Prediction of Lung Cancer Rates
1986-2005 in 24 countries

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Note: This document was reformatted from the 1989 original in 2013 – Table 6 and all the Figures are missing from the original document, and cannot now be found.

SUMMARY

In a previous report, trends in lung cancer from 1951-85 in 24 countries were studied using the method of Osmond & Gardner to fit log-linear age-period-cohort models. The countries studied included North America, Australia, New Zealand, Japan, Hong Kong, as well as most of Western Europe. This report extends the models to predict lung cancer rates over the next 20 years (1986-2005). This approach looks only at trends within the age-specific mortality rates and does not attempt to model possible causal relationships with cigarette smoking or other environmental factors.

The method used relies on the following assumptions:

- the model will continue to be appropriate
- established age values will continue to apply
- in the larger countries where there are sufficient deaths to analyse below age 40, cohort values established at young ages will remain valid as those cohorts get older
- further cohort values can be estimated by extrapolation of existing values
- new period values can be estimated by extrapolation of existing values.

When extrapolating cohort values, a particular difficulty is to decide the amount of weight to be given to the most recent values, since these are the most relevant to recent trends, yet are the least reliable estimates.

In those countries where the original model showed a definite peak in the cohort values, the prediction method gives a reliable indication of the pattern in the lung cancer rate. However where the cohort pattern showed a rise or uncertain peak, or where the period values were rising steeply, the predictions are less well founded and may overestimate rates; this applies to a few countries for males and about half the countries for females. The predicted patterns for the 20 year period can be summarised as follows:

Falling: in England & Wales, Finland, Hong Kong, Netherlands, New Zealand, N. Ireland, Scotland, Switzerland. Females in Greece, Hong Kong, Spain.

Starting to rise again: Males in Austria, W. Germany, Sweden.

Reaching a peak: Males in Australia, Belgium, Canada, Denmark, Ireland, USA. Females in England & Wales, Scotland and possibly Finland and N. Ireland.

Continuing rise in all other countries

These varying directions of trend will cause major changes to the relative positions of the countries, with Belgium predicted to have the highest rate for males, and Denmark for females. Rates for males are not predicted to exceed the highest seen to date, but for females substantially higher rates are expected in several countries.

1. Introduction

In a recent report[1], lung cancer trends in 24 countries from 1951-85 were studied, mainly by using the method of Osmond and Gardner[2] (O&G). This approach uses only trends contained in the mortality rates themselves rather than attempting to model mortality on possible causal relationships, such as to cigarette smoking or environmental factors. An earlier report by CDG[3] investigated methods of using the O&G model to predict mortality over a 20 year period in England and Wales. This document briefly describes further investigations into these methods and others (full details in separate report[4]) and then presents predictions for 24 countries.

It concentrates mainly on age standardised rates for age 40-74, this being the most suitable age range for modelling, though age 40+ predictions are also given as more closely representing overall trends. Future work will include model fitting using cigarette consumption data.

2. Data

Mortality and population data were obtained from WHO for the period 1951-85 by 5 year age groups, as far as possible. Data were grouped into 5-year periods which are referred to by their mid-point year. Analyses were based on ages 25-74, with younger age groups omitted if the average number of deaths per 5-year period was less than 20. Countries are loosely referred to as "large" or "small" according to the numbers of deaths and hence the number of age groups included. Table 1 shows the countries, years and ages studied. Details of how some incomplete data items were estimated are given in reference 1. (Analyses for Spain are up to 1983).

Data for age 75+ were available broken down into 75-79, 80-84 and 85+, except for Denmark 1951 mortality and Hong Kong 1972-77 population (see Appendix A).

3. Methods

3.1 Appropriate age-group for detailed study

The principal objective of this report is to predict future patterns in lung cancer mortality. Although trends in age-specific rates are of obvious importance, for comparisons of a large number of countries overall mortality is a more practical concept. However it is not valid to fit models covering the youngest ages where deaths are extremely rare, and inclusion of the oldest age-groups is undesirable due to diagnostic unreliability. Accordingly, previous model fitting was restricted to ages 25-74 at most. In this report we will give predictions for age 40-74, since this age range is available for all countries except females in Finland, New Zealand, N. Ireland and Norway. Exclusion of the 25-39 year olds, where they are available, will make little difference to overall trends since the 40-74 rate will be dominated by the much higher rates at the upper end of the age range. The rates are standardised to the sex-specific England and Wales population for 1981-85, and are rates per million.

3.2 Underlying ideas

In the O&G model, period and age specific mortality rates are fitted as a product of age, period (i.e. of death) and cohort (i.e. period of birth) effects:

$$r_{ijk} = a_i p_j c_k \qquad i = 1, na,\ j = 1, np,\ k = 1, nc,$$

$$\text{where } k = na - i + j \text{ and } nc = na + np - 1$$

This is referred to as the A-P-C, or full, model. It is also possible to fit a sub-model containing any two of the effects, with the A-C sub-model relevant to this report.

Extending the A-P-C model to predict rates for a further four periods (i.e. 20 years) gives:

$$r_{ijk} = a_i p_j c_k \qquad i = 1, na,\ j = 1, np+4,\ k = 1, nc+4,$$

$$\text{where } k = na - i + j \text{ and } (nc+4) = na + (np+4) - 1$$

Thus four additional period values p_j, j = np+1, np+4 and four additional cohort values ck, k = nc+1, nc+4 are needed. It is assumed that these can be obtained by some form of extrapolation from the existing values. It is also assumed that the age values will continue to be appropriate, and that the recent cohort values, based on young age groups, will continue to be appropriate as those cohorts get older.

The need for additional cohort values is indicated in this diagram relating age values (shown on the left), period values (shown at the top) and cohort values (shown in the body of the table).

		Period										
		1	2	3	4	5	6	7	8	9	10	11
Age		53	58	63	68	73	78	83	88	93	98	03
1	25-29	10	11	12	13	14	15	16	17	18	19	20
2	30-34	9	10	11	12	13	14	15	16	17	18	19
3	35-39	8	9	10	11	12	13	14	15	16	17	18
4	40-44	7	8	9	10	11	12	13	14	15	16	17
5	45-49	6	7	8	9	10	11	12	13	14	15	16
6	50-54	5	6	7	8	9	10	11	12	13	14	15
7	55-59	4	5	6	7	8	9	10	11	12	13	14
8	60-64	3	4	5	6	7	8	9	10	11	12	13
9	65-69	2	3	4	5	3	7	8	9	10	11	12
10	70-74	1	2	3	4	5	6	7	8	9	10	11

It can be seen that an analysis based on age 25-74 for seven periods 1953-83 (i.e. left of the vertical line) provides estimates of the first 16 cohort values, although cohort value 16 in particular is uncertain since its estimate is based on only one data point containing few deaths. In order to predict to 2003 we require also estimates of cohort values 17-20. However since we are concentrating on presenting the age-standardised rate for 40-74 year olds (i.e. below the horizontal line), the only new cohort value required is 17, with cohorts 8-15 dominating the calculations. Estimates of cohort values 14-16 are available from rates under age 40 in recent periods, and use of these estimates entails the implicit assumption that cohort patterns are established at young ages that can be extended to older ages. (The same of course applies to cohorts 8-13, for which estimates are based on progressively fewer and younger ages).

Now consider a smaller country where the number of deaths is sufficient to allow analyses only from age 40. We now have estimates of 13 cohort values, with cohort value 13 particularly uncertain. For projections of 40-74 years to 2003, we additionally require cohort values 14-17. Since cohorts 8-15 will again dominate the calculations, these new cohort values are of much greater importance here.

The estimation of cohort values to use for projections therefore falls into two categories:

A use of cohort values estimated at young ages being extended to older ages, with the final point(s) uncertain due to be being based on few data points, and

B estimation of new cohort values, to be based on some extrapolation procedure on the existing cohort values.

As explained above, A is important for all countries, but B will be relatively unimportant in the larger countries where analysis below age 40 is possible. Estimation of new period values will also be important for all countries.

3.3 Extrapolation procedures

CDG[3] tried various extrapolation techniques and found that four were worth considering, on the basis of England & Wales data. The methods all assume that either linear or log-linear regression is appropriate to both cohort and period values, and use the principle of weighting recent results more heavily than those in the distant past. The methods suggested were:

1. A-P-C model; linear extrapolation of period values using powers of 10 as weights; linear extrapolation of cohort values using weights of 0 before the peak value and of 1 after the peak value.

2/a. As method 1, but with log-linear extrapolation.

3. A-C model; log-linear extrapolation of cohort values weighted as method 1.

4. As method 2, with residual correction (log-linear extrapolation of the age-specific residuals using powers of 10 as weights, the predicted residuals then being subtracted from the predictions obtained by method 3).

These methods, and others, have been tried out for males in six countries (Canada, Denmark, England & Wales, Greece, USA and West Germany). Detailed comparisons are presented elsewhere[4], with the conclusions briefly summarized here.

Linear extrapolation was felt to be inappropriate since it can result in negative values, which are meaningless in the model. The reason that linear extrapolation appeared to give "better" predictions for England & Wales is attributed to the poor fit of a log-linear model to the cohort values after the peak.

Use of the A-C model gave higher predictions than the A-P-C model in most countries. This was due to misfit of the model in the final period, and although this was generally improved by use of residual correction, the results for the younger age groups in some countries were clearly unsatisfactory. There seems no reason not to make use of the full model.

Thus the second of CDG's methods is preferred and will be referred to from now on as method a.

The method of extrapolating cohort values in method a was unsatisfactory for many countries since it requires one cohort to be identified as having the peak value - previous cohorts are then excluded from the extrapolation procedure by a zero weighting, and all subsequent cohort values are weighted equally. In many countries, there is no clear peak available - there may be a plateau, a double peak, a very recent peak or a continuing rise. Another problem with the method was a non-smooth join between the original and extrapolated values when the log-linear model fitted poorly. A log-linear regression using powers of 2 as weights was found to give satisfactory results. This does involve the difficulty of giving heaviest weight to the most recent, most unreliable cohort value. The regression procedure was also applied with the final 1 or 2 points omitted from the regression and their values replaced by extrapolated values. Exclusion of the 1 final point was felt to give the best compromise between unreliability and loss of information on recent trends. Recalling the discussion in the last section, in the larger countries alteration of recent existing cohort values will have a greater effect on results than estimation of new cohort values.

The assumption that period values could be fitted by a log-linear model was also found to be inappropriate to many countries. In fact the very heavy weighting with powers of 10 meant that the extrapolation was largely determined by the last 2 values.

Further examination of period effects has suggested that the period effects may follow a similar pattern for many countries - level, steep rise, level, gradual decline - with different part of the pattern visible in different countries, the countries with established cohort declines tending to show a later part of this suggested period pattern. Although there is no formal justification for supposing all countries should follow this pattern, nor for knowing when the turn to the next stage should occur, it none the less seems desirable that any extrapolation procedure should be compatible with this hypothesis. Accordingly the use of log-linear extrapolation based only on the last 2 period values is proposed. This is equivalent to using the same percentage change between successive periods as occurred between the last 2 periods. It is also proposed that estimates are made of upper and lower period values based on percentage change 3% above and below that used for the main estimate. This is <u>not</u> intended to represent any sort of statistical confidence interval, but to give a range of values encompassing reasonable future possibilities. Bringing together these ideas, our preferred method is defined as:

method b : A-P-C model; period values extrapolated by % change based on last two values, with upper and lower values ± 3%; cohort values extrapolated by log-linear regression with weighting by powers of

2 and last value omitted from regression, last value and future values estimated from fitted regression.

Where this results in a substantial change to the final cohort value, then method c should also be considered:

method c : as method b, but last cohort value retained and used in the extrapolation procedure.

For the four countries (Finland, New Zealand, N. Ireland, Norway) where the analysis started at age group 45-49, the age value for 40-44 was estimated as 0.52 x the age value for 45-49, based on the average for the other 20 countries females; for method b, two cohort values (cohorts 12 and 13) were estimated from the extrapolation procedure and for method c one was estimated.

3.4 Graphical techniques

Three main types of graph are presented.

1. For individual sex/country, a 3 part graph is presented. This shows first the O&G fitted cohort values (solid line), the extrapolation by method b (dashed) and, if appropriate, the extrapolation by method c (dotted); secondly the O&G fitted period values (solid line), extrapolation by method b (dashed) with upper and lower 3% values (dotted); age-specific mortality rates, observed (solid line), fitted and projected by method b (dashed). Note that cohort and period values are plotted on the same scales for all countries, in order to emphasise differences between the countries.

2. Age-standardised rates are presented for the period 1953-2003. The values for 1953-83 are observed, and for 1988-2003 predicted. These graphs either compare prediction methods for a sex/country, or compare predictions by method b in a group of countries.

3. Age-standardized rates for all countries are also compared by means of rank diagrams, which show the relative positions of the countries as a "lung cancer league table".

4. Results

Method b was applied to lung cancer rates in 24 countries for sexes separately. Cohort and period values and age-specific rates (observed, fitted and expected) for each sex/country are given in Figures 1-24.

4.1 Period values

The % change in period values based on the last 2 values are shown in Table 2. For males, the changes are mostly between -5% and 10%. For females, there are fewer negative changes, and higher positive values, with 4 over 20% - Denmark, Netherlands, Norway and Switzerland. Apart from these and also Austria, Finland, France and W. Germany females, where the earlier pattern was different, the range of values suggested by the ±3% does seem to have successfully covered the desired possibilities.

4.2 Cohort values

Table 3 shows the final cohort value, as fitted in the original O&G analysis and as fitted by method b, together with the % difference between the two. There are substantial differences, with 25 sex/countries having a difference above 20% (positive or negative). For these, method c was also applied and the alternative cohort extrapolation is shown in the figures as a dotted line. In cases where a cohort peak is well established (with the exception of Spain female), the general direction of both cohort trends is downwards, with the method c steeper than method b (France, Netherlands, N. Ireland males; France, Greece, USA females). Choice between the two methods here depends on whether the most recent low rate for the youngest age group should be taken as a true trend or merely natural variation. For a few countries where there was a substantial upturn in the last cohort value (due to a high rate at the youngest age group), it certainly seems safer to accept method b (Denmark males; Norway, Spain, Switzerland females). However, for the others, the cohort values have reached a peak at either the second- or third-to-last value (W. Germany, Japan, Norway, Spain, Sweden male; Austria, Belgium, Denmark, Finland, W. Germany, Hong Kong, Ireland, Netherlands, New Zealand, N. Ireland female). Here method b mostly shows a level pattern against a decline by method c. It is in these countries that choice between the two methods makes the most fundamental difference to understanding future trends, although, as previously discussed, it is only in the smaller countries that this will much affect overall rates in the time-span considered. Most serious is Denmark female (and, to a lesser extent, Netherlands and N. Ireland female) where method b shows a substantial cohort rise.

4.3 Age-standardised rates by different methods

Table 4 shows the age-standardised lung cancer rates for 40-74 in the period 2003, as predicted by methods a (males only), b and, where appropriate, c. The years in which peaks occurred under the different methods are shown in Table 5, with c indicating a continuing rise at the end of the period. There is generally little difference between methods a and b (for males only, except method b gives Hong Kong lower and Norway higher, peak reached in Italy, not reached in Sweden). There is a substantial difference in rates due to choice of period values, with the rate based on the upper value between 20% and 30% higher than the lower value. In many countries for males, and some for females, the lower period values give an earlier peak than the upper values. The largest apparent differences are in Belgium and Sweden males where the low value gives an early peak (1983, 1978 respectively) while the high value shows rates continuing to rise in 2003, but in both countries the predicted rates are fairly level.

Method c (applied only where there was a greater than 20% difference between the original and method b final cohort value) can give either a higher or lower rate than method b, following the patterns already discussed in the cohort values. Only in the smaller countries is the difference substantial. In Finland and N. Ireland, 2 of the smallest countries, method c suggests that a peak will be reached soon (1993) with rates then falling below 1983 rates whereas method b suggests a larger increase possibly peaking around the end of the study period. Figures 25-30 present comparisons of the rates predicted by different methods for six countries for males. The observed rates for 1953-83 are shown, followed by predictions by method a, b and c as solid lines. The predicted rates using the upper and lower period values for method b are shown as dotted red lines; for Denmark only the upper and lower period values for method c are also shown as dotted blue lines.

These figures illustrate the large differences due to choice of period extrapolation, compared to the relatively small influence of cohort extrapolation, particularly in the larger countries.

4.4 Trends in different countries

Table 6 shows for all countries the age-standardised rates for 40-74, observed and fitted (with modified final cohort value) for 1953-83 and predicted by method b for 1988-2003. The observed and predicted rates are plotted for groups of countries in Figures 31-33. Comparisons between the countries are also shown in the form of a rank diagram in Figure 34.

4.4.1 Males

The predictions for males show quite different patterns in different countries. For those countries with a well-established early cohort peak, rates have already peaked and are predicted to continue falling - England & Wales, Finland and Scotland. This is also the case for Hong Kong, Netherlands, New Zealand, N. Ireland and Switzerland where falls have started more recently. However, in Austria, W. Germany and Sweden, where rates have fallen between 1978 and 1983, the rates are predicted to remain level or start rising again, reflecting the double peak in their cohort patterns.

In Belgium rates are virtually at their peak and are expected to remain level throughout the projected period. In Australia, Canada, Denmark, Ireland and the USA, the peak is expected to be reached and passed by 2003. (Method c predicts Denmark continuing to rise.)

For the remaining countries, a continuing increase is forecast: France, Greece, Italy, Japan, Norway, Portugal, Spain.

These varying trends have led to substantial changes in the relative positions of the countries. England & Wales, Finland and Scotland, which had the highest rates throughout the 50s and 60s are set to fall dramatically through the rankings. Belgium and Netherlands have currently the highest levels along with Scotland, and the predictions show that Belgium is set to hold the highest place while rates in the Netherlands fall away. The increasing rates in the southern European countries, together with Norway and possibly Denmark, are pushing them up the rankings towards the end of our study period.

4.4.2 Females

Only in Hong Kong and Spain has there been a fall in the lung cancer rate between 1978 and 1983, and that is predicted to continue. The predictions suggest that Greece has now reached its peak and that a peak will be reached within the study period for England & Wales and Scotland; also possibly for Finland and N. Ireland (by method c). For all other countries a continuing increase is forecast: Denmark and Netherlands are discussed below (4.4.3); the rise is also very steep for Norway (31/2 fold increase) and for Canada, Sweden and Switzerland, around 21/2 fold increase between 1983 and 2003.

4.4.3 Denmark and Netherlands, females

The predicted rises for Denmark and Netherlands females are very steep - giving more than a 4-fold increase from 1983 to 2003. Since these have already been mentioned as having particular difficulties with both period and cohort values, they have been looked at in a little more detail. (Tables 7,8, Figures 35-36)

For Denmark, the O&G analysis was based only on age 40-74, and the cohort extrapolation does therefore have a substantial effect on the predicted rate. The final cohort value, based on 62 deaths, is the only downward indication in an uncompromising upward pattern of age-specific rates. If it is used, i.e. with method c, the final rate predicted falls from 2851 to 2083 per million, which still represents more than a 3-fold increase since 1983.

Such substantial rises have taken place over a 25-year period in the past (USA 1963-83, by 4.0). However, it does seem implausible that such a rise should continue unabated in Denmark, where the rates have already risen 3.2 times since 1963, giving a rate in 2003 that is double the next highest country for females, and higher than the peak country for males.

Since this was one of the few countries for which the period effect was not significant in the original O&G model, the A-C model was also used for prediction (using the same methods b and c to extrapolate the cohort values). This resulted in predictions only slightly lower than from the A-P-C model. It is of course possible that the latest cohort value truly represents the beginning of a sharp downward cohort pattern, and a heavier weighting in the cohort values regression achieves this effect.

This predicts a rate of 1854 by 2003, again not much lower than the original method c prediction. In any case, the rates for the following cohorts at younger ages, (based of course on very small numbers of deaths), do not lend much support to this idea.

The period values in the full model also rose very steeply, and some levelling might reasonably be expected to take place. However, even with a really extreme assumption of no further rise in period value, the rate is still predicted to continue rising, by 2.0-fold for method b or 1.4-fold for method c.

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Alternative models have also been tried for Netherlands females. Here the A-C model gave lower predictions, but this seems basically attributable to lack of fit.

The enforced reduction in period values has a greater effect than in Denmark (since the original rise was steeper) but a continuing rise is still predicted.

4.4.4 Comparison of males and females

It can be seen that the age-standardised rate generally follows the same pattern as the cohort values, some years later. Thus various observations in our previous report[1] on geographical groupings are seen here.

In many Northern European and North American countries, the female rate continues to rise after a peak has been passed in the male rate. For England & Wales and Scotland, the female rate is predicted to peak 25 years after the male rate, and the other countries look on course for a similar pattern.

The countries of Central Europe (Austria, West Germany and Switzerland) show the least variation for males while for females the increase seen in the last 10 years is expected to accelerate.

Rates in Southern European countries are expected to rise throughout the period (possibly reaching a peak in Italy) except for females in Greece and Spain where a decline is expected.

Patterns are most similar between the sexes in the two Asian countries studied - a peak in 1978 in Hong Kong and a continuing steady rise in Japan.

4.5 Discussion of predictions

At this point it is useful to recall the basic assumptions implicit in this work:

- the O&G method will continue to be an acceptable model
- established age values will continue to apply
- cohort values established at young ages only will continue to apply as those cohorts get older
- new cohort values can be estimated by extrapolation of existing values
- new period values can be estimated by extrapolation of existing values
- no new outside influences will change trends

The first two of these assumptions seem quite reasonable (except perhaps where large scale immigration/emigration is to be expected), the third is debatable but would seem acceptable, the fourth and fifth are very speculative, while the sixth is beyond the scope of this report. Experience in many countries suggests that cohort peaks and levelling of period effects are to be expected. In countries where this is not currently seen, extrapolation ignoring these expectations is perhaps unwise, but inter-country variation is so great that there is no basis to predict when future changes in direction of the values will take place. Consequently, the most doubtful predictions are those where cohort values are rising or reaching a doubtful peak, or where the period values are rising very steeply. Leaving out those larger countries where cohort extrapolation is less important, the particularly doubtful countries are:

Males	Females
Austria	Austria
Greece	Canada
Norway	Denmark
Portugal	Finland
Sweden	France
Japan	W. Germany
	Netherlands
	New Zealand
	N. Ireland
	Sweden
	Switzerland

The predictions in these cases may be excessively high.

On the other hand, the general direction of trends in those countries where a cohort peak is well established is fairly reliable, although a fairly small change in the period values can have quite a large effect on the magnitude of the rates.

5. Predictions for age 40+

All the predictions discussed so far have been based on analyses for age up to 74. In this section, the age-range is extended by adding 3 further age groups 75-79, 80-84 and 85+. Thus rates for age 40+ are presented, again standardised to the 1981-85 England & Wales sex-specific population. These very closely represent overall rates.

There are two possible problems in this analysis. Firstly, diagnostic reliability is reduced at these highest age groups. This is reflected in the fact that the age-values estimated in the O&G model are not always monotonically increasing. Secondly, the final age group is open ended. Deaths at age 85-90, 90-94, 95-99 etc. should be allocated to successive cohorts, but when the data are grouped together they will all be allocated together. However the actual numbers of deaths at age 90+ is small enough for this to be unimportant.

Extending the analysis to include three older age groups requires estimation in the O&G model of three additional age values and three additional cohort values, relating to cohorts born earlier than those previously considered. Results relating to the later cohorts and periods which affect the extrapolation procedures are rescaled, but otherwise little altered.

Table 9 gives the final cohort values from the model and from method b, and comparison with Table 3 shows that the % difference is very similar to the 40-74 analysis. Hence the alternative method c has been applied for the same countries as before.

Table 10 shows the standardised rate at age 40+ in 2003 as predicted by methods b and c, together with predictions based on upper and lower period values, while Table 11 shows the periods when a peak is expected to occur. The observed rates to 1983 and rates predicted by method b for 1988-2003 are shown in Table 12 and Figures 37-39. Figure 40 presents the rates as a rank diagram.

Comparisons with the results of section 4 show that patterns in these 40+ rates are very similar to the 40-74 rates, and hence all points discussed there are relevant. The major difference is that peak rates generally occur 5 or 10 years later. This is as expected, when the peak rate is caused by a cohort peak which has now to work its way through a further 3 age groups. This also has the effect of masking the double peaks in Austria, W. Germany and Sweden. In some countries a peak is not now reached within the time period studied.

As before, choice of period values has a greater effect on the results by 2003 than does choice of cohort values. The pattern of results is least certain in those countries with a steeply rising period effect and in the smaller countries without a definite cohort peak.

References

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Table 1 Periods and age groups used for O&G analysis

Country	WHO code	Years	Lowest age group Male	Female
Australia	5020	51-85	30	35
Austria	4010	56-85	35	40
Belgium	4020	56-84	30	35
Canada	2090	51-85	30	30
Denmark	4050	51-85	35	40
England & Wales	4310	51-85	25	25
Finland	4070	52-85	35	45
France	4080	51-85	25	25
Germany W.	4100	52-85	25	25
Greece	4140	61-85	30	35
Hong Kong	3090	61-85	35	35
Ireland	4170	51-85	35	40
Italy	4180	51-84	25	25
Japan	3160	51-85	25	25
Netherlands	4210	51-85	30	35
New Zealand	5150	51-85	40	45
N. Ireland	4320	51-85	40	45
Norway	4220	51-85	40	45
Portugal	4240	56-85	35	40
Scotland	4330	51-85	30	35
Spain	4280	51-83	25	25
Sweden	4290	51-85	35	40
Switzerland	4300	51-85	35	40
USA	2450	51-85	25	25

Table 2 Extrapolation of period values - % increase based on last 2 values, age 40-74

Country	Male	Female
Australia	−0.9	5.8
Austria	−1.6	13.6
Belgium	−0.5	3.6
Canada	1.4	19.1
Denmark	4.1	22.3
England & Wales	−4.1	0.1
Finland	−6.4	10.4
France	2.0	12.6
Germany W.	0.7	16.0
Greece	3.9	−0.2
Hong Kong	−5.7	−5.7
Ireland	3.1	14.0
Italy	2.3	5.4
Japan	10.2	7.5
Netherlands	−2.0	29.4
New Zealand	−4.0	9.3
N. Ireland	0.8	8.5
Norway	12.5	29.0
Portugal	6.6	8.8
Scotland	−2.8	8.7
Spain	7.9	−4.0
Sweden	−4.2	19.1
Switzerland	−1.2	24.2
USA	−1.5	3.0

Table 3 Extrapolation of cohort values, age 40-74

	MALE					FEMALE				
	Final cohort value			Slope of extrapolation		Final cohort value			Slope of extrapolation	
	Orig	b	% diff	b	c	Orig	b	% diff	b	c
Australia	.560	.661	18.2	−.049		1.399	1.346	−3.8	.005	
Austria	1.061	1.064	0.3	.011		.798	1.038	30.1	−.000	−.029
Belgium	1.133	1.062	−6.3	−.007		.840	1.101	31.1	−.007	−.037
Canada	1.088	1.111	2.1	−.007		1.552	1.417	−8.7	−.001	
Denmark	1.237	.818	−33.8	−.035	.010	1.325	2.447	84.7	.068	.001
England & Wales	.244	.279	14.3	−.084		.861	.788	−8.6	−.050	
Finland	.498	.413	−16.9	−.073		.625	.954	52.6	−.015	−.061
France	.792	1.044	31.8	−.025	−.055	.435	.565	29.9	−.060	−.088
Germany W.	.497	.899	80.9	−.025	−.090	.439	.901	105.2	−.015	−.093
Greece	1.606	1.382	−13.9	.025		.640	.879	37.3	−.013	−.048
Hong Kong	.870	.781	−10.2	−.034		.770	1.005	30.5	−.003	−.033
Ireland	.712	.723	1.5	−.049		.653	1.103	68.9	−.008	−.065
Italy	.993	1.113	19.3	−.018		.734	.699	−4.8	−.053	
Japan	.686	1.106	61.2	−.000	−.052	.950	1.010	6.3	−.006	
Netherlands	.532	.761	43.0	−.031	−.070	1.139	1.668	46.4	.030	−.012
New Zealand	.816	.858	5.1	−.024		1.068	1.417	32.7	.028	−.003
N. Ireland	.646	.801	24.0	−.026	−.049	.711	1.334	87.6	.012	−.057
Norway	.998	1.297	30.0	.011	−.017	1.670	1.303	−22.0	.023	.050
Portugal	1.229	1.405	8.2	.013		.975	1.071	9.8	−.000	
Scotland	.479	.463	−3.3	−.055		.988	1.142	15.6	−.017	
Spain	1.091	1.517	48.9	.014	−.029	1.014	.683	−32.6	−.032	.011
Sweden	.968	1.347	39.2	.019	−.017	1.354	1.389	2.6	.027	
Switzerland	.952	.801	−15.8	−.032		1.616	1.193	−26.2	.011	.045
USA	.591	.541	−8.5	−0.71		1.285	1.596	24.6	−0.17	−0.40

Table 4 Lung cancer rate 40-74 in 1983 and in 2003 predicted by different methods based on A-P-C model – MALES

	1983	a	b	b (lower)	b (upper)	c	c (lower)	c (upper)
Australia	1504	1274	1281	1133	1443			
Austria	1474	1634	1607	1420	1813			
Belgium	2491	2669	2502	2214	2818			
Canada	1754	1966	1920	1702	2157			
Denmark	1759	1893	1784	1587	1998	1954	1738	2189
England & Wales	2054	1034	1021	892	1145			
Finland	1932	886	812	713	922			
France	1387	1895	1790	1588	2010	1771	1572	1989
Germany W.	1528	1761	1749	1549	1967	1723	1526	1937
Greece	1497	2206	2000	1779	2241			
Hong Kong	1744	1462	1267	1113	1436			
Ireland	1593	1403	1420	1262	1593			
Italy	1839	2381	2312	2052	2595			
Japan	779	1176	1182	1058	1315	1167	1045	1299
Netherlands	2406	1869	1868	1649	2107	1824	1610	2057
New Zealand	1500	1104	1092	961	1235			
N. Ireland	1732	1217	1360	1205	1530	1231	1091	1385
Norway	950	1430	1716	1540	1906	1517	1361	1685
Portugal	681	1146	1117	997	1248			
Scotland	2499	1453	1415	1248	1598			
Spain	1159	2008	1947	1739	2173	1914	1710	2136
Sweden	735	767	749	660	848	693	610	784
Switzerland	1586	1373	1280	1132	1443			
USA	1822	1596	1551	1371	1749			

Table 4 (cont.) **Lung cancer rate 40-74 in 1983 and in 2003 predicted by different methods based on A-P-C model – FEMALES**

	1983	b	b (lower)	b (upper)	c	c (lower)	c (upper)
Australia	382	542	483	606			
Austria	260	437	392	485	388	348	430
Belgium	211	259	230	290	242	215	271
Canada	556	1470	1328	1624			
Denmark	643	2851	2581	3141	2083	1886	2295
England & Wales	659	609	539	685			
Finland	201	259	232	289	190	170	211
France	131	190	171	211	189	169	210
Germany W.	209	365	329	404	355	319	393
Greece	210	176	156	198	162	143	182
Hong Kong	789	593	521	673	561	493	635
Ireland	616	967	869	1073	782	703	868
Italy	211	255	227	285			
Japan	235	303	271	339			
Netherlands	232	969	882	1062	864	787	947
New Zealand	507	919	822	1024	727	651	810
N. Ireland	555	819	732	913	502	449	560
Norway	243	835	760	916	1046	952	1148
Portugal	121	172	158	192			
Scotland	920	1194	1067	1331			
Spain	114	81	71	91	83	73	94
Sweden	265	688	621	760			
Switzerland	202	533	483	586	641	581	705
USA	696	1225	1089	1374	1217	1081	1365

Table 5 Lung cancer rate 40-74, peak year, predicted by different methods based on A-P-C model – MALES

	a	b	b (lower)	b (upper)	c	c (lower)	c (upper)
Australia	83	83	83	83			
Austria	<u>68</u>,c	<u>68</u>,c	<u>68</u>,98	68,<u>c</u>			
Belgium	c	83,<u>c</u>	83	c			
Canada	98	98	93	c			
Denmark	93	93	93	98	c	93	c
England & Wales	68	68	68	68			
Finland	68	68	68	68			
France	c	c	98	c	c	98	c
Germany W.	78,<u>c</u>	78,<u>c</u>	78,<u>98</u>	78,<u>c</u>	c	98	c
Greece	c	c	c	c			
Hong Kong	78	78	78	78			
Ireland	88	93	83	93			
Italy	c	98	98	c			
Japan	c	c	c	c	c	c	c
Netherlands	78	78	78	78	78	78	78
New Zealand	78	78	78	78			
N. Ireland	78	78	78	<u>78</u>,88	78	78	78
Norway	c	c	c	c	c	c	c
Portugal	c	c	c	c			
Scotland	73	73	73	73			
Spain	c	c	c	c	c	c	c
Sweden	78,<u>98</u>	<u>78</u>,c	78	78,<u>c</u>	78	78	78,<u>98</u>
Switzerland	78	78	78	<u>78</u>,88			
USA	88	88	83	93			

c indicates continuing rise at 2003
In countries showing a double peak, the higher is underlined

Table 5 (cont.) **Lung cancer rate 40-74, peak year, predicted by different methods based on A-P-C model – FEMALES**

	b	b (lower)	b (upper)	c	c (lower)	c (upper)
Australia	c	c	c			
Austria	c	c	c	c	c	c
Belgium	c	98	c	98	93	c
Canada	c	c	c			
Denmark	c	c	c	c	c	c
England & Wales	93	88	93			
Finland	c	98	c	93	88	93
France	c	c	c	c	98	c
Germany W.	c	c	c	c	c	c
Greece	83	83	93	83	83	88
Hong Kong	78	78	78	78	78	78
Ireland	c	c	c	98	98	98
Italy	c	98	c			
Japan	c	c	c			
Netherlands	c	c	c	c	c	c
New Zealand	c	c	c	c	c	c
N. Ireland	c	98	c	93	93	98
Norway	c	c	c	c	c	c
Portugal	c	c	c			
Scotland	98	98	98			
Spain	73	73	73	73	73	73
Sweden	c	c	c			
Switzerland	c	c	c	c	c	c
USA	c	c	c	c	c	c

c indicates continuing rise at 2003
In countries showing a double peak, the higher is underlined

Table 7

Further prediction models for Denmark, female 40-74 rates

1983 rate = 642.8

	Method b		Method c	
	2003 rate	2003/1983	2003 rate	2003/1983
A-P-C, period 22.3%	2851	4.4	2083	3.2
−3%	2581	4.0	1886	2.9
+3%	3141	4.9	2295	3.6
A-C	2523	3.9	1843	2.9
with resid.corr	2546	4.0	1906	3.0
A-P-C with cohorts weighted by powers of 10				
period 22.3%			1854	2.8
−3%			1679	2.6
+3%			2043	3.2
A-P-C, period 0%	1274	2.0	931	1.4
3%	1434	2.2	1047	1.6

Numbers of deaths and rates per million for age 25-49, Denmark, female

	1953	1958	1963	1968	1973	1978	1983
25-29	2	3	2	2	4	2	3
30-34	5	1	6	10	4	9	13
35-49	12	8	18	27	23	21	27
40-44	22	22	19	38	49	67	62
45-49	28	31	40	78	112	152	200
25-29	2.6	4.2	2.8	2.4	3.9	2.1	3.3
30-34	6.2	1.3	8.5	13.9	4.9	8.9	13.9
35-39	15.5	10.1	24.1	38.5	32.1	25.5	26.9
40-44	27.9	28.9	24.2	51.2	70.0	93.5	75.8
45-49	38.0	40.0	53.2	100.7	151.8	220.8	282.8

Table 8

Further predictions models for Netherlands, female 40-74 rates

1983 rate = 232

2003	Method b		Method c	
	2003 rate	2003/1983	2003 rate	2003/1983
A-P-C, period 29.4%	969	4.2	864	3.7
−3%	882	3.8	787	3.4
+3%	1062	4.6	947	4.1
A-C	589	2.5	528	2.3
with resid.corr	674	2.9	612	2.6
A-P-C with cohorts weighted by powers of 10				
period 29.4%			828	3.6
−3%			754	3.2
+3%			907	3.9
A-P-C, period 0%	346	1.5	308	1.3
3%	389	1.7	347	1.5

Numbers of deaths and rates per million for age 25-44, Netherlands, female

	1953	1958	1963	1968	1973	1978	1983
25-29	6	2	3	9	4	12	6
30-34	12	11	10	13	9	18	21
35-39	19	9	27	24	39	33	53
40-44	36	26	37	37	55	61	113
25-29	3.1	1.0	1.6	4.3	1.5	4.2	2.1
30-34	6.3	5.7	5.2	6.8	4.3	6.7	7.4
35-39	11.0	4.8	14.2	12.6	20.4	15.7	19.8
40-44	21.3	15.3	19.9	19.5	28.8	31.8	53.6

Table 9 Extrapolation of cohort values, age 40+

	MALE					FEMALE				
	Final cohort value			Slope of extrapolation		Final cohort value			Slope of extrapolation	
	Orig	b	% diff	b	c	Orig	b	% diff	b	c
Australia	0.536	0.632	17.9	−.053		1.634	1.575	−3.6	.008	
Austria	1.014	1.010	−0.4	.008		.774	1.002	29.5	−.004	−.003
Belgium	1.585	1.495	−5.7	.006		.870	1.152	3.04	−.006	−.037
Canada	1.241	1.270	2.3	−.004		1.702	1.557	−8.5	−.003	
Denmark	1.273	0.844	−33.7	−.037	.008	1.880	3.463	84.2	.083	.019
England & Wales	0.232	0.266	14.7	−.088		0.969	0.888	−8.4	−.052	
Finland	0.449	0.372	−17.1	−.080		0.611	0.931	52.4	−.017	−.063
France	0.839	1.109	32.2	−.024	−.054	0.405	0.522	28.9	−.064	−.091
Germany W.	0.571	1.034	81.1	−.020	−.085	0.419	0.853	103.6	−.018	−.095
Greece	1.838	1.585	−13.8	.031		0.616	0.838	36.0	−.019	−.053
Hong Kong	0.809	0.729	−9.9	−.041		0.711	0.934	31.5	−.012	−.041
Ireland	0.754	0.769	4.8	−.049		0.645	1.097	70.1	−.014	−.072
Italy	1.176	1.409	19.8	−.010		0.745	0.711	−4.6	−.056	
Japan	0.825	1.339	62.3	.005	−.047	1.017	1.090	7.2	−.007	
Netherlands	0.582	0.832	43.0	−.031	−.070	1.377	2.011	46.0	.038	−.003
New Zealand	0.795	0.843	6.0	−.028		1.122	1.498	33.5	.025	−.006
N. Ireland	0.622	0.776	24.8	−.030	−.054	0.663	1.256	89.4	.001	−.069
Norway	1.141	1.486	30.2	0.16	−.012	1.916	1.502	−21.6	.031	.057
Portugal	1.284	1.389	8.2	.010		0.960	1.053	10.7	−.003	
Scotland	0.465	0.451	−3.0	−.057		1.022	1.193	16.7	−.002	
Spain	1.123	1.680	49.6	.017	−.027	0.895	0.603	−32.6	.041	.002
Sweden	0.994	1.369	37.7	.018	−.016	1.647	1.665	1.1	.038	
Switzerland	0.956	0.806	−15.7	−.034		1.782	1.291	−27.6	.015	.050
USA	0.637	0.584	−8.3	−.070		1.477	1.837	24.4	−.020	−.044

Table 10 Lung cancer rate 40+ in 1983 and in 2003 predicted by different methods based on A-P-C model – MALE

	1983	b	b (lower)	b (upper)	c	c (lower)	c (upper)
Australia	1875	1637	1448	1845			
Austria	1874	1897	1678	2136			
Belgium	3070	3309	2921	3735			
Canada	2130	2531	2243	2845			
Denmark	2156	2318	2062	2598	2465	2192	2762
England & Wales	2638	1482	1307	1675			
Finland	2374	1161	1021	1315			
France	1617	2138	1899	2397	2121	1883	2380
Germany W.	1911	2045	1809	2304	2022	1788	2277
Greece	1775	2412	2144	2705			
Hong Kong	2067	1634	1439	1849			
Ireland	1934	1908	1695	2140			
Italy	2079	2841	2519	3193			
Japan	1083	1837	1645	2044	1822	1632	2028
Netherlands	3077	2496	2201	2819	2458	2158	2776
New Zealand	1919	1578	1394	1780			
N. Ireland	2167	1848	1640	2075	1729	1535	1942
Norway	1104	2019	1810	2246	1841	1650	2048
Portugal	786	1275	1138	1425			
Scotland	3155	2053	1813	2315			
Spain	1375	2366	2114	2639	2335	2086	2605
Sweden	994	814	715	924	771	677	875
Switzerland	1878	1664	1473	1873			
USA	2154	2090	1849	2354			

Table 10 (cont.) Lung cancer rate 40+ in 1983 and in 2003 predicted by different methods based on A-P-C model – FEMALE

	1983	b	b (lower)	b (upper)	c	c (lower)	c (upper)
Australia	443	774	690	865			
Austria	365	578	528	653	551	495	612
Belgium	274	398	355	445	381	340	426
Canada	633	1977	1787	2182			
Denmark	717	2997	2698	3317	2389	2152	2644
England & Wales	782	1021	905	1148			
Finland	266	380	340	423	327	293	364
France	180	264	237	293	263	235	292
Germany W.	280	456	410	506	448	403	498
Greece	275	235	207	265	225	199	254
Hong Kong	110	962	848	1087	934	824	1055
Ireland	724	1420	1279	1572	1263	1137	1398
Italy	279	385	343	430			
Japan	368	558	500	622			
Netherlands	296	1138	1033	1250	1055	958	1159
New Zealand	586	1171	1049	1303	1055	901	1119
N. Ireland	615	1188	1067	1319	903	811	1002
Norway	280	1075	979	1178	1272	1158	1394
Portugal	153	240	215	267			
Scotland	1032	1978	1774	2199			
Spain	168	129	114	146	132	116	149
Sweden	332	721	647	801			
Switzerland	246	564	509	624	644	581	712
USA	770	1756	1563	1967	1750	1557	1959

Table 11 Lung cancer rate 40+, peak year, predicted by different methods based on A-P-C model – MALES

	b	b (lower)	b (upper)	c	c (lower)	c (upper)
Australia	83	83	93			
Austria	73,c	73	73,c			
Belgium	c	83	c			
Canada	c	98	c			
Denmark	98	83	c	c	93	c
England & Wales	73	73	73			
Finland	78	78	78			
France	c	c	c	c	c	c
Germany W.	c	83	c	c	83	c
Greece	c	c	c			
Hong Kong	83	83	88			
Ireland	93	88	98			
Italy	c	c	c			
Japan	c	c	c	c	c	c
Netherlands	83	83	88	83	83	88
New Zealand	78	78	78,88			
N. Ireland	83	83	88	83	83	88
Norway	c	c	c	c	c	c
Portugal	c	c	c			
Scotland	78	78	78			
Spain	c	c	c	c	c	c
Sweden	78	78	78,c	78	78	78
Switzerland	83	83	93			
USA	93	88	98			

c indicates continuing rise at 2003
In countries showing a double peak, the higher is underlined

Table 11 (cont.) Lung cancer rate 40+, peak year, predicted by different methods based on A-P-C model – FEMALES

	b	b (lower)	b (upper)	c	c (lower)	c (upper)
Australia	c	c	c			
Austria	c	c	c	c	c	c
Belgium	c	c	c	c	c	c
Canada	c	c	c			
Denmark	c	c	c	c	c	c
England & Wales	98	98	c			
Finland	c	c	c	98	98	c
France	c	c	c	c	c	c
Germany W.	c	c	c	c	c	c
Greece	83	83	88	83	83	88
Hong Kong	88	83	93	88	83	93
Ireland	c	c	c	c	c	c
Italy	c	c	c			
Japan	c	c	c			
Netherlands	c	c	c			
New Zealand	c	c	c	c	c	c
N. Ireland	c	c	c	c	98	c
Norway	c	c	c	c	c	c
Portugal	c	c	c			
Scotland	c	c	c			
Spain	78	78	78	78	78	78
Sweden	c	c	c			
Switzerland	c	c	c	c	c	c
USA	c	c	c	c	c	c

c indicates continuing rise at 2003
In countries showing a double peak, the higher is underlined

Appendix A Estimation of missing data at age 75+

Date for both mortality and population at age 75+ were available broken down into 75-79 and 85+, with the exception of Denmark 1951 mortality and Hong Kong 1972-77 population.

The data for Denmark were estimated according to the proportion of deaths in 1952-55.

The available population data for Hong Kong for 1966-86 are shown in Table A1. It can be seen that there has been a very substantial overall increase during this period. A gradual shift towards the older age groups would be expected, but this does not seem to have occurred for males, and for females, although there was a general trend, there was little difference between 1971 and 1978. The missing data was therefore estimated using average proportion based on 10 years data 1967-71 and 1978-82.

However, it does raise a note of caution. Looking at Table A2, the age x period data on which analyses have been based, and following each cohort (down and to the right), numbers do not decrease as would be expected. This implies either that immigration has had a substantial influence, or that the accuracy of the population figures is doubtful. Both these matters are beyond the scope of this report, but both influence the fundamental assumptions of a cohort analysis.

Table A1 Hong Kong population, age 75+ 1966-86, MALE

	numbers (hundreds)				Percentage		
	75-79	80-84	85+	Total	75-84	80-84	85+
1966	65	23	15	103	63	22	15
1967	68	26	15	109	62	24	14
1968	69	29	16	114	61	25	14
1969	69	33	16	118	58	28	14
1970	71	36	17	124	57	29	14
1971	76	39	18	133	57	29	14
1972				143			
1973				157			
1974				173			
1975				196			
1976				196			
1977				213			
1978	144	60	28	232	62	28	12
1979	153	66	40	249	61	27	12
1980	163	71	36	270	60	26	13
1981	193	82	36	311	62	26	11
1982	212	89	42	343	62	26	12
1983	233	98	49	380	61	26	13
1984	256	106	57	419	61	25	14
1985	280	119	64	463	60	26	14
1986	269	118	49	436	62	27	11

Table A1 (cont.) Hong Kong population, age 75+ 1966-86, FEMALE

	numbers (hundreds)				Percentage		
	75-79	80-84	85+	Total	75-84	80-84	85+
1966	160	69	42	271	59	25	15
1967	170	77	44	291	58	26	15
1968	180	85	46	311	58	27	15
1969	190	95	49	334	57	28	15
1970	201	105	53	359	56	29	15
1971	215	114	60	389	55	29	15
1972				413			
1973				451			
1974				489			
1975				526			
1976				522			
1977				563			
1978	333	170	105	608	55	28	17
1979	357	184	114	655	55	28	17
1980	376	197	124	697	54	28	18
1981	369	214	128	711	52	30	18
1982	389	227	142	758	51	30	19
1983	413	239	157	809	51	30	19
1984	437	254	175	866	50	29	20
1985	416	270	195	926	50	29	21
1986	436	284	186	906	48	31	21