	1.938	0.1998
50-54	2.545	0.2090
55-59	2.992	0.2227
60-64	3.290	0.2399
65-69	3.478	0.2598
70-74	3.629	0.2819
75-79	3.573	0.3068
80-84	3.631	0.3346
Period		
1960-1964	0.000	---
1965-1969	0.032	0.0687
1970-1974	0.147	0.0862
1975-1979	0.190	0.1100
1980-1984	0.382	0.1358
1985-1989	0.461	0.1635
Birth cohort		
1875-1879	0.000	-----
1880-1984	0.193	0.3533
1885-1889	-0.118	0.3473
1890-1894	0.320	0.3421
1895-1899	0.326	0.3488
1900-1904	0.253	0.3587
1905-1909	0.194	0.3717
1910-1914	0.239	0.3869
1915-1919	0.158	0.4041
1920-1924	0.286	0.4219
1925-1929	0.304	0.4416
1930-1934	0.176	0.4643
1935-1939	0.242	0.4896
1940-1944	0.347	0.5211
1945-1949	0.504	0.5664
1950-1954	-1.199	1.1490

Table-6: Parameter estimates for the age-period-cohort model for the incidence of cancer in the larynx among Scottish females, 1960-1989 (Robertson and Boyle model)

	Estimate	Standard error
Mean	2.644	1.170
Age group		
35-39	0.000	---
40-44	0.309	0.2837
45-49	0.840	0.2859
50-54	1.381	0.3097
55-59	1.526	0.3491
60-64	1.953	0.3908
65-69	1.949	0.4404
70-74	2.159	0.4913
75-79	1.946	0.5482
80-84	2.051	0.6065
Period		
1960-1964	0.000	-----
1965-1969	0.385	0.1488
1970-1974	0.549	0.1806
1975-1979	0.500	0.2264
1980-1984	0.765	0.2755
1985-1989	0.745	0.3303
Birth cohort		
1875-1879	0.000	-----
1880-1884	1.183	1.0400
1885-1889	0.863	1.0320
1890-1894	0.652	1.0360
1895-1899	0.528	1.0440
1900-1904	0.814	1.0550
1905-1909	0.688	1.0740
1910-1914	0.965	1.0940
1915-1919	1.099	1.1180
1920-1924	1.120	1.1440
1925-1929	1.124	1.1730
1930-1934	0.850	1.2080
1935-1939	0.833	1.2450
1940-1944	0.663	1.2960
1945-1949	-0.063	1.4020
1950-1954	-0.236	1.6780

REFERENCES

- [1] Registrar General for Scotland, (1992), "Annual report 1991", H.M.S.O. Edinburgh.
- [2] Clayton, D. and Schifflers (1987), "Models for temporal variation in cancer rates. I: age-period and age-cohort Models", *Statistics in Medicine*, vol. 6, 449-467.
- [3] Clayton, D. and Schifflers (1987), "Models for temporal variation in cancer rates. II: age-period and age-cohort Models", *Statistics in Medicine*, vol. 6, 469-481.
- [4] Decarli, Adriano and La Vecchia, Carlo (1987), "age, period and cohort Models; review of knowledge and implementation of GLIM", *Revista di Statistics Applicata* Vol 20 1987.
- [5] Robertson, Chris and Boyle, Peter (1986), "Age, period and cohort Models: The use of individual records", *Statistics in Medicine*, Vol. 5, 527-538.
- [6] Boyle, P. and Robertson, c. (1987), "Statistical Modelling of Lung Cancer and Laryngeal Cancer incidence in Scotland, 1960-1979", *American Journal of Epidemiology*, vol. 125, No. 4 (1987; 125:731-44).
- [7] Barclay, Gorge W. (1962), "Techniques of Population Analysis", John Wiley & Sons, New York.
- [8] Wetherill, G. Barrie (1982), "Elementary statistical methods", Chapman and Hall, New York.
- [9] Osmond, C. and Gardner, M. J. (1982), "Age, period and cohort Models applied to cancer mortality rates", *Statistics in Medicine*, vol. 1, 245-259.
- [10] Holford, T. R. (1983), "The estimation of age, period and cohort effects for vital rates", *Biometrics*, 39, 311-324.
- [11] Morgan, Byron J. T. (1984), "Elements of simulation", Chapman and Hall, New York
- [12] Efron, Bradley and Tibshirani, Robert J. (1993), "An Introduction to the Bootstrap", Chapman and Hall, New York and London.

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