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Going up or coming down? The changing phases of the lung cancer epidemic from 1967 to 1999 in the 15 European Union countries

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Abstract

Lung cancer, the most common cause of cancer death in the European Union (EU), continues to have an enormous impact on the health experience of the men and women living in the constituent countries. Information on the course of the lung cancer epidemic is essential in order to formulate an effective cancer control policy. This paper examines recent trends in lung cancer mortality rates in men and women in each of the 15 countries, comparing cross-sectional rates of death in younger (aged 30–64 years) and older populations (aged 65 years or over), and the age, period of death, and birth cohort influences in the younger age group. The latter analysis establishes the importance of year of birth, related to modifications in the tobacco habit among recently born generations. The stage of evolution of the lung cancer epidemic varies markedly by sex and country in terms of the direction, magnitude, and phase of development of national trends. In males, there is some consistency in the direction of the trends between EU countries, declines are apparent in most countries, at least in younger men, with rates in older men either reaching a plateau, or also falling. In younger persons, a decreasing risk of lung cancer death reflects changes in successive birth cohorts, due to modifications in the smoking habit from generation to generation, although these developments are in very different phases across countries. Portugal is the exception to the male trends; there are increases in mortality in both age groups, with little sign of a slowing down by birth cohort. In women, there are unambiguous upsurges in rates seen in younger and older women in almost all EU countries in recent decades, and little sign that the epidemic has or will soon reach a peak. The exceptions are the United Kingdom (UK) and Ireland, where lung cancer death rates are now declining in younger women and stabilising in older women, reflecting a declining risk in women born since about 1950. It is too early to say whether the observed plateau or decline in rates in women born very recently in several countries is real or random. To ascertain whether recent trends in lung cancer mortality will continue, trends in cigarette consumption should also be evaluated. Where data are available by country, the proportion of adult male smokers has, by and large, fallen steadily in the last five decades. In women, recent smoking trends are downwards in Belgium, Denmark, Sweden and the Netherlands, although in Austria and Spain, large increases in smoking prevalence amongst adults are emerging. Unambiguous public health messages must be effectively conveyed to the inhabitants of the EU if the lung cancer epidemic is to be controlled. It is imperative that antitobacco strategies urgently target women living in the EU, in order to halt their rapidly increasing risk of lung cancer, and prevent unnecessary, premature deaths among future generations of women.

Keywords: Lung neoplasms; Mortality; Epidemiology; European Union; Smoking; Time trends; Registries; Data collection; Public health

1. Introduction

Lung cancer is the most common cause of death from cancer in the European Union (EU). Over 180 000 deaths were estimated in 1997 [1], representing nearly one-third of the total cancer mortality experienced in the 15 constituent countries. Over three-quarters of these deaths were in men. Tobacco smoking has long been established as the principal cause of lung cancer [2–5], and in 1995, was estimated to account for 90% of lung cancer deaths among men, and around 60% in women, although a great deal of variation was present between countries [6].

The lung cancer epidemic continues to have an enormous impact on the health experience of the men and women living in the EU countries. The public health resources required to meet these needs are correspondingly large. Information on the evolution of the lung

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cancer epidemic is therefore essential to formulate effective cancer control policies. Previous studies have revealed the divergent trends in lung cancer mortality rates across EU countries [7–9]. The variation is related primarily to the prevalence and intensity of cigarette smoking in different countries, the main form of tobacco consumed in the EU.

This paper describes the key characteristics of the current lung cancer epidemic in each of the 15 countries in the EU, using an analysis of time trends in national mortality between 1967 and 1999. The independent effects of age, period of death and generation of birth (cohort) on the evolution of trends are evaluated in men and women aged between 30 and 64 years at the time of death. The emphasis on the evolution of death rates in younger populations highlights the change in risk between recent generations, related to changes in tobacco consumption patterns. As Muir and colleagues [10] rationalise, such trends are "uncomplicated by the effect of changes in the prevalence of carcinogenic agents in the distant past, which may have a major effect on the trends in the old". This overview provides an indication of the overall effectiveness of national and regional prevention strategies within the EU. On the basis of these and recent trends in the prevalence of smoking, the potential future development of the disease burden in the EU is discussed.

2. Patients and methods

2.1. Sources of data/methods

2.1.1. Data sources

Mortality from malignant neoplasms of the trachea, bronchus and lung were extracted from the World Health Organization (WHO) Mortality Databank for each EU country, by 5-year age group and sex, using the rubric 162 according to the ICD-8 and ICD-9 revisions. Data were available covering a 30-year span for the following countries: Austria (1970–1999), Denmark (1967–1996), Finland (1969–1998), France (1968–1997), Greece (1969–1998), Ireland (1968–1997), Italy (1968–1997), The Netherlands (1968–1997), Spain (1968–1997), Sweden (1967–1996), and the United Kingdom (UK) (1969–1998). Data were available for 25 years for Belgium (1971–1995), Luxembourg (1973–1997) and Portugal (1974–1998). In Germany, data covering the re-unified country were available for 15 years (1984–1998). Corresponding population data, by age, sex and year, were also extracted.

In order to fit age period cohort models, the data were grouped into periods of 5 years and approximate overlapping 10-year synthetic cohorts derived by subtracting the midpoint of the 5-year age group from the midpoint of the period. The age range was restricted to persons dying of lung cancer aged 30–64 years. Twelve overlapping birth cohorts could be computed for the 11 countries with six 5-year periods and for the seven age groups, e.g. for Austria, the mortality data from 1970 through 1999 were collapsed into six 5-year periods (1970–1974, 1975–1979, .., 1995–1999) for seven age-groups (30–34 years, 35–39 years, .., 60–64 years), to obtain 12 approximate birth cohorts centred on 1910, 1915, .., up to 1965. In the same way, 11 cohorts could be derived for the three countries with five periods. In Germany, with national data covering three 5-year periods, nine birth cohorts were attained.

2.1.2. Trends in age-adjusted rates by year of diagnosis

To quantify the recent direction of temporal trends in younger (persons aged 30–64 years) and older populations (persons aged 65 years or over) over time, truncated age-standardised rates were calculated for each age group respectively, by sex and country, using the weights of the European Standard Population [11]. The estimated annual mean percentage change in rates over time was calculated for those population trends exhibiting linearity on a log scale, by fitting linear regression models to the log of adjusted rate, with time as a covariate. 95% Confidence Intervals (95% CI) are provided for each estimate.

2.1.3. Age period cohort modelling

The age period cohort statistical model provides a quantitative and comparable method of estimating trends over time using a set of objective criteria to choose the best description of the data [12]. Statistical tests provide evidence as to whether trends are real or random, and allow a formal statistical examination of the importance of secular changes in risk (*period* effects, affecting age groups equally) and changes in risk from generation to generation (birth *cohort* effects, affecting age groups unequally). Unfortunately, the model suffers from the well-known problem of identifiability [13–15]. Thus, for A age groups, if we denote a_i as the age effect in age group i, p_j the effect of jth period and c_k the birth cohort effect then age, period and cohort effects are linearly dependant on one another as $k = A - i - j$.

Some of the methods that have been described to cope with the non-identifiability problem require arbitrary model constraints or further assumptions, often not supported by the data in question. The approach by Clayton and Schifflers [13,14], while relatively conservative, avoids the over-interpretation of trends over time [16], and has been adopted for this analysis. Using their method, one can only determine the *non-linear* effects of period and cohort, whilst the linear effect, denoted *drift*, is an estimate of the rate of change of the regular trend attributable to either period or cohort effects, or both. The individual effects of linear period or cohort cannot be unscrambled.

For each combination of country and sex, the following hierarchy of models [13,14] was fitted to the lung cancer mortality rates: (1) Age; (2) Age + (Period and Cohort) Drift; (3a) Age + Drift + non-linear Period; (3b) Age + Drift + non-linear Cohort; (4) Age + Drift + non-linear Period + non-linear Cohort. The relative contribution of each effect to the model was determined by comparing the change in the deviance and degrees of freedom in two sequentially fitted models with the appropriate chi-squared statistic. Hence, a comparison of model (2) with (1) provides a test for drift against the model of no temporal trend (model (1)), a comparison of model (3a) versus (2), and model (3b) versus (2) tests for the effects of non-linear period and non-linear cohort, respectively. Comparing model (4) versus (3a) tests for the effects of non-linear cohort effects, adjusting for drift and non-linear period. Finally, the comparison of model (4) versus (3b) tests the effects of non-linear period, adjusting for drift and non-linear cohort. The simplest model was considered to adequately describe the observed data if the model did not suffer from a significant lack of fit, and the inclusion of an additional term was not statistically significant at the 5% level. The following rules were adopted for presenting the results, on the basis of the final model:

(i) no model fitted the data: no model results described—only the observed rates plotted by period and cohort;
(ii) model (1) best fit: plot of observed and fitted rates by period and cohort;
(iii) model (2) best fit: plot of observed and fitted rates by period and cohort;
(iv) model (3a) best fit: plot of observed and fitted rates by period and cohort, plot of estimated period parameters (including drift), with 95% CIs;
(v) model (3b) best fit: plot of observed and fitted rates by period and cohort, plot of estimated cohort parameters (including drift), with 95% CIs;
(vi) model (4) best fit: plot of observed and fitted rates by period and cohort, plots of the 'second differences' of period and cohort parameters, respectively, with 95% CIs. Further information on interpreting this re-parameterisation is given below.

2.1.4. Second differences

A unique set of parameters can be obtained from the infinite number of maximum likelihood estimates of age, period and cohort by utilising the fact that on an antilogarithmic scale, non-drift effects can be expressed as relative risks between adjacent periods or cohorts [14]. These *second order* effects (as opposed to *first order* effects which measure the *magnitude* of the slope) identify *changes* in the magnitude of trends between two consecutive periods or cohorts. Sharp period or cohort-specific increases or decreases should be considered most important, with values greater than one representing accelerations in trend (concave curvature), and values less than one equivalent decelerations (convex curvature). Values close to unity are indicative of regular linear increases. 95% CIs for the second differences were obtained directly from the standard errors of the age period cohort model on transforming the design matrix to incorporate these measures of curvature. Graphs of the second differences are presented together with those of the observed and fitted rates to indicate local departures from linearity. They also serve to indicate the precision of the model parameters, and in particular, the considerable caution required in interpreting these estimates of trend, particularly those representing the younger cohorts.

3. Results

In the text that follows the terms 'younger' and 'under 65 years' are used as synonyms for persons aged from 30 to 64 years; and 'older', for persons aged 65 years or above.

3.1. Cross-sectional trends in age-truncated rates

Fig. 1 shows the truncated (30–64 years, 65+ years) age-standardised rates in men and women in each country between 1971 and 1999. The evolution of the epidemic of lung cancer differs markedly by country, sex and age group. In males, there is some consistency between countries, with declines apparent in most countries, at least in younger men, while rates in older men are either reaching a plateau, or starting to decline. The phase of this development is more variable however. In the UK, for example, lung cancer mortality trends in males have been decreasing for several decades in both age groups. In contrast, rates in older men living in France and Spain are not as yet on the decline, but are flattening out, while in younger men, some very recent declines are now apparent. Portugal is an exception to this pattern: rates in older men show no sign of abating, whilst in younger men no levelling off of the rates is apparent.

In women, there is an unambiguous upsurge in rates in both younger and older women in almost all countries in recent decades, and little sign that the epidemic has, or will soon, peak. The UK and Ireland are exceptions, where lung cancer death rates are now beginning to fall in younger women, and have reached a plateau in women aged 65 years and over.

Table 1 shows the ASRs and the corresponding ranking of countries in each of the last three decades.

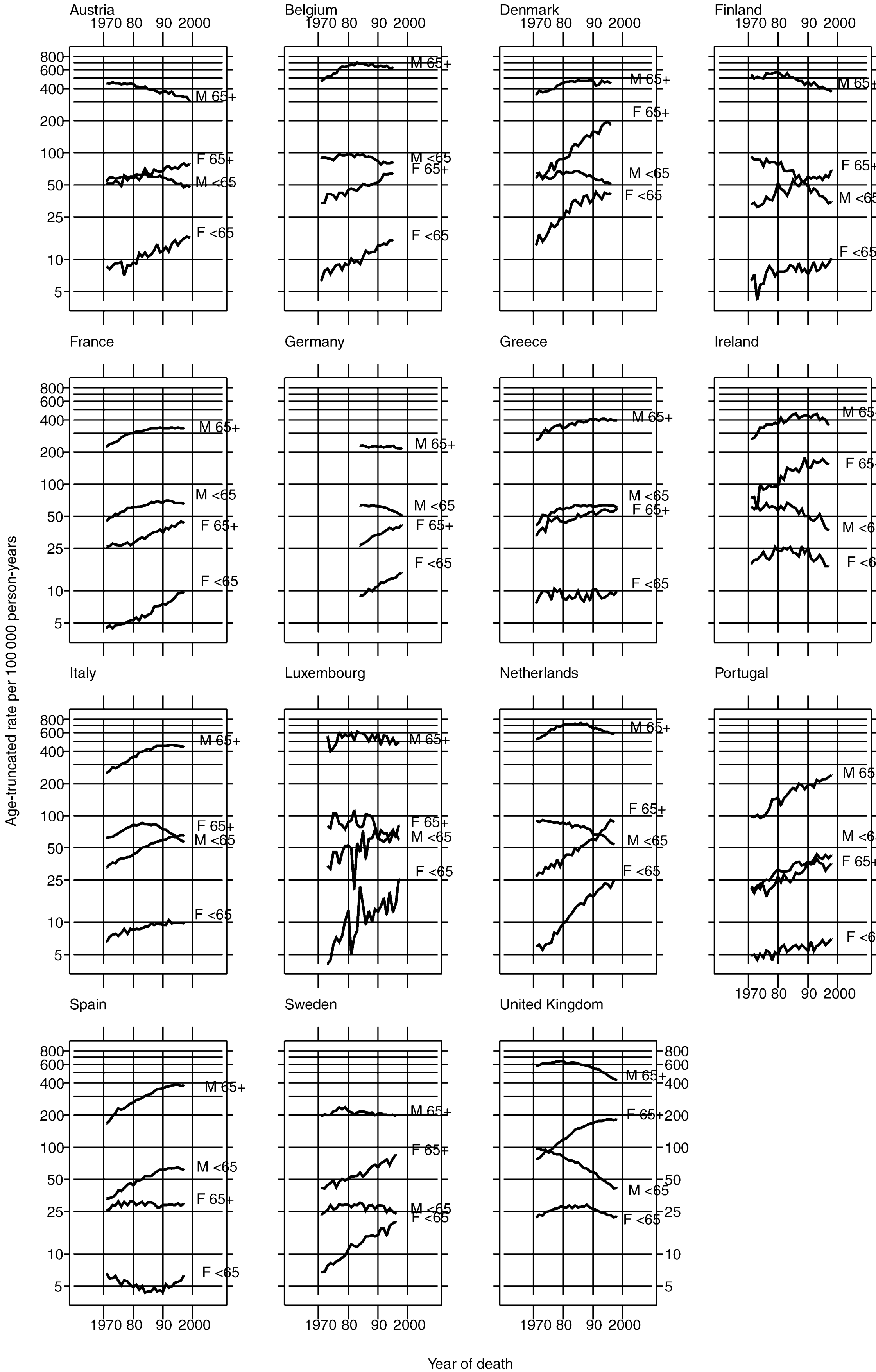

Fig. 1. Truncated (30–64 years, 65+ years) age-standardised rates in men and women by country and sex 1971–1999. M, males; F, females.

Table 1
ASR[a] (ranking) of lung cancer mortality in men and women in EU Member States in 1975, 1985 and 1995, sorted by relative ranking in 1975

Males				Females			
	1975	1985	1995		1975	1985	1995
United Kingdom	108.7 (1)	100.4 (4)	73.3 (6)	United Kingdom	21.6 (1)	28.9 (1)	30.7 (2)
Netherlands	107.6 (2)	116.7 (2)	94.3 (2)	Ireland	20.5 (2)	25.2 (3)	27.9 (3)
Belgium	100.1 (3)	119.8 (1)	106.2 (1)	Denmark	15.8 (3)	28.3 (2)	40.4 (1)
Luxembourg	95.9 (4)	101.5 (3)	89.3 (3)	Austria	10.0 (4)	11.9 (5)	14.1 (6)
Finland	89.2 (5)	87.4 (5)	63.3 (11)	Greece	9.7 (5)	10.4 (9)	10.5 (10)
Austria	75.9 (6)	71.4 (10)	60.7 (12)	Sweden	9.0 (6)	11.9 (6)	17.6 (5)
Denmark	68.0 (7)	83.6 (7)	75.3 (5)	Belgium	8.4 (7)	10.4 (8)	14.0 (7)
Ireland	65.0 (8)	77.4 (8)	66.9 (10)	Luxembourg	7.8 (8)	10.0 (4)	11.7 (8)
Italy	63.2 (9)	85.2 (6)	77.7 (4)	Italy	7.8 (9)	14.6 (11)	13.8 (9)
Greece	57.1 (10)	72.3 (9)	72.6 (7)	Netherlands	6.4 (10)	11.8 (7)	19.6 (4)
France	52.2 (11)	65.5 (11)	68.1 (9)	Finland	6.4 (11)	10.1 (10)	10.3 (11)
Spain	43.6 (12)	58.9 (12)	72.4 (8)	Spain	6.0 (12)	5.5 (15)	5.8 (15)
Sweden	35.8 (13)	37.2 (14)	33.6 (15)	France	5.2 (13)	6.4 (13)	9.0 (13)
Portugal	22.0 (14)	36.1 (15)	42.2 (14)	Portugal	4.8 (14)	5.7 (14)	7.1 (14)
Germany	–	54.9 (13)	51.1 (13)	Germany	–	7.2 (12)	10.1 (12)

EU, European Union.
[a] ASR, Age-Standardised Rate using European standard Population [11].

The shifting time trends have had some impact on the ranking of lung cancer mortality between countries. It has been a persistent source of premature loss of life in men living in the Benelux countries over the last 30 years: the three component countries still have the highest rates in the EU. The time trends in these countries are in similar phases of development, with the very high mortality rates beginning to diminish (Fig. 1). Marked decreases in the relative burden of lung cancer death are seen in Austria, Finland, Ireland and the UK, the latter of which had the highest mortality rate in 1975, but by 1995, ranked only sixth. The ranking in Denmark, France, Greece, Italy and Spain has increased over the 30-year period, while in Germany, Sweden and Portugal, rates have been consistently low relative to the other countries (Table 1).

In women, there are less dramatic changes in ranking over time, perhaps because the baseline risk is low in the EU, while the corresponding time trends indicate steady rises throughout the 30-year period (Table 1). Mortality rates are very high in the UK and Ireland, but their relative contribution in the EU is declining somewhat. Similarly, diminishing shifts in rank are seen in Austria and Greece. In contrast, Denmark now has the highest female rate in the EU, and the relative importance of lung cancer deaths in The Netherlands has also increased rapidly in the last decades.

3.2. Cross-sectional and cohort-specific trends in age-specific rates

Table 2 shows the optimal age period cohort model selected for males and females in each country. Cohort effects, related to modifications of the smoking characteristics of different generations, are particularly relevant to the study of temporal trends in the disease; however period effects are also required to explain the variation in many of the populations. The latter results from changes in risk that affect all age groups, perhaps the outcome of national anti-smoking campaigns, or the changing levels of tar in cigarettes [17]. Figs. 2–16 present the observed rates, and, where applicable, the fitted period and cohort effects and parameters, according to the final model adopted for each population. The figures, including plots of the second differences, are available on the CaMon (Comprehensive Cancer Monitoring in Europe) website at http://www-dep.iarc.fr/hmp/tt/figures2_16.pdf.

3.3. Austria

Lung cancer mortality in older men has been declining since 1980 (Fig. 1) at a rate of 1.5% per year (95% CI: −1.6%, −1.4%). In younger men, the fall occurred about a decade later, the average yearly decline estimated at about −2.4% (95% CI: −2.6%, −2.2%). Age, period and cohort influences are important (Table 2), and the combination of these effects can be seen in the age-specific curves in Fig. 2a. The cohort effect shows as successive declines in rates in generations born since about 1945.

In women, rates are moderately high relative to other countries, ranking sixth in 1995 (Table 1), and have been rising in the last decades (Fig. 1). The increase in younger women (2.6% per year (95% CI: 2.5%, 2.8%) in 1971–1999) is greater than in older women (1.5% per annum (95% CI: 1.4%, 1.6%)), respectively. As for men, the relative importance of period and cohort effects is difficult to determine (Table 2); the general pattern is of consecutive increases in the risk of death

Table 2
'Goodness-of-fit' statistics of adopted model on fitting age period and cohort effects to trends in men and women aged 30–64 years

Country	Period	Males				Females			
		Model[a]	D[b]	d.f.[c]	P[d]	Model[a]	D[b]	d.f.[c]	P[d]
Austria	1970–1999	APC	11.6	20	0.93	APC	28.7	20	0.09
Belgium	1971–1995	APC	15.0	15	0.45	AD	19.3	27	0.86
Denmark	1967–1996	APC	16.7	20	0.67	APC	17.9	20	0.60
Finland	1969–1998	AC	34.3	24	0.08	AC	24.1	24	0.45
France	1968–1997	APC	30.1	20	0.07	APC[e]	69.4	20	<0.001
Germany	1984–1998	APC	7.4	5	0.19	AC	7.0	6	0.32
Greece	1969–1998	APC	19.3	20	0.50	APC	29.4	20	0.08
Ireland	1968–1997	AC	30.7	24	0.16	AC	27.6	24	0.28
Italy	1968–1997	APC	19.6	20	0.48	APC[e]	38.6	20	<0.01
Luxembourg	1973–1997	AC	21.7	18	0.25	AD	35.1	27	0.14
Netherlands	1968–1997	APC	6.3	20	0.99	APC	28.7	20	0.09
Portugal	1974–1998	APC[e]	26.6	15	0.03	AD	26.1	27	0.51
Spain	1968–1997	APC[e]	43.5	20	<0.01	APC	29.4	20	0.08
Sweden	1967–1996	APC	15.0	20	0.77	AD	39.2	34	0.25
United Kingdom	1969–1998	APC	31.1	20	0.05	AC	27.3	24	0.30

[a] Adopted model based on goodness-of-fit tests: AD, Age + Drift model; AP, Age + Drift + (non-linear) period; AC, Age + Drift + (non-linear) cohort; APC, Age + Drift + (non-linear) period + (non-linear) cohort.
[b] Total deviance of adopted model.
[c] Degrees of freedom of adopted model.
[d] P value of adopted model based on formal test of $D_{d.f.} \sim \chi^2_{d.f.}$
[e] Models suffer from a significant lack of fit ($P<0.05$).

from lung cancer in women born since the mid-1930s. Mortality rates may have reached a plateau in cohorts born since the 1950s (Fig. 2b), although conclusions are difficult to draw for the youngest birth cohorts, in which few deaths occurred.

3.4. Belgium

Lung cancer death rates in Belgian males have been the highest in the EU for two decades (Table 1), although there have been decreases in mortality in both younger and older men since 1985 (Fig. 1). The mean percentage change during this period is around 2% (95% CI: −2.2%, −1.8%) per year in men under 65 years, and 0.8% (95% CI: −1.0%, −0.7%) per year in older men. Both period and cohort effects are required to achieve a good model fit (Table 2). Nevertheless, the age-specific trends in the under 65 year olds (Fig. 3a) indicate a strong cohort-led plateau phase in risk of death between 1935 and 1945 and, in men born thereafter, a consequent decline in lung cancer rates.

Mortality rates in women have been low relative to other countries, with the ASR ranking around 7th (Table 1). However, as for women in other countries, there has been a steady increase in mortality rates in both younger and older age groups (Fig. 1). Between 1971 and 1995, the increase was 3.3% annually (95% CI: 3.2%, 3.4%) in women under 65 years, and 2.5% (95% CI: 2.4%, 2.6%) in women 65 years or over. The age-drift model provides a reasonable description of the data (Table 2), indicating neither period nor cohort curvature is required to explain the fitted, strictly linear, time trend. The drift parameter specifies a linear increase of 17% (95% CI: 14.8%, 18.5%) in the rates for each five-year period between 1971 and 1995. Fig. 3b suggests that the risk of death from lung cancer in younger women is likely to continue to increase in the immediate future.

3.5. Denmark

Denmark had the fifth highest rate of mortality in men in 1995 (Table 1). After an increase in the 1970s, annual rates in older males have been relatively stable since 1980, the mean yearly change estimated at −0.2% (95% CI: −0.3%, −0.0%). In younger men, there was a peak in the risk of death around 1985 (Fig. 1), with a subsequent mean decrease of about 2.3% (95% CI: −2.4%, −2.2%) per year. The best-fitting model of the trends in younger men includes both non-linear period and cohort influences (Table 2), and inspection of the age-specific trends in Fig. 4a does not show an obvious period or cohort-effect underlying the trend, although there does appear to have been a marked period-specific decline since 1985.

Lung cancer mortality rates in Danish women are now the highest in the EU (Table 1). Mortality trends in women aged 65 years or over show a substantial increase in risk; rates have increased on average by 5.1% (95% CI: 4.9%, 5.4%) each year between 1971 and 1996 (Fig. 1). In contrast, there is a suggestion that rates in younger women will begin to plateau in the next

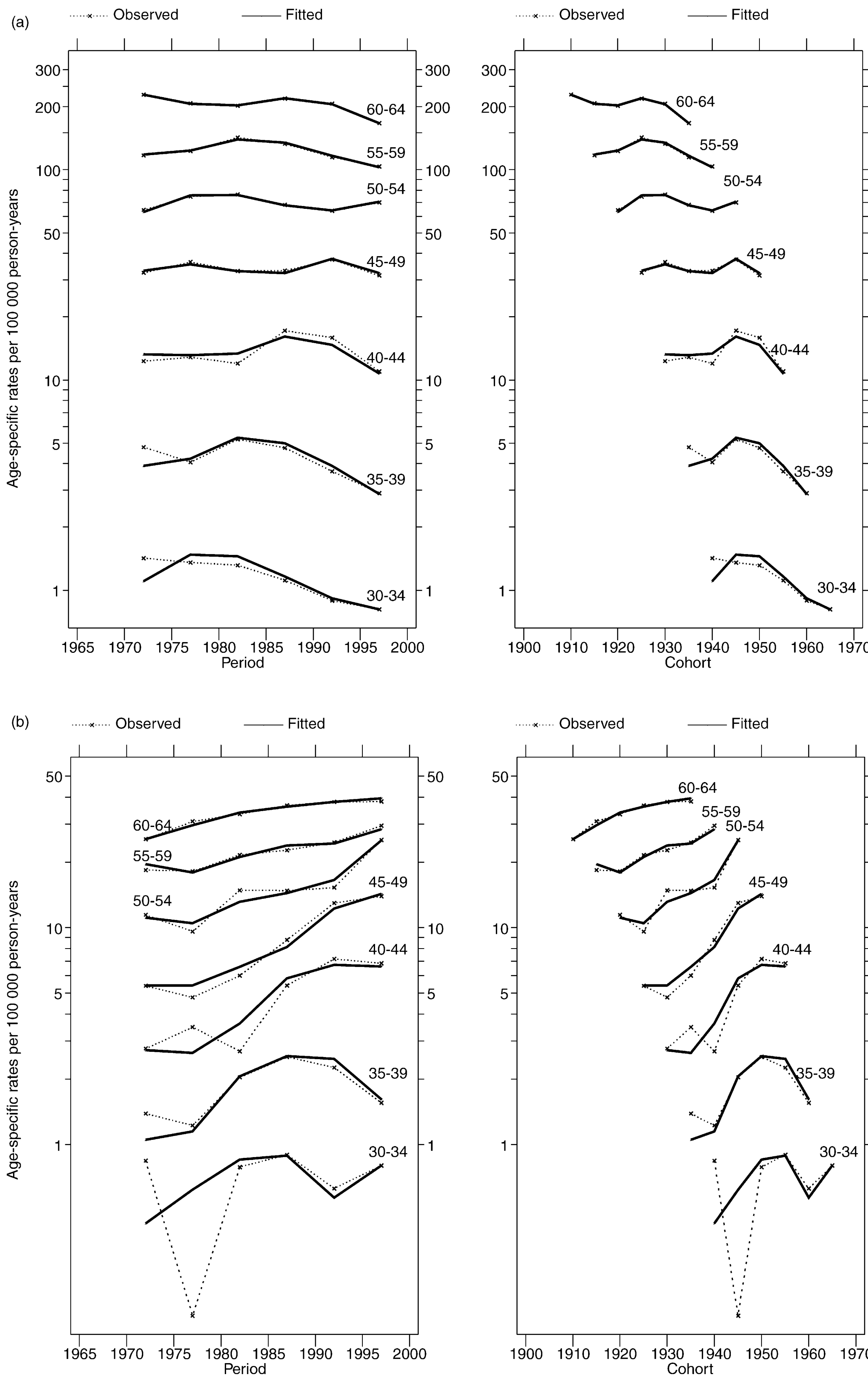

Fig. 2. Austria: (a) males—period and cohort trends; (b) females—period and cohort trends.

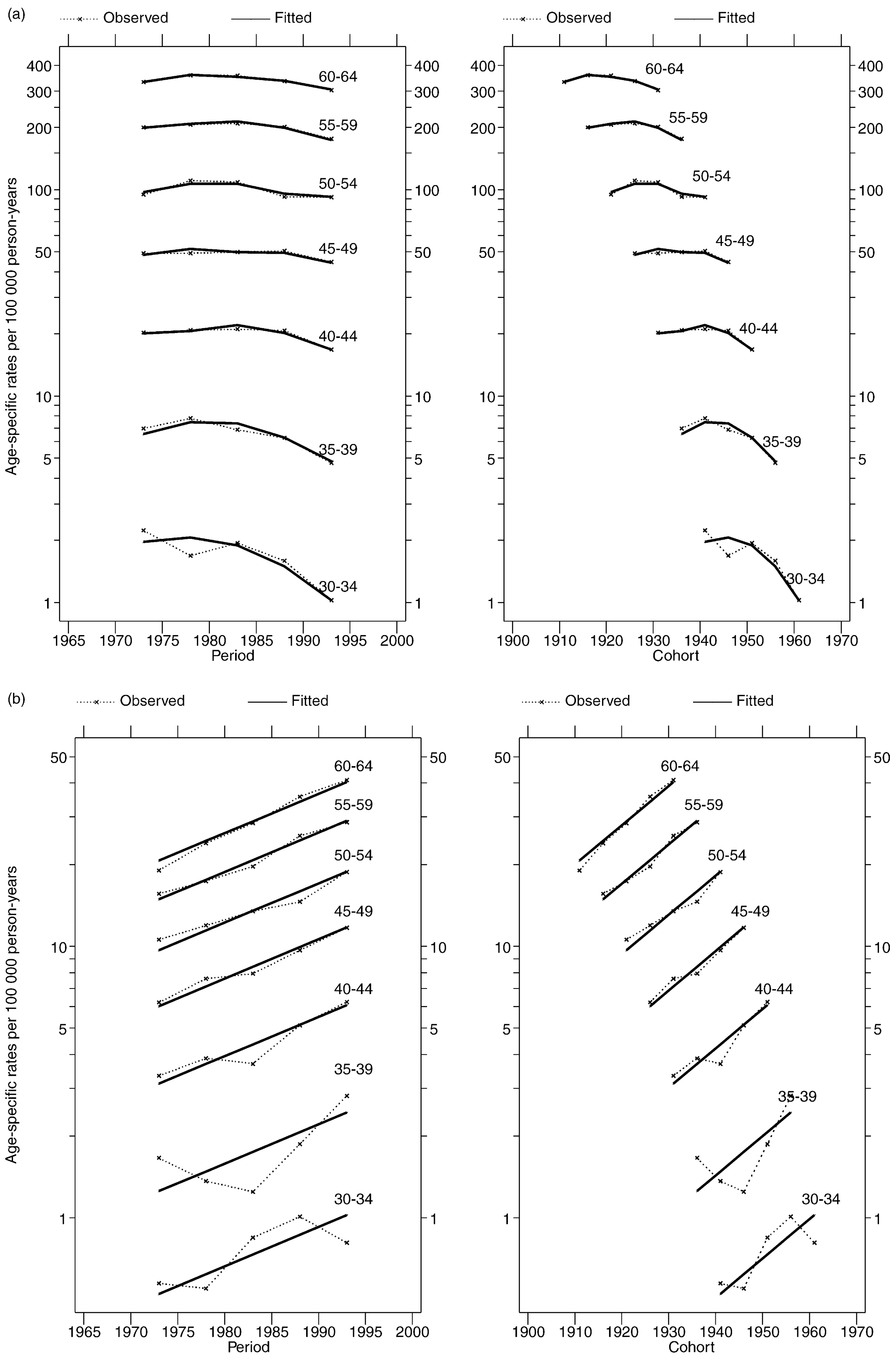

Fig. 3. Belgium: (a) males—period and cohort trends; (b) females—period and cohort trends.

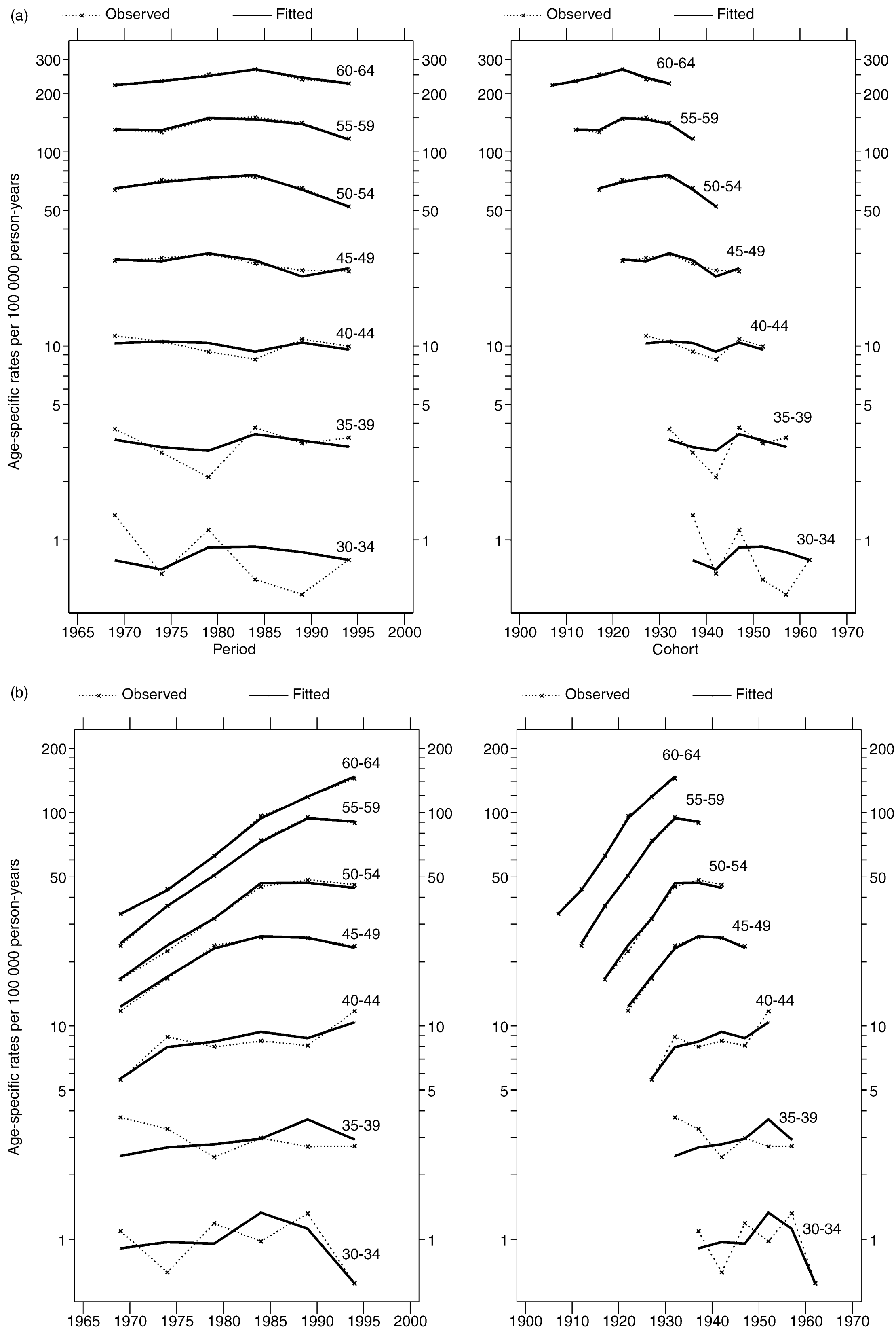

Fig. 4. Denmark: (a) males—period and cohort trends; (b) females—period and cohort trends.

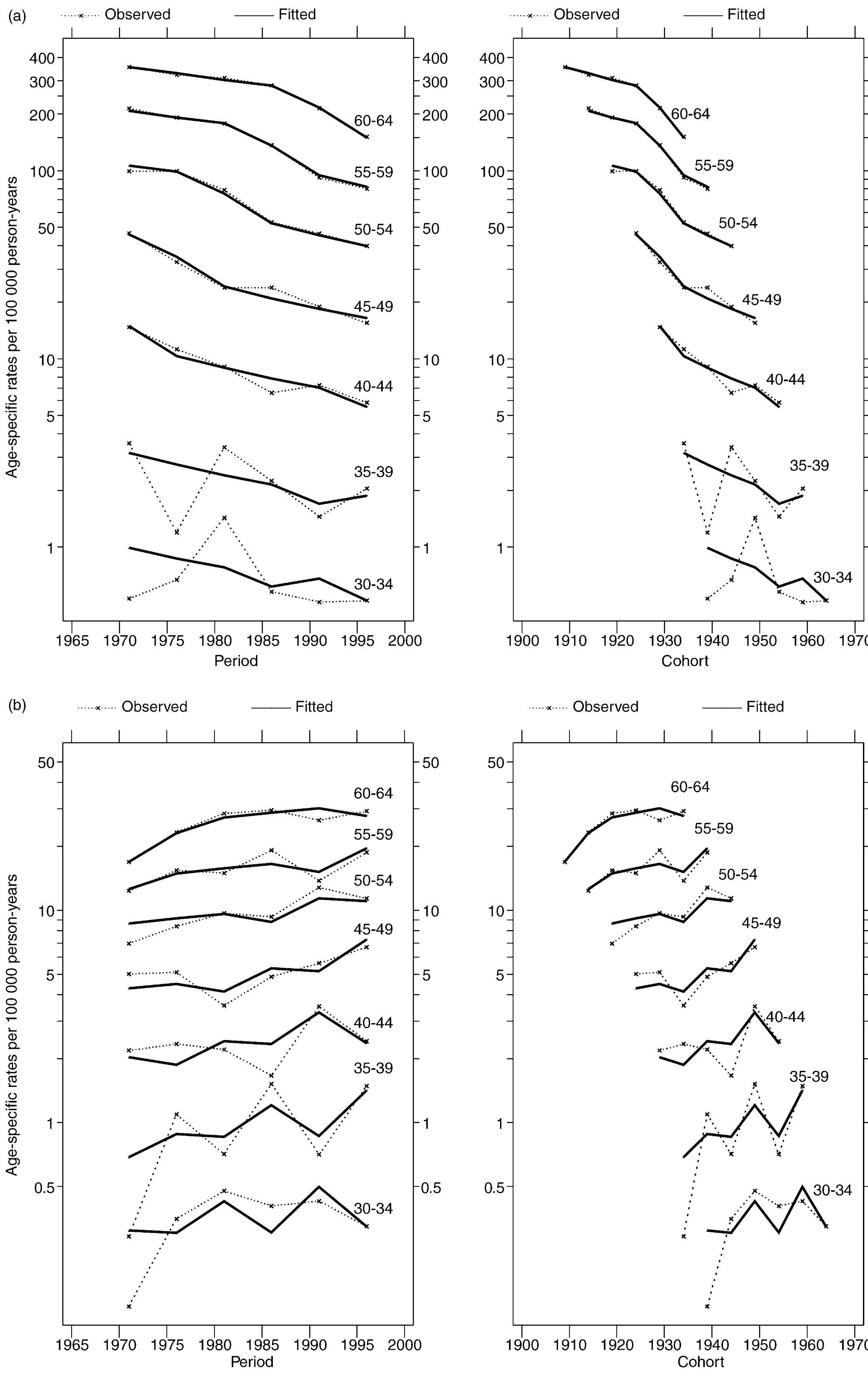

Fig. 5. Finland: (a) males—period and cohort trends; (b) females—period and cohort trends.

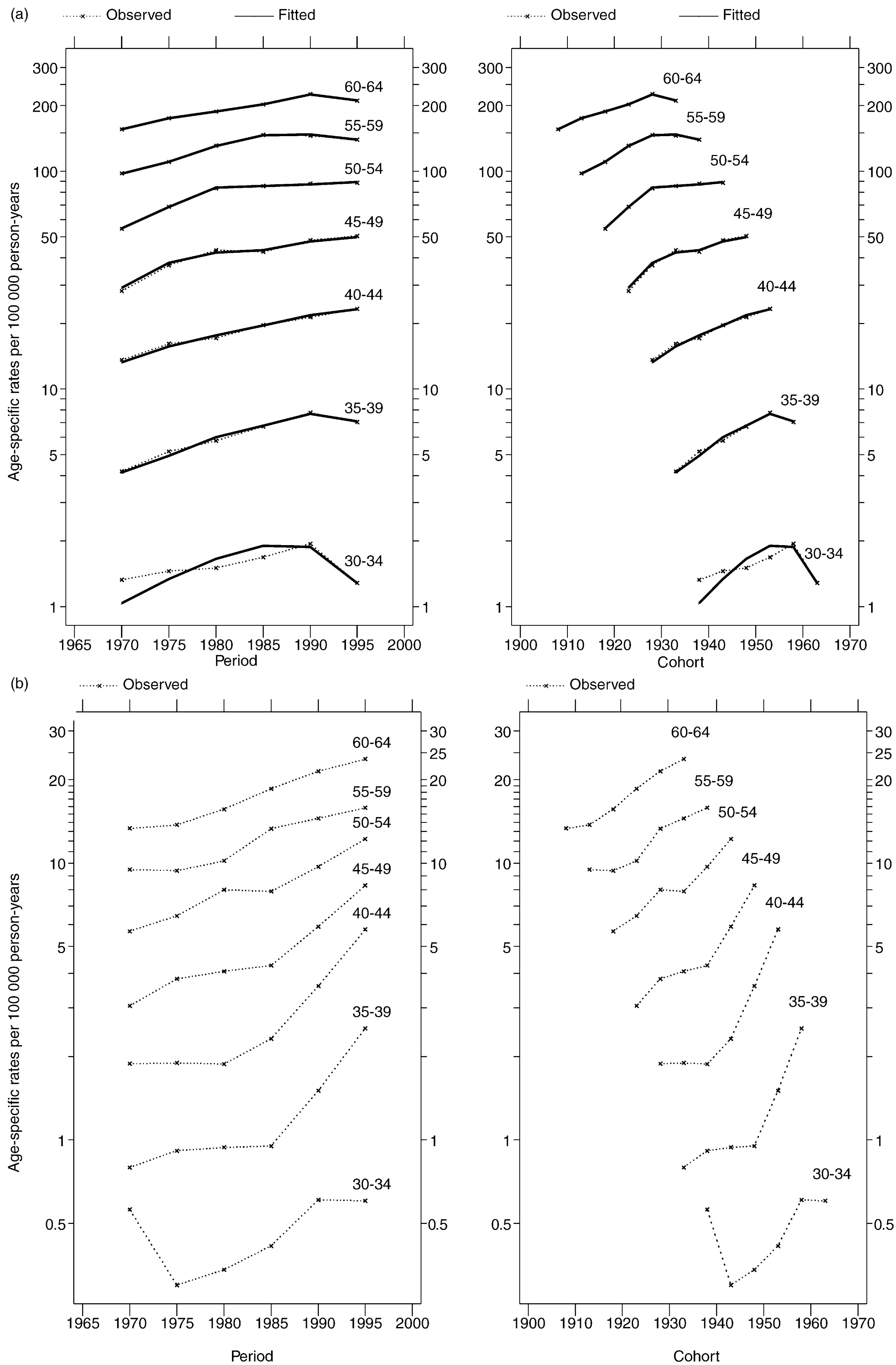

Fig. 6. France: (a) males—period and cohort trends; (b) females—period and cohort trends.

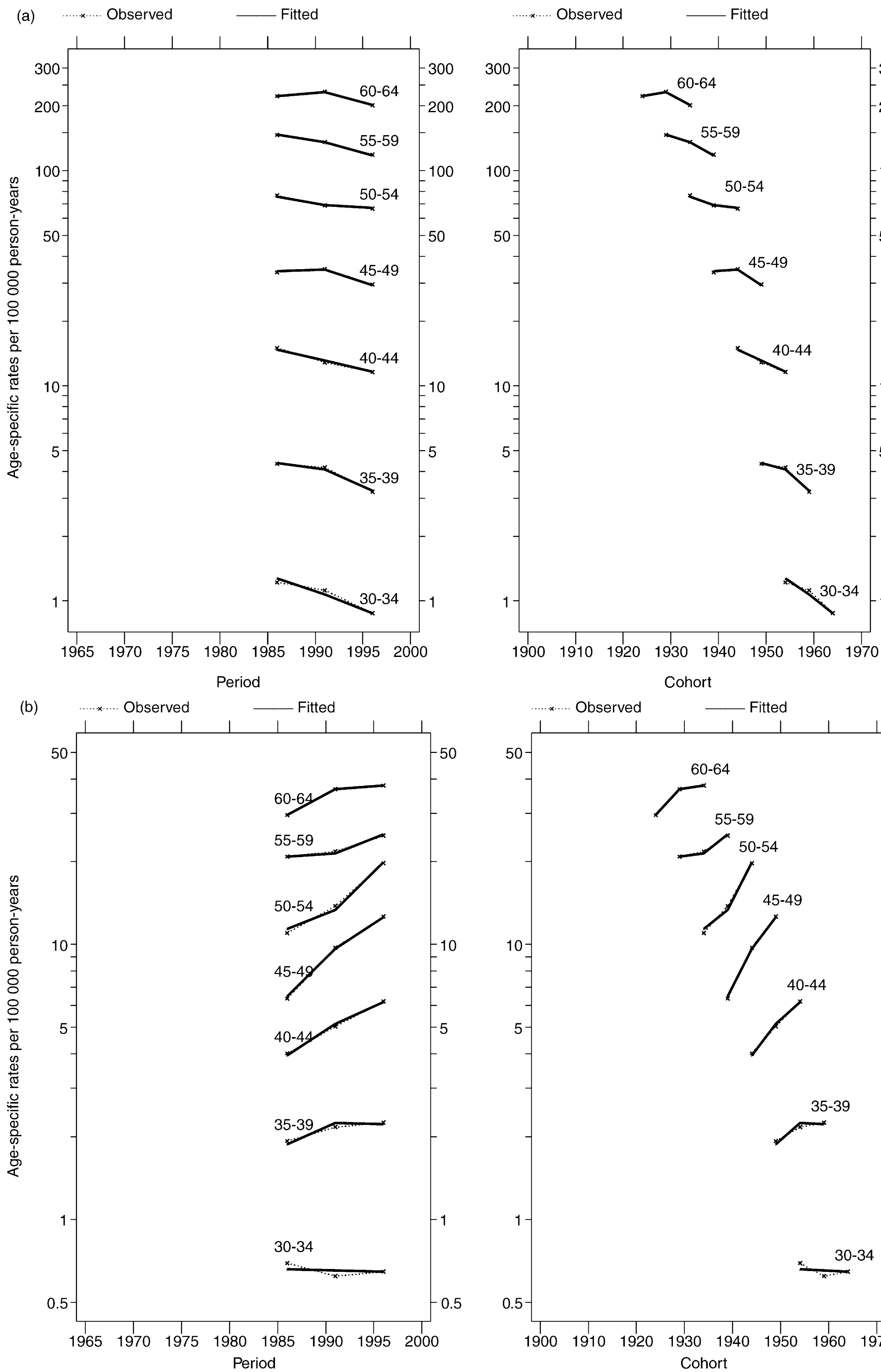

Fig. 7. Germany: (a) males—period and cohort trends; (b) females—period and cohort trends.

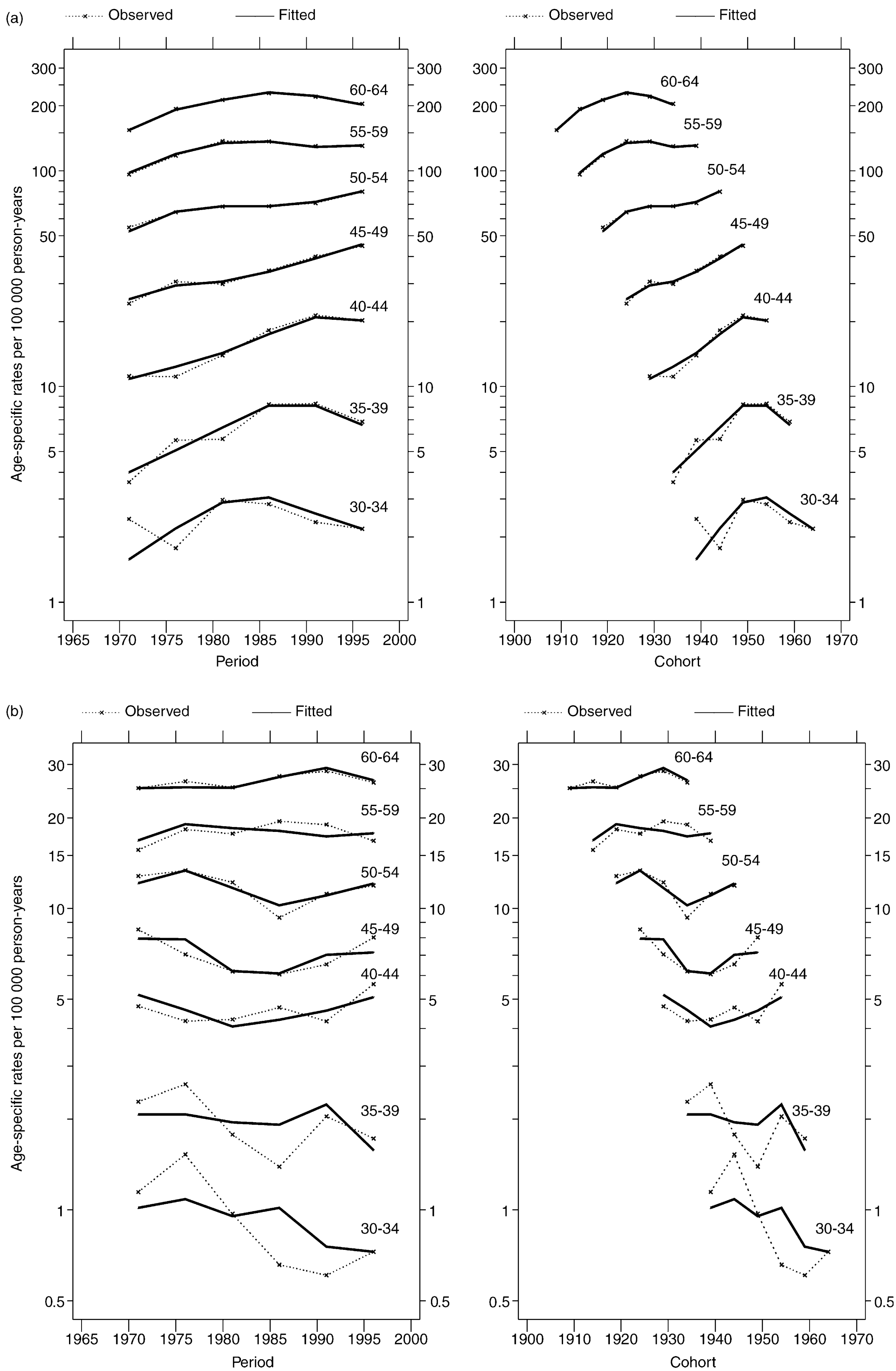

Fig. 8. Greece: (a) males—period and cohort trends; (b) females—period and cohort trends.

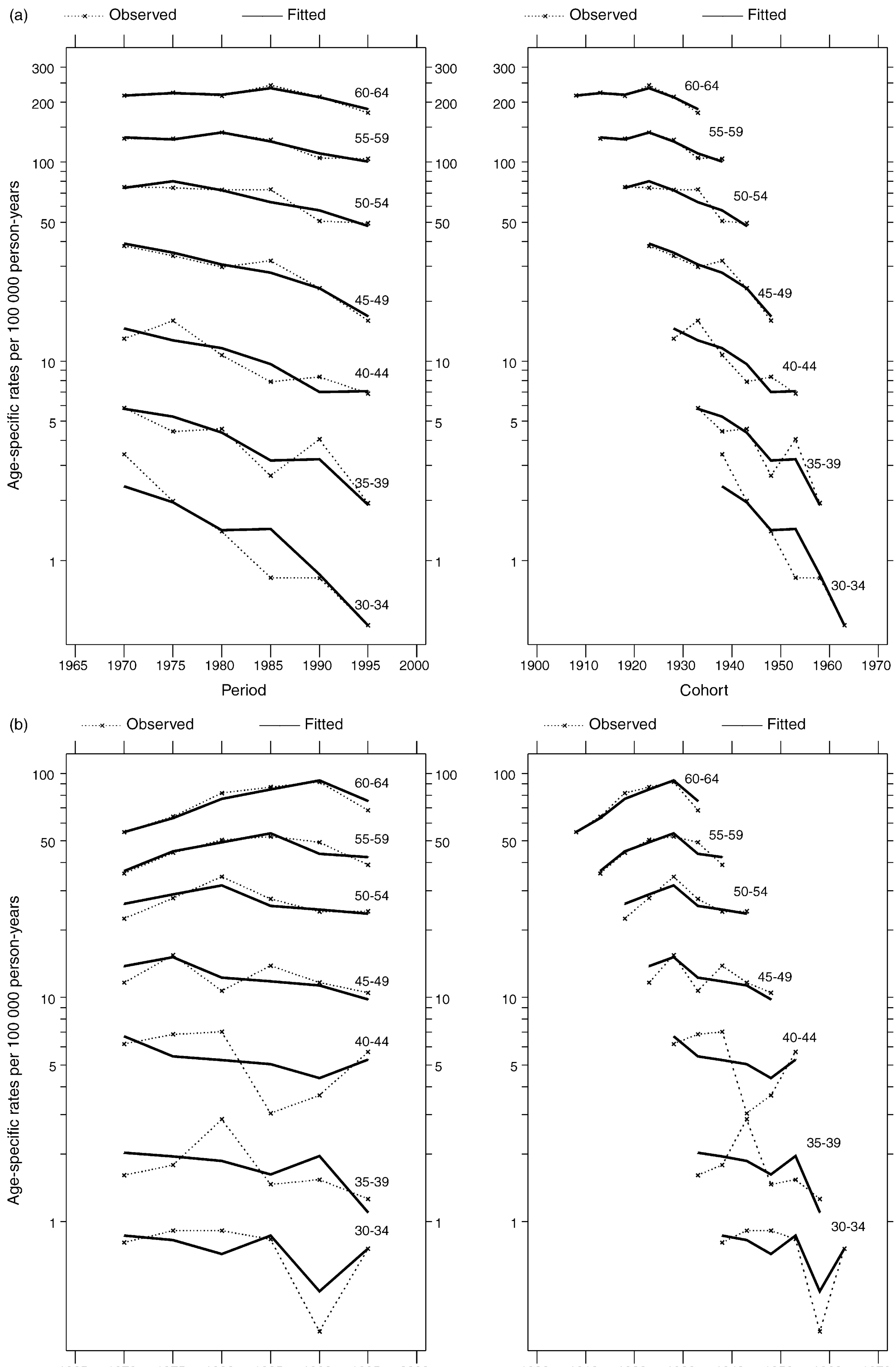

Fig. 9. Ireland: (a) males—period and cohort trends; (b) females—period and cohort trends.

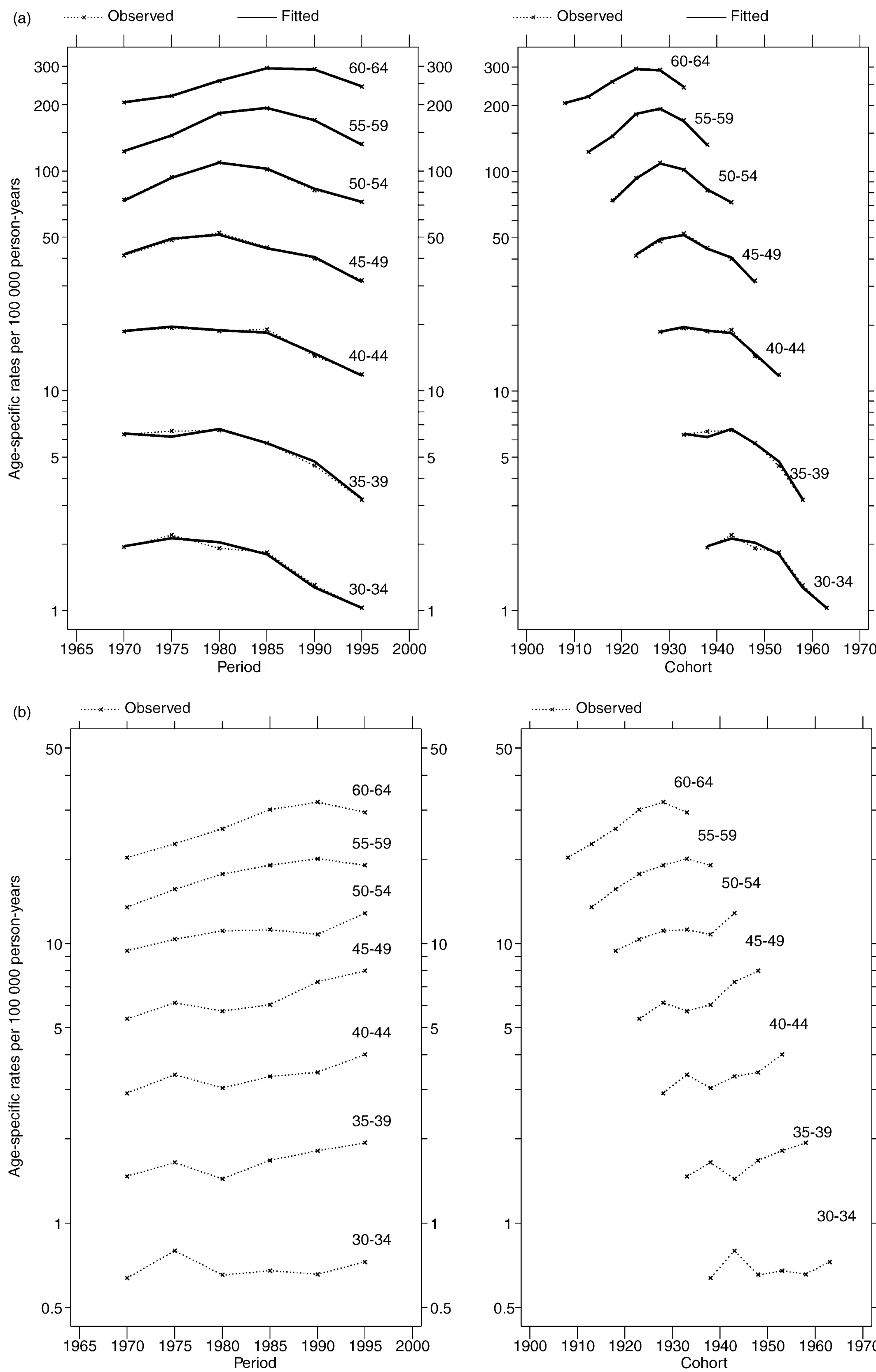

Fig. 10. Italy: (a) males—period and cohort trends; (b) females—period and cohort trends.

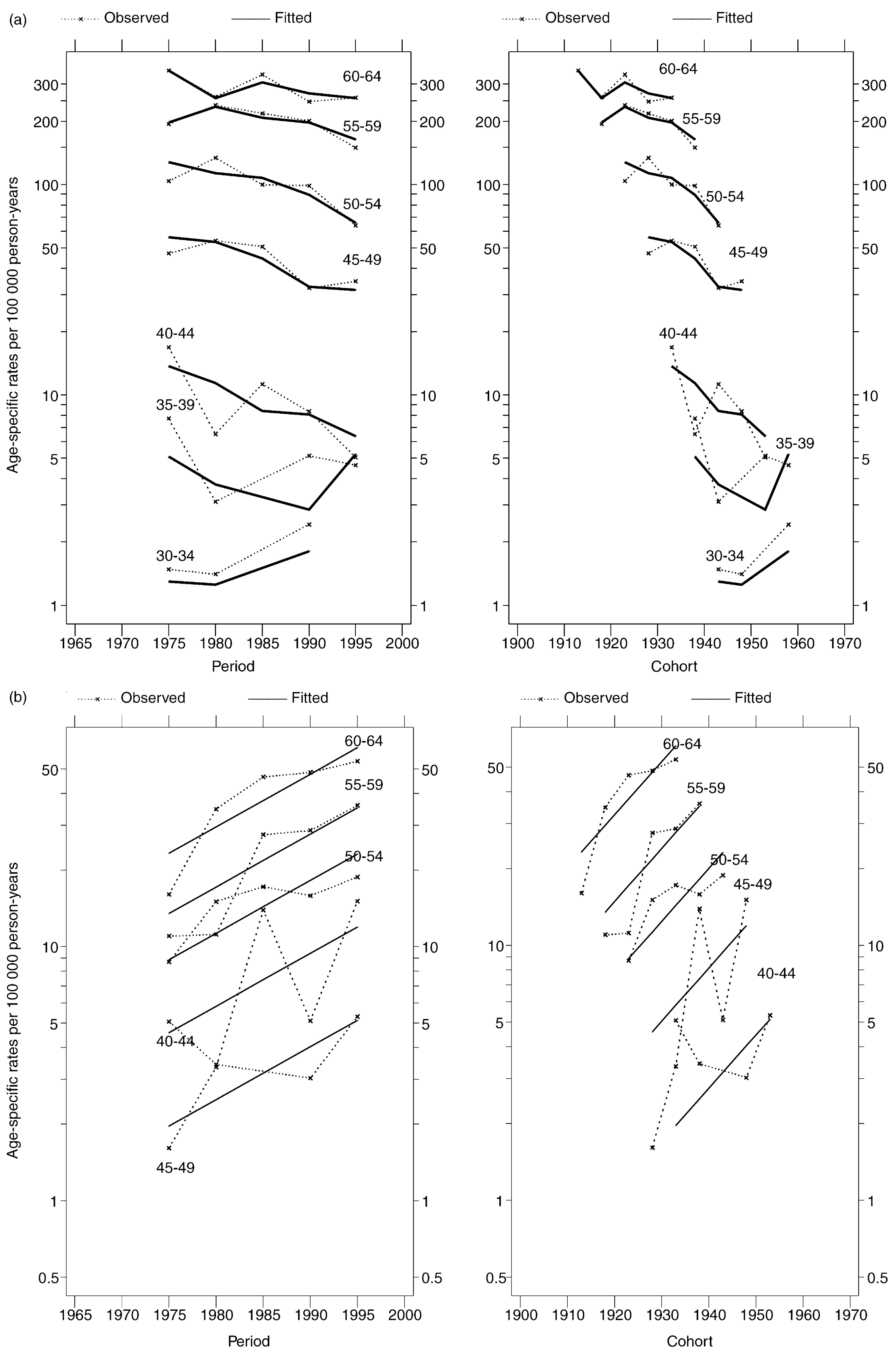

Fig. 11. Luxembourg: (a) males—period and cohort trends; (b) females—period and cohort trends, no data for youngest age group (30–39).

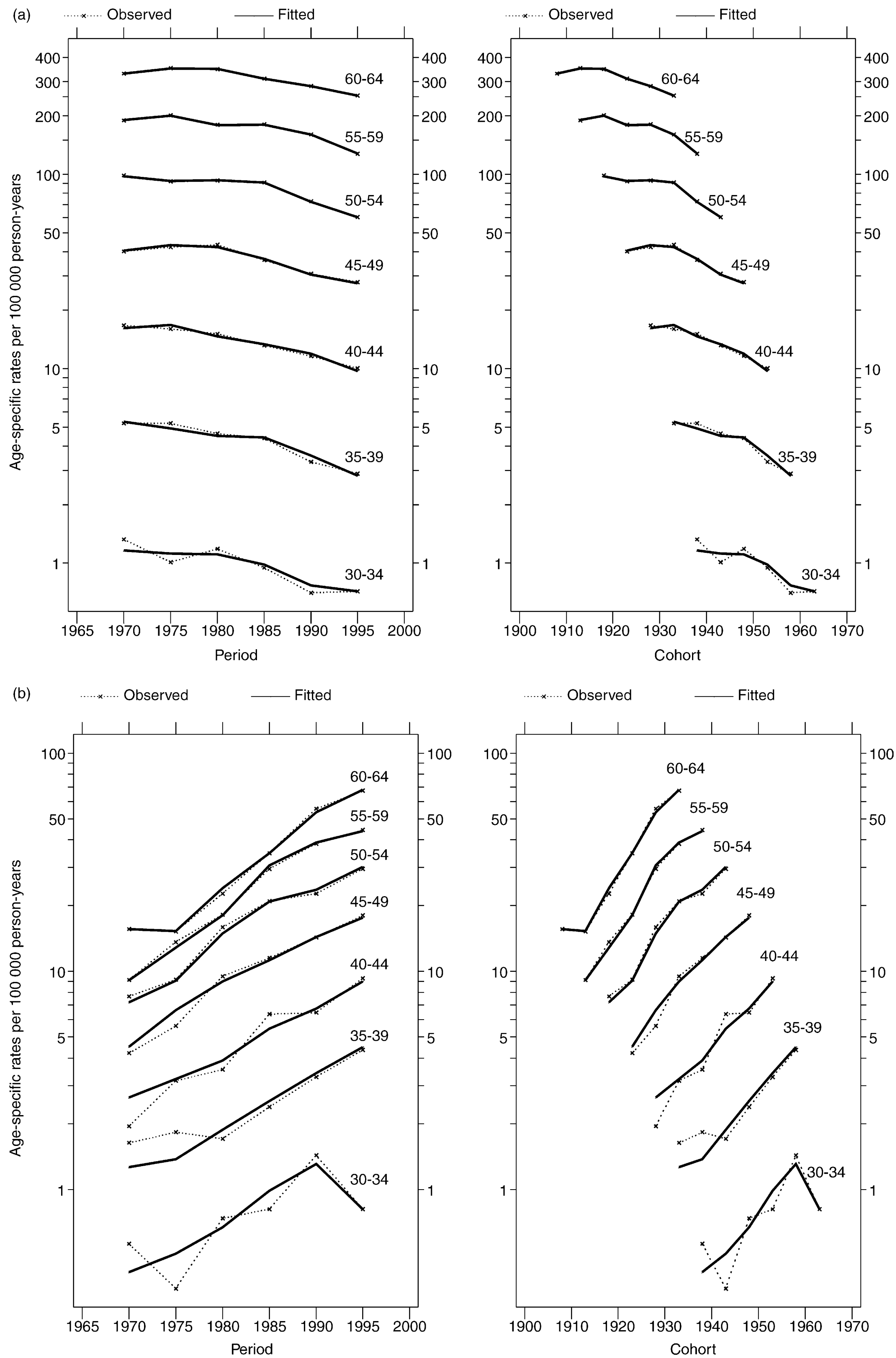

Fig. 12. The Netherlands: (a) males—period and cohort trends; (b) females- period and cohort trends.

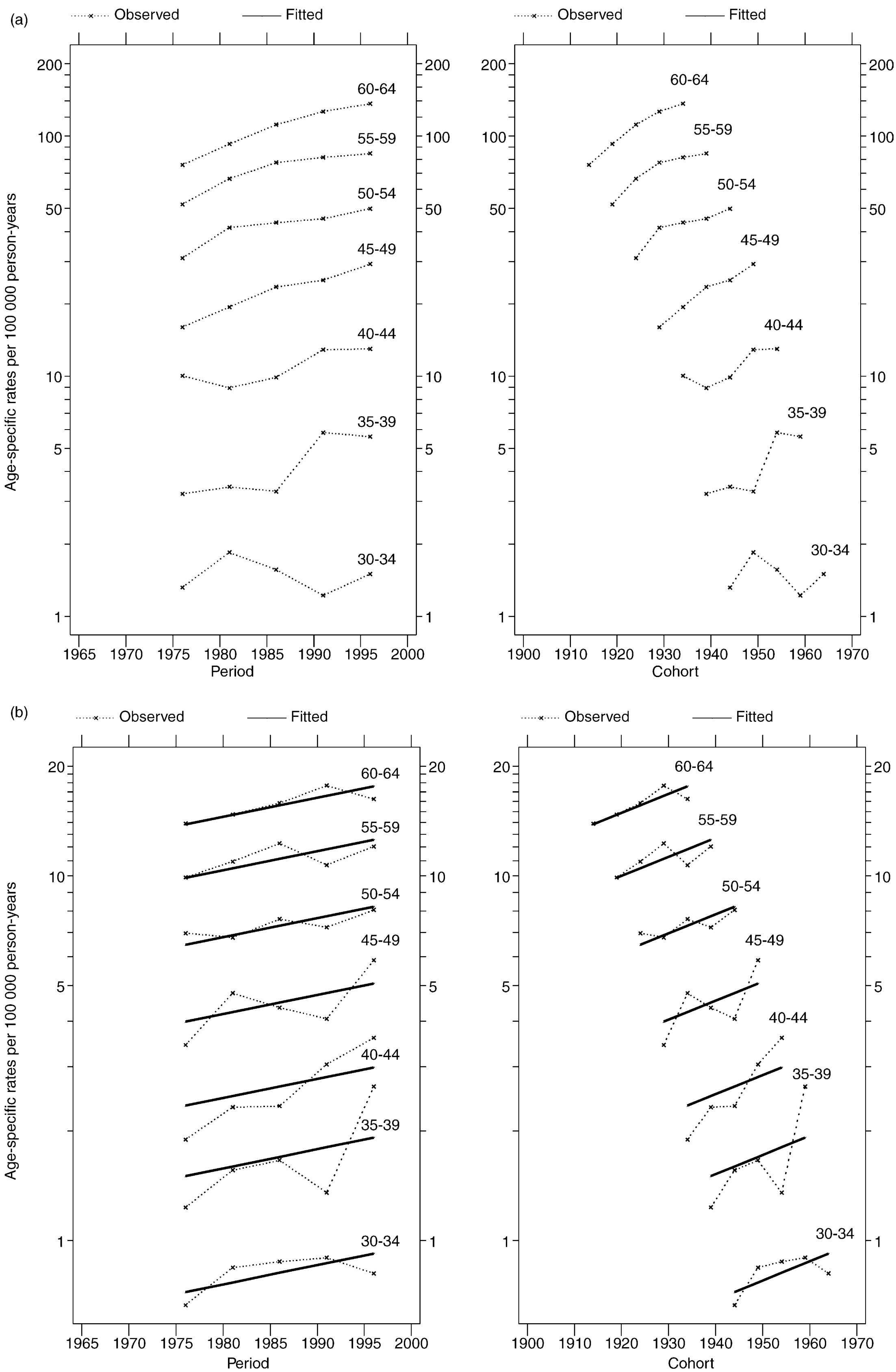

Fig. 13. Portugal: (a) males—period and cohort trends; (b) females—period and cohort trends.

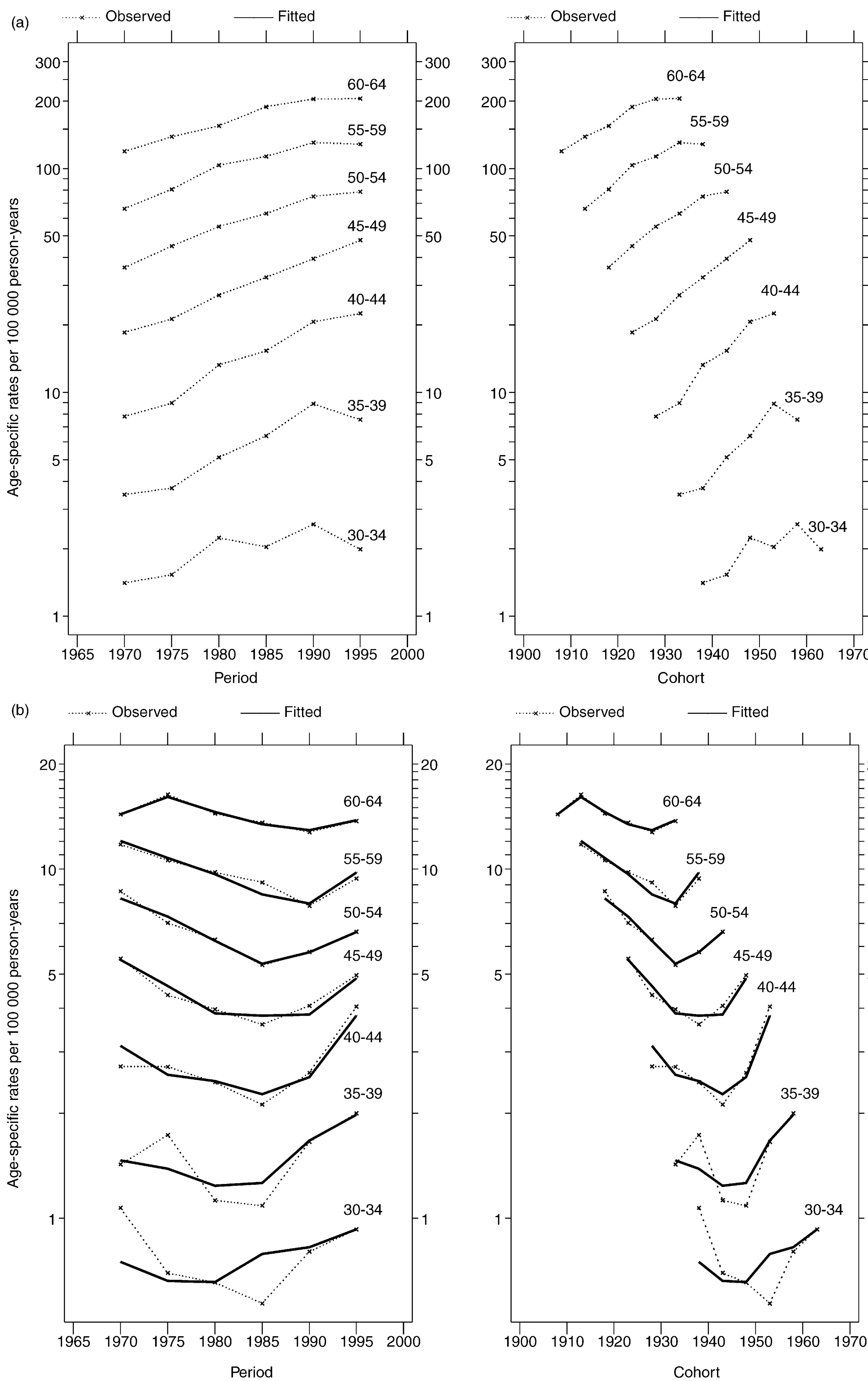

Fig. 14. Spain: (a) males—period and cohort trends; (b) females—period and cohort trends.

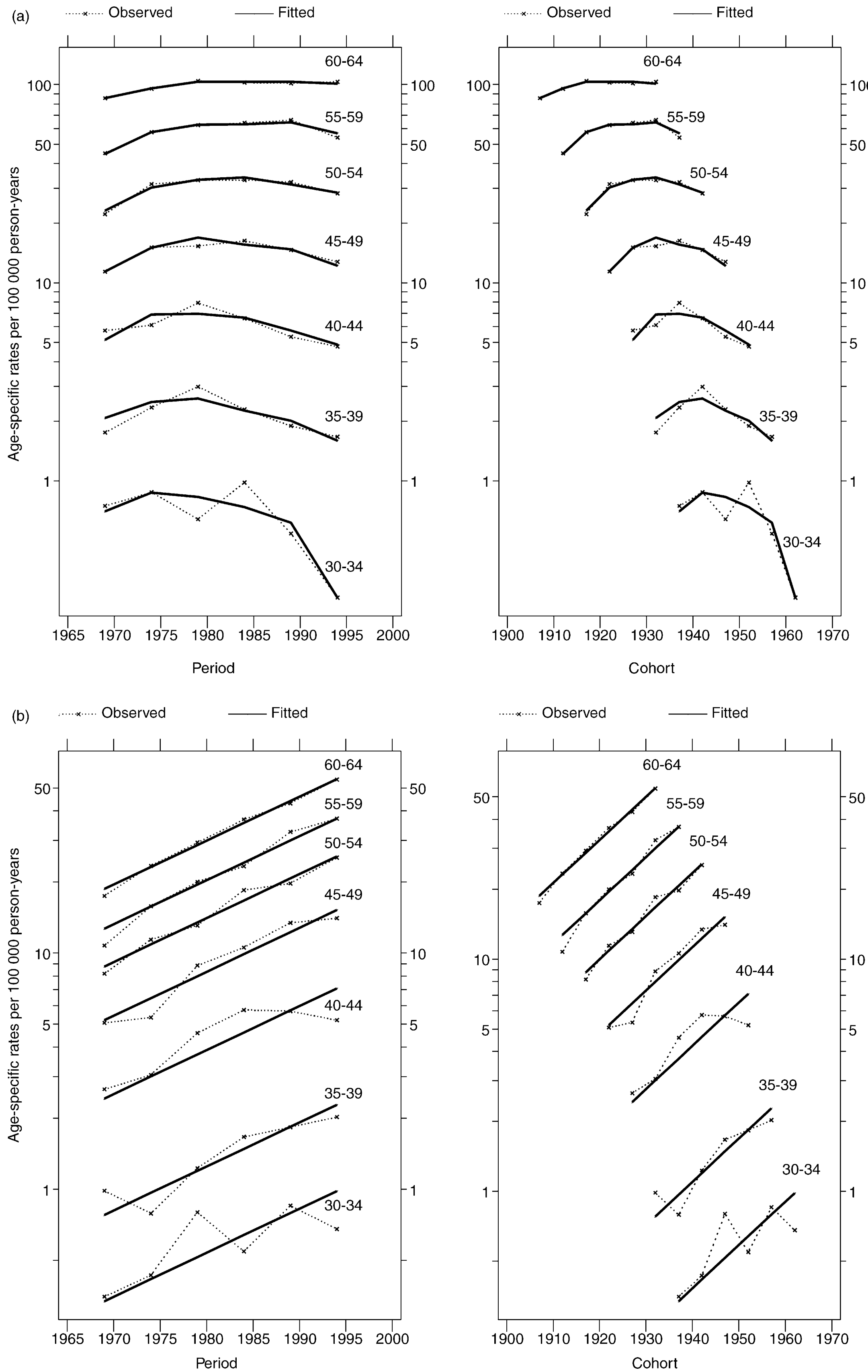

Fig. 15. Sweden: (a) males—period and cohort trends; (b) females—period and cohort trends.

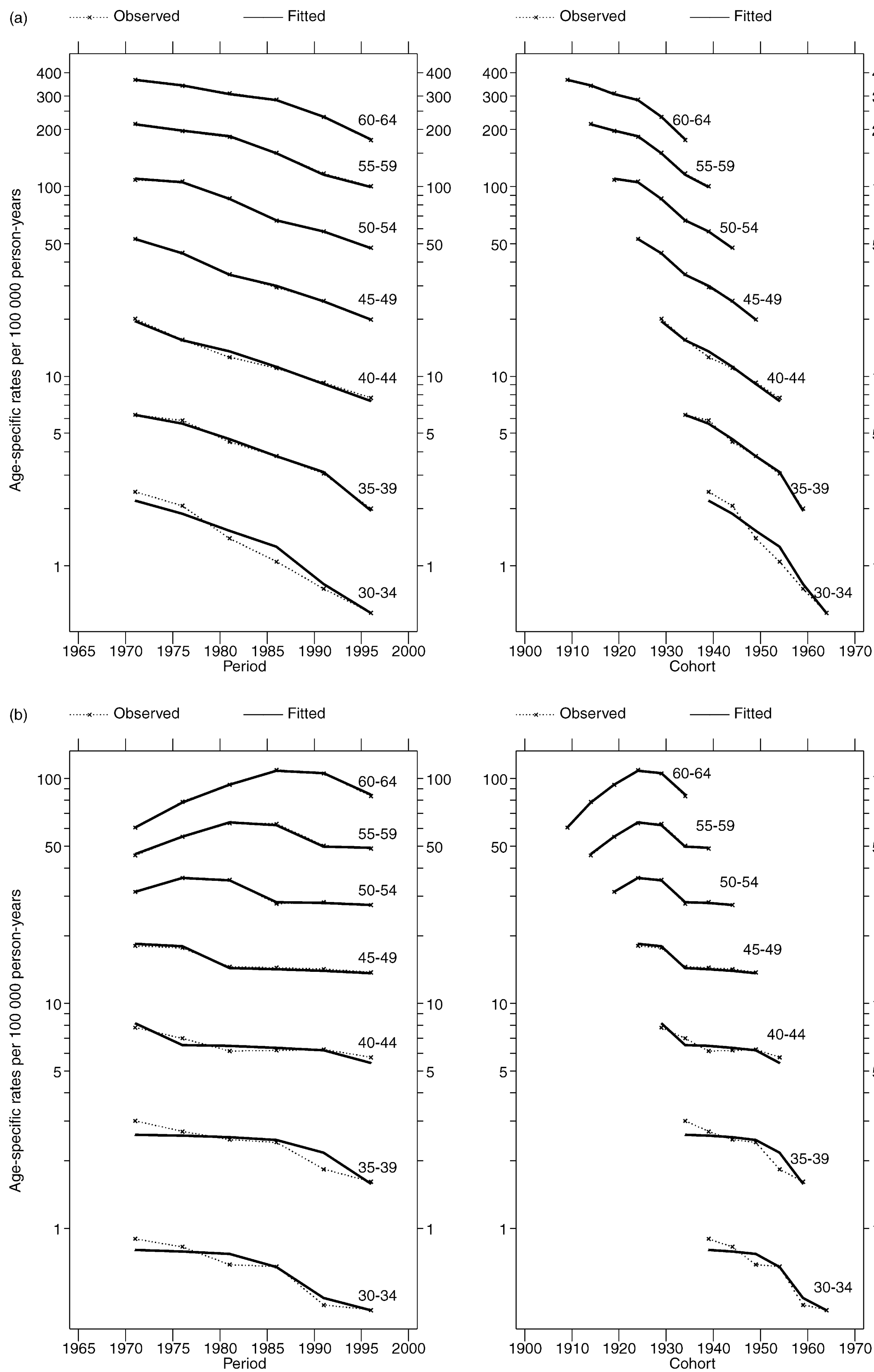

Fig. 16. United Kingdom: (a) males—period and cohort trends; (b) females—period and cohort trends.

few years; the 6.4% (95% CI: 6.0%, 6.8%) increase in rates between 1971 and 1986 diminished to a 1.1% (95% CI: 0.6%, 1.6%) growth from 1987 onwards. An age period cohort model is necessary to describe the underlying trends (Table 2). Following major increases in risk in successive cohorts since 1910, a subsequent drop in the fitted rates is seen in the youngest cohorts born after 1950 (Fig. 4b).

3.6. Finland

Mortality in men has been declining for several decades, and by 1995, rates were amongst the lowest in the EU (Table 1). In older men, rates peaked around 1983 (Fig. 1) and declined on average 2.1% (95% CI: −2.4%, −2.1%) annually thereafter. In younger men, the decrease started some years earlier, with an average annual fall in the rate of 4.9% (95% CI: −5.1%, −4.6%) between 1986 and 1998. The age-cohort model provided a reasonable fit to the rates in younger men (Table 2), and Fig. 5a shows the decline in mortality in successive birth cohorts, particularly since the mid-1920s.

Risk of lung cancer death in Finnish women has been consistently low amongst EU populations in recent decades, ranking 11th overall in 1995 (Table 1). Despite this, rates have been gradually rising; the mean annual percentage change between 1971 and 1998 was 1.4% (95% CI: 1.2%, 1.5%) in younger women and 2.6% (95% CI: 2.4%, 2.7%) in older women. Cohort influences are important in explaining the time trend (Table 2), with increases in risk in successive generations born since 1930; there is no apparent plateau in the risk in recent generations.

3.7. France

In men, risk of lung cancer death remains low relative to other EU countries (Table 1). Lung cancer mortality rates increased in the 1970s and 1980s, but by 1985, trends in males aged 65 years or over peaked, remaining constant in the last decade (Fig. 1). In younger men, there is some evidence of a small, non-significant decline in rates since 1990. Age, period and cohort components are required to explain the trends in age-specific rates, which are characterised by increases by both period and birth cohort (Fig. 6a), although there is a suggestion of a plateau in the mortality trends in men born in more recent decades (from around 1950).

Mortality rates in French women have been amongst the lowest in the EU in the last 20 years (Table 1), although they are increasing over time, with no hint of a slowdown in the rate of increase in either older or younger age groups (Fig. 1). Since 1971, age-standardised rates have risen by an average of 3.3% (95% CI: 3.2%, 3.4%) per annum in females aged under 65 years, and by 2.3% (95% CI: 2.2%, 2.4%) in those aged 65 years or over. No model could be fitted to explain the variation in the age-specific mortality; Fig. 6b, shows steady and sizable increases in the risk of lung cancer death, regardless of whether the data are inspected by period or birth cohort.

3.8. Germany

The mortality rate from lung cancer in German males is amongst the lowest in the EU countries, ranking 13th in both 1985 and 1995 (Table 1). In younger men, there was a clear downturn in rates (Fig. 1) after 1989, diminishing at about 2.5% (95% CI: −2.6%, −2.4%) per year, on average, subsequently. In older men, rates were stable in the same period, with a possible (very recent) minor decline. The joint effects of age, period and cohort (Table 2) are required to explain the trend in younger men (Fig. 7a); according to the latter component, risk begins to fall in cohorts of men born after 1930.

The lung cancer mortality rate in women also ranks low among EU populations (Table 1), but rates have been progressively climbing since 1984 (Fig. 1), by an average of 3.6% (95% CI: 3.5%, 3.7%) per year in younger women, and by 3.0% (95% CI: 2.7%, 3.2%) in females 65 years or over. An age-cohort model reasonably describes the observed data (Table 2); the cohort parameters point to steady rises in lung cancer mortality rates in women born after the mid-1930s, but for generations born around 1955 and thereafter, there is a suggestion that rates are beginning to level off (Fig. 7b).

3.9. Greece

In 1995, rates in men ranked seventh in the EU, increasing from tenth place, 20 years earlier (Table 1). In fact, subsequent to increases in mortality rates until the mid-1980s there has been little change; rates are consistently around 60 per 100 000 in Greek males under 65 years, and around 400 per 100 000 in older men (Fig. 1). Although an age period cohort model is required to explain the observed variation (Fig. 8a), there is a fairly strong cohort effect, with age-specific death rates increasing in successive generations born after 1910. Despite the small numbers of deaths involved, there is some evidence of a decline in rates in the youngest cohorts (born since 1950).

The relative rank of the ASRs in Greek women fell, from fifth in 1975 to tenth position in 1995 (Table 1), despite a modest annual increase in rates (1.6% (95% CI: 1.5%, 1.7%) per annum) in older women since the 1970s (Fig. 1). Rates in younger women, however, show remarkably little change in 25 years; age-truncated rates are around 9 per 100 000 throughout. Even with the aid of modelling, it is difficult to makes inferences on the evolution of the time trend; clearly both period and cohort effects are important (Table 2). The decline in risk in the youngest cohorts of women (born since 1955) may be an artefact, given the sparse numbers involved in the rate calculations.

3.10. Ireland

Rates of lung cancer mortality amongst Irish men are relatively low, ranking 10th in the EU in 1995 (Table 1). Following a plateau in the 1970s, rates in men aged under 65 years have been declining steadily since 1984 (Fig. 1), at about 3.3% (95% CI: −4.2%, −2.8%) per annum on average. Amongst older men, death rates remained fairly constant during the 1980s and 1990s, following a considerable increase in risk seen in the previous decade. Nevertheless, since 1994, a mean decline of 3.3% (95% CI: −4.8%, −1.7%) per year has been observed. Modelling of the age-specific rates in these men reveals the importance of birth cohort effects in explaining the observed time trend (Table 2). Indeed, such cohort-driven influences are unambiguous in Fig. 9a; following an increase until about 1920, subsequent generations of Irish men experienced successive diminutions in the risk of death from lung cancer.

Death from lung tumours in Irish women is high relative to other female populations in the EU (Table 1). In older women, the rising trends show signs of levelling off; the annual percentage change in estimated as −0.6% (95% CI: −1.6%, 0.4%) per year since 1993, compared with 3.9% (3.5%, 4.2%) between 1971 and 1992. In younger women, rates are diminishing (Fig. 1). In fact, the magnitude and direction parallel those seen in younger Irish men—female rates peaked in the late-1980s, dropping on average by 3.7% (95% CI: −4.4%, −3.0%) per annum after 1988. As with men, the age-cohort model is a reasonable explanation of the underlying variation (Table 2). Consecutive generations of women born since around 1930 have experienced small, but persistent, declines in their risk of lung cancer death (Fig. 9b).

3.11. Italy

Italian men have acquired an increasing proportion of the lung cancer mortality burden in the EU, rates ranking fourth highest in 1995 in comparison to ninth in 1975. Despite this, the waning of the lung cancer epidemic is more advanced in Italy than in other Southern European countries. Rates in younger men peaked around 1987 and have been on a clear downwards trajectory ever since (Fig. 1); falling on average 3.9% (95% CI: −4.0%, −3.8%) every year. In older men, a decline in rates can be anticipated in the future, should rates follow the patterns already seen in many Northern European countries; rates peaked at about 450 per 100 000 during the late 1980s to mid-1990s, and the most recent data suggest that a downward development is in progress, starting after 1993. The joint effects of age, period and cohort are required to explain the trend (Table 2) in younger men. Although there are marked decreases in risk in successive birth cohorts, this appears to begin earlier in older men (aged 50–64 years) than in younger men (aged 30–49 years), implying the additional period component.

Mortality rates in Italian women, as in women in other Mediterranean countries, have been relatively low during the last 25 years (Table 1). In older women, there has been a rather constant increase at an average of 2.7% (95% CI: 2.6%, 2.8%) every year between 1971 and 1997. Rates in younger women show some indication of reaching a peak—rates have settled at around 10 per 100 000 during the 1990s. No model fitted these trends (Table 2). The observed rates in Fig. 10b provide little evidence that the most recent generations of Italian women have as yet experienced any reduction in risk, relative to previous birth cohorts. Only in women aged between 55 and 64 years has there been a decline in lung cancer mortality rates in the last five-year period; in younger women, rates are uniformly increasing.

3.12. Luxembourg

With a population of only 400 000, the age-truncated rates show considerable random fluctuation. Nevertheless, rates in older men have clearly been declining slowly since the mid-1980s. In younger men, the trend is less evident, but suggests stability in the rates during the 1990s, following previous increases. Fig. 11a suggests a decline in risk of lung cancer death in men born since 1925.

The numbers of deaths amongst women are few, so that the underlying trends in truncated rates are not easy to clarify (Fig. 1); rates appear to be increasing in both age groups. Fig. 11b suggests increases according to both period of death and year of birth, compatible with the best fit of the age-drift model (Table 2).

3.13. The Netherlands

Lung cancer death rates amongst men in The Netherlands have been second only to those in Belgium throughout the last 25 years (Table 1). The evolution of the very high mortality in elderly males is similar to that in Belgium (Fig. 1). The rates reached a plateau around 1988, and during the most recent 10-year period there has been a steady decline; estimated at 2% (95% CI: −2.1%, −1.9%) per annum, on average. In younger men, the downward trend occurred considerably earlier, with rates declining steadily throughout the period of observation, with a more rapid decline after 1985 of

3.3% (95% CI: −3.5%, −3.1%) per year. Age, period and cohort effects are required to explain this variation (Table 2). It is clear from the period and cohort second differences displayed in Fig. 12a that there is little curvature in either of these effects.

Mortality from lung cancer has trebled between 1975 and 1995 (Table 1), and the trends in the truncated rates for both younger and older women are perhaps the most dramatic of all those shown in Fig. 1. Between 1971 and 1997, annual rates increased on average by 4.8% (95% CI: 4.7%, 5.0%) amongst older women, while in younger women, risk accelerated even more rapidly over the period, by an estimated 5.7% (95% CI: 5.5%, 5.9%) per year. Both period and cohort effects are required in the model to describe the data; the graphs of age-specific rates give no indication of a decrease in risk in recent generations of women.

3.14. Portugal

Death from lung cancer is rare amongst Portuguese men relative to other EU populations (Table 1), and in contrast to all other countries, there is no evidence that the increase in mortality rates is abating in either age group (Fig. 1). The mean increase between 1971 and 1998 was 2.6% (95% CI: 2.4%, 2.7%) per year in younger men, and 3.3% (95% CI: 3.1%, 3.5%) in men 65 years or over. Mortality rates have been rapidly escalating by both period of death and cohort of birth (Fig. 13a) and none of the models fitted the observed trends (Table 2).

As with men, rates of lung cancer death in Portuguese women have been consistently amongst the lowest in the EU (Table 1) between 1975 and 1995. Since 1971, rates increased by an average of 1.2% (95% CI: 1.1%, 1.3%) per annum for women aged under 65 years and by 2.5% (95% CI: 2.3%, 2.7%) in the older group. An age-drift model adequately fitted the trends in younger women (Table 2). Fig. 13b illustrates clearly the upward trend by both period and cohort, the combined linear increase, estimated from the drift parameter, as 6% (95% CI: 3.5%, 8.5%) every 5 years of death/birth.

3.15. Spain

There is some evidence from Fig. 1 that rates in Spanish men are beginning to plateau following steady increases in the last three decades. In fact, in younger men, a slight downturn in rates was observed very recently. In older men, rates have been relatively constant since the mid-1990s. The joint effects of age, period and cohort effects did not provide an adequate explanation of the data, but nevertheless in Fig. 14a, one can see fairly linear period increases from the 1970s to the mid-1980s, corresponding with across-the-board rises in cohort trends up to around 1950.

The age-adjusted lung cancer mortality rate in women ranks lower in Spain than any other country in the EU, and is some 13 times less than in Spanish men. However early signs of a lung cancer epidemic are now apparent in younger women (Fig. 1); for the period 1991 to 1997, there has been, on average, a 3.8% (95% CI: 3.2%, 4.3%) annual increase in lung cancer death rates. Rates in older women have been reasonably stable since the mid-1970s. An examination of the age-specific trends (Fig. 14b) reveals there are clearly both period and cohort influences at work, the model necessitating both time components to adequately fit the data observed (Table 2). As already noted, there are large period increases across all age groups in women aged under 65 years in the last 5 years of available data. In terms of birth cohort, following a consistent decline in rates in generations of women born around 1915, and a plateau during the mid-1940s, there is a clear upsurge in rates in women born since around 1950.

3.16. Sweden

There have been small, but steady, declines in lung cancer mortality rates in younger and older Swedish men since the mid-1980s (Fig. 1). The mean year-on-year decline is around 1.2% (95% CI: −1.5%, −0.9%) and 0.7% (95% CI: −0.8%, −0.6%) per year since 1985, respectively. Following a period increase in rates across all age groups in the early 1970s, there have been declines thereafter, first in younger men and spreading to older men by the 1990s (Fig. 15a). Consequently, there are clear cohort effects apparent, with a steady diminution in risk occurring in generations of men born after 1940.

In women, lung cancer death rates are about half those of Swedish men. In sharp contrast to men, however, rates have been steadily rising in the last three decades (Fig. 1), by 4.1% (95% CI: 4.0%, 4.2%) yearly in those aged under 65 years, and 2.8% (95% CI: 2.7%, 2.9%) in those aged 65 years or over. The observed trends by period and cohort are difficult to interpret (Fig. 15b). The best-fitting model, age + drift (Table 2), implies increases in combined period and cohort influences of about 23.9% (95% CI: 22.1%, 25.7%) per 5-year period/cohort.

3.17. United Kingdom

The U.K. was the first country to show a decline in the rates of lung cancer incidence and mortality in males (Fig. 1). In older men, risk has been decreasing since around 1984, rates consistently falling at about 2.6% (95% CI: −2.7%, −2.4%) per year, on average. The diminution of risk in younger men started not later than 1972. A convincing decline in the rate of about 3% (95% CI: −3.1%, −2.9%) annually has been seen over the last 25 years. While the joint effects of period and cohort are required in the model to explain the observed variation (Table 2), it is clear that much of the changes in levels of risk can be attributed to birth cohort, related to the declining tobacco habits of successive generations of men. There have been rapid and regular downward trends in lung cancer mortality rates in men below the age of 65 years for many decades. There is also a suggestion of a more rapid decrease in risk of death in younger men born since 1955 (Fig. 16a).

In women, there has been a recent slowdown in age-adjusted lung cancer mortality trends in older women, and a decline in rates in younger women (Fig. 1), reflecting a later uptake of cigarettes than men, and subsequently, a later abandonment of the habit. The average year-on-year decrease of 2.4% (95% CI: −2.5%, −2.3%) in rates in younger women from 1987 is in fact similar to the equivalent decline in males between 1972 and 1981. Trends in birth cohort are considered the main contributors to the representation of the time trends (Table 2). Death rates peaked in women born in 1925, and, following a decline in the early-1930s, rates seemed to plateau somewhat in women born during the next 20 years (Fig. 16b). Since around 1950, however, rates have fallen steadily in consecutive generations of UK women.

3.18. *Summary: direction, magnitude and phase of development*

It is instructive to attempt to summarise recent national patterns in terms of the current level of risk of lung cancer death and the direction, magnitude and phase of development of the trend (Table 3). The overall trends in males indicate there are some grounds for optimism; rates are declining or levelling off in 14 of the 15 countries, at least amongst younger men. Where risk is very high, in countries in group I (Belgium, The Netherlands), or high to intermediate, in II (Luxembourg, Italy, UK), trends are declining fairly rapidly, particularly amongst younger men. What sets these populations apart is the phase of the development; rates began to decline several decades ago in the UK, corresponding to decreasing risk in successive generations of men born throughout the 20th century. Equivalent declines by birth cohort are seen more recently in the other countries.

Group III (Greece, Denmark, Spain, Germany, France) includes countries where risk is intermediate and for which rates are either constant or decreasing in younger men, and beginning to level out in older men. Other than in Germany, where relative decreases in birth cohort have been seen as early as 1930, the cohort declines are quite recent, affecting men born since the 1950s. In groups IV (Austria, Finland) and V (Ireland, Sweden), risk of lung cancer death is relatively low, particularly in the latter group. In both, regular declines in risk are seen in younger and older populations, although again, the phase at which risk diminishes by birth cohort varies considerably, at the start of the century in Finland, in the 1920s in Ireland, and during the 1940s in Sweden and Austria. Group VI contains only Portugal. It can be singled out from the other national trends in men; rates have risen rapidly in both younger and older men, and by year of birth, with no indication of a genuine deceleration in risk in successive birth cohorts yet emerging.

For almost all the EU countries, the lung cancer epidemic is still developing in women—the risk of lung cancer death has steadily and rapidly escalated since the early-1970s, a phenomenon observed in both younger and older women. Six groups can again be ascertained; groups I and II contain just one country each, Denmark and UK, respectively. In both populations, risk is very high. However, the underlying trends are in quite opposite directions. In the UK, there has been a decline in rates since 1987 in younger persons, corresponding to an equivalent decline in risk in generations born since 1930. Rates in older women in the UK are now reaching a plateau phase. In Denmark, rates in both age groups are still rising, rapidly so in women aged 65 years and over. In younger Danish women, there is speculation that rates might plateau soon, corresponding to cohort declines in women born after 1950.

Group III countries (The Netherlands, Luxembourg, Sweden, Austria) represent female populations at high to intermediate risk, but for which rates are increasing rapidly in both age groups in the last three decades, and corresponding to major increases in risk in consecutive generations of women born during the 20th century. Only in Austria is there evidence of a plateau phase emerging by cohort of birth (after 1945). Group IV contains only Ireland, where risk in women is moderate, and declining rapidly for a decade in women over 65 years and also, more recently in younger women. As in women living in the UK, generations born since 1930 have successively lower rates of lung cancer as they reach the same age.

Group V contains a large group of countries (Germany, Belgium, Italy, Finland, Greece, France) for which risk ranges from moderate to low. In older women, rates are increasing quite rapidly throughout the last decades. Trends in the national rates have climbed rapidly amongst younger women, with two exceptions: in Greece, where they are (at least for the moment) still very low, and in Italy, where rates are perhaps beginning to flatten out in younger women. In Greece, as in Germany and Finland, we can hypothesise that plateau phases are starting to emerge in cohorts of women born since 1950, or thereabouts. In Italy, where cross-sectional trends appear to flatten in younger women around 1993, no cohort-led decline is thus far apparent. The final group, VI, contains countries with very low risk (Portugal, Spain). In Spain, risk has remained very low in older women throughout the period. This contrasts with younger Spanish women aged under 65 years, for which sizeable increases in rates are now clearly observed.

4. Discussion

This paper brings together the most recent trends in lung cancer mortality rates in the 15 countries of the EU. The focus is on a systematic analysis of the cross-

Table 3
Direction and magnitude of most recent change in lung cancer mortality trends

Population	SMR[a] (1997)	Cross-sectional trend aged 30–64[b] years (%)	Cross-sectional trend aged ⩾65 years[b] (%)	Birth cohort trend aged 30–64 years[c]
Men				
Very high risk, decreasing (I)				
Belgium	148	−2.0 (1985)	−0.8 (1985)	−(1946)
The Netherlands	131	−1.7 (1971)	−2.0 (1989)	−(1933)
High to moderate risk, decreasing (II)				
Luxembourg	117	−4.1 (1985)	−1.3 (1985)	−(1923)
Italy	112	−3.9 (1988)	−1.0 (1994)	−(1943)
United Kingdom	101	−3.0 (1971)	−2.6 (1984)	−(1909)
Moderate risk, plateau/decreasing (III)				
Greece	105	−0.1 (1984)	−0.3 (1990)	−(1954)
Denmark	103	−2.3 (1986)	−0.2 (1980)	−? (1947)
Spain	101	*+0.1 (1990)*	*−0.2 (1993)*	0? (1953)
Germany	96	−2.5 (1990)	−0.3 (1984)	−(1929)
France	96	−0.5 (1989)	−0.2 (1992)	−? (1953)
Low risk, decreasing (IV)				
Austria	86	−2.4 (1990)	−1.5 (1980)	−(1945)
Finland	85	−4.8 (1986)	−2.2 (1983)	−(1909)
Very low risk, decreasing (V)				
Ireland	49	−3.4 (1984)	−3.3 (1994)	−(1923)
Sweden	49	−1.2 (1985)	−0.7 (1985)	−(1942)
Very low risk, increasing (VI)				
Portugal	62	+2.6 (1971)	+3.3 (1971)	+ (1914)
Women				
Very high risk, increasing (I)				
Denmark	261	+1.1 (1987)	+5.1 (1971)	−? (1952)
Very high risk, plateau/decreasing (II)				
United Kingdom	206	−2.4 (1987)	*+0.1 (1994)*	−(1929)
High to moderate risk, increasing (III)				
The Netherlands	128	+5.7 (1971)	+4.8 (1971)	+ (1913)
Luxembourg	121	+4.8 (1971)	+2.9 (1971)	+ (1913)
Sweden	114	+4.1 (1971)	+2.8 (1971)	+ (1907)
Austria	106	+2.6 (1971)	+1.5 (1971)	0? (1945)
Moderate to low risk, plateau/decreasing (IV)				
Ireland	94	−3.7 (1989)	*−0.6 (1993)*	−(1928)
Moderate to low risk, increasing (V)				
Germany	93	+3.6 (1984)	+3.0 (1984)	−? (1954)
Belgium	83	+3.3 (1971)	+2.5 (1971)	+ (1911)
Italy	81	*−0.0 (1993)*	+2.7 (1971)	+ (1908)
Finland	73	+1.4 (1971)	+2.6 (1971)	0? (1949)
Greece	71	*+0.0 (1971)*	+1.6 (1971)	−? (1954)
France	61	+3.3 (1971)	+2.3 (1971)	+ (1908)
Very low risk, increasing (VI)				
Portugal	45	+1.2 (1971)	+2.5 (1971)	+ (1914)
Spain	41	+3.8 (1991)	−0.1 (1973)	+ (1948)

[a] Standardised Mortality Ratios of observed deaths versus those expected if age-specific rates in the EU applied, i.e. SMR (EU) = 100 [1].
[b] Estimated average annual percentage change in truncated rates since (year change in trend observed); year 1971 indicates trend observed throughout study period; italics denotes trend not significantly different from zero (null hypothesis of no trend).
[c] Midpoint of approximate 10-year overlapping birth cohort; 0, plateau phase; ?, cohort trend not clear, speculation.

sectional trends by age in men and women, and, subsequently, how the joint effects of age, period and cohort influence lung cancer mortality trends in persons (aged under 65 years). The objectives of such a synthesis were to identify the major changes in trends, highlighting the successes and failures of lung cancer prevention efforts in the EU in recent decades, and to draw attention to specific populations for which tobacco control strategies must be urgently implemented, or, if necessary, re-evaluated.

Systematic investigations of time trends in cancer incidence and mortality serve to generate and validate hypotheses regarding the aetiology of the disease. Increases in lung cancer have been documented since the turn of the century in several developed countries, while tobacco emerged as the main aetiological risk factor for the disease in several landmark large-scale epidemiological studies published in 1950 [18–20]. In the EU, about 9 out of 10 cases of lung cancer in men, and two-thirds of those in women are attributed to tobacco smoking, although there is substantial inter-country variability [5,21]. Thus, temporal trends in lung cancer mortality are explained in developed countries, by and large, by population changes in smoking behaviour (e.g. duration, dose and tobacco type), delayed by a latency period determined by the number of years between the onset of exposure and the development of the cancer. As a result, shifts in risk in younger birth cohorts can alert us to recent modifications in the smoking habit, which are of immediate consequence to organisations concerned with tobacco and cancer control.

There are many difficulties in studying trends in cancer, encountered at the data collection, data analysis, and analysis interpretation phases [12]. In many instances, it is becoming increasingly important to jointly analyse cancer incidence, mortality and survival to appreciate the subtleties and complexities of the underlying trends. The main advantage of mortality data are their availability. Certainly, given the continued poor survival rates of lung cancer patients in Europe [22], mortality trends should closely reflect the underlying trends in incidence. There are some possible problematic areas: although cause of death is well recorded, there are well-documented variations between countries in the coding of death certificates mentioning lung cancer. Several studies have estimated the extent of the disparity for different cancer sites [23,24]. In evaluating secular trends between countries, however, such incongruities ought not to adversely alter interpretation, should practices at the national level remain unchanged over time [10]. Furthermore, the focus of this study was on trends in younger men and women, for which the coding of lung cancer death is less likely to be erroneous. Changes in the content of rubrics over successive revisions of ICD can affect the validity of time trend comparisons [10]. In this study, however, the transition between the ICD-8 (1965) and ICD-9 (1975) volumes, in which trachea, bronchus and lung is coded 162, should not adversely affect the rates described here.

We have taken a conservative approach to the analysis and interpretation of trends using the age period cohort model. Nevertheless, we believe this presentation of the observed versus fitted rates (together with the model parameters available online at http://www-dep.iarc.fr/hmp/tt/figures2_16.pdf) provides sufficient insight into the underlying components of the lung cancer mortality trends, and together with the preliminary cross-sectional analyses by age, it succeeds in quantifying recent developments in the risk of death from the disease in the EU countries.

To attempt to ascertain whether these recent trends in lung cancer mortality will continue, at least in the short term, it is essential that they be evaluated alongside available data on trends in cigarette consumption. Recent changes in the percentage of male and female smokers in each country, can be related mainly to recent generation-specific trends in lung cancer. Fig. 17 displays the trends in the prevalence of adult daily smokers in men and women taken from various national surveys compiled in a recent report [25]. Similar patterns are demonstrated in other publications describing trends [26–28], and in recent European multicentre case–control studies examining the variations in risk estimates of lung cancer attributable to cigarette smoke [29,30].

With the provisos regarding the sparseness of data for some countries (e.g. Germany and Luxembourg), the proportion of male smokers has fallen consistently in most countries in the last five decades, the smoking trends being consistent with the birth cohort declines in lung cancer mortality observed in young men. The worrying exception is the smoking pattern in Austrian men. Continued monitoring of the upward trends in this population are essential. It should be noted that other sample surveys have also pointed to a recent increase in the smoking prevalence among Austrian men [31].

Somewhat encouragingly, the adult smoking prevalence trends in women in several countries, do not replicate the recent lung cancer mortality trends reported here. In Belgium, Denmark, Sweden and The Netherlands, the estimated smoking prevalence in women has fallen recently. One could therefore anticipate that future lung cancer death rates will begin to taper and decline should the trends in smoking prevalence continue to decay in this manner (as seen in the UK, and Ireland). Elsewhere, there are still major causes of concern. In Austria, smoking prevalence amongst women (as with men) is rapidly increasing, confirmed by Haidinger and colleagues [31]. The rapid rises seen in females in Spain support evidence from other studies, e.g. Regidor and colleagues [32] reported smoking prevalence increased from 22.9 to 27.2% between 1987 and 1997. It was noted earlier in this paper that the rapid development of lung cancer mortality rates in Spanish women is still at an early stage. Previous studies had observed that smoking prevalence was relatively high amongst recent generations of Spanish women [9,33], but there was little suggestion of increasing mortality rates at that time. The trends indicated here concur with the influence of smoking duration as the major long-term determinant of the course of the lung cancer epidemic [34]. Rates in Spanish women have for some time been misleadingly low, only recently is the massive impact of duration, delayed by several decades, evident.

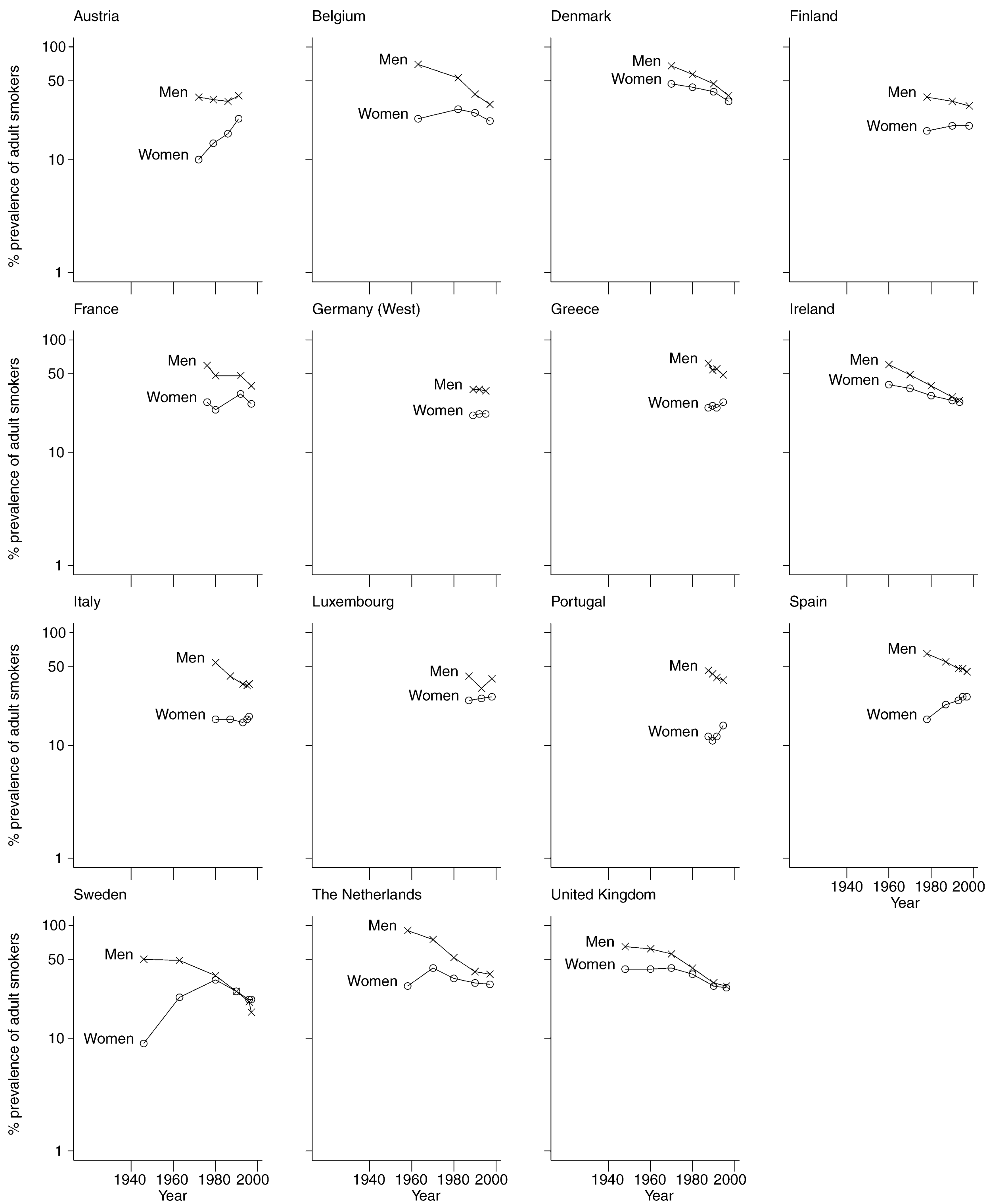

Fig. 17. Estimates of smoking prevalence in the EU (Source: European Network for Smoking Prevention).

Many factors related to the tobacco habit, such as duration and intensity of smoking, degree of inhalation, age at initiation and cessation of smoking, and the type of cigarettes or tobacco smoked, affect time trends in lung cancer at the population level. Changes in cigarette design and manufacturing technology in the second part of the 20th century have influenced the composition and carcinogenicity of tobacco exposure. The switch from high-yield to low-yield cigarettes, and from non-filtered to filtered cigarettes in the 1960s and 1970s resulted in a change of histological structure of lung cancer cases and, in particular, to an increase in the incidence rates of adenocarcinoma. Smokers, who, rather than quit, switched to low-yield cigarettes, experienced a longer duration of exposure to tobacco carcinogens, and in consequence, an increased risk of lung cancer. In addition, smokers switching to low-yield cigarettes tend to increase their daily consumption of cigarettes, in order to compensate for the lower levels of nicotine. Changes in cigarette production thus may not have had a favourable influence on time trends seen in the EU countries in last few decades.

It is likely that the most important tobacco-related modifier of lung cancer risk (and hence of trends observed later) is duration of exposure to carcinogens from tobacco smoke [21,34–36]; other than not taking up the habit, stopping smoking is the best way to avoid getting lung cancer. Smoking cessation rates in the EU population are important markers of the current and future trends in lung cancer incidence and mortality. Strategies to reduce lung cancer burden in EU countries should account for this; the main goal should be the further reduction of prevalence of male smokers, and the inhibition of the observed epidemic of smoking amongst women. Other prevention strategies aimed at reducing lung cancer mortality are not currently feasible: early detection strategies are ineffective at the population level (increasing survival is not accompanied by decreasing mortality rates), while chemoprevention approaches have yielded no apparent health benefit to smokers [37,38].

Other factors known to increase risk of lung cancer are occupational exposure to asbestos, some metals (e.g. nickel, arsenic, cadmium), radon, and ionising radiation [39]. The effect of some of these agents on lung cancer risk may be synergistic with smoking [40]. A recent study on lung cancer in lifetime non-smoking men showed that both occupational exposure to carcinogens (classified according to the A-List) [41] and residential exposure to radon may increase the risk of lung cancer [30]. However, the overall impact of such exposures in the development of trends in lung cancer in the last decades is minimal relative to that of tobacco consumption.

To conclude, an unequivocal public health message must be effectively conveyed to the inhabitants of the EU if the lung cancer epidemic is to be controlled and gradually eradicated. It is imperative that anti-tobacco strategies urgently target women living in the EU in order to halt their rapidly increasing risk of lung cancer, and prevent premature deaths among future generations of women. Community intervention strategies, such as populationwide (national or regional) quitting campaigns or educational programmes should be implemented simultaneously with approaches aimed at smoking cessation among individual smokers.

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