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Future alcohol-attributable mortality in France using a novel generalizable age-period-cohort projection methodology

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Abstract

Background: Alcohol is a major public health issue in Europe. Although future estimates of alcohol-attributable mortality can aid public health policy making, forecasts are scarce. Moreover, previous forecasts did not include the cohort dimension, despite the important role birth cohorts play in determining alcohol-attributable mortality trends. We forecast age- and sex-specific alcohol-attributable mortality in France for the period 2015-2050 using a novel generalizable methodology that includes different scenarios regarding period and cohort change. Within Western Europe, France has one of the highest levels of alcohol-attributable mortality.

Methods: For the French national population aged 25-90 years (1979-2014), we estimated alcohol-attributable mortality by mortality from the main causes of death wholly-attributable to alcohol, plus liver cirrhosis mortality. We modelled sex-specific alcohol-attributable mortality by adjusting for age, period, and birth cohort. We forecasted the model parameters to obtain future age- and sex-specific alcohol-attributable mortality up until 2050 using a conventional baseline, scenario I (favourable period change) and scenario II (unfavourable cohort change).

Results: Alcohol-attributable mortality is clearly declining in France, with the decline decelerating from 1992 onwards. In 2014, the age-standardized alcohol-attributable mortality rates, in deaths per 100,000, were 34.7 among men and 9.9 among women. In 2050, the estimated rates are between 10.5 (prediction interval: 7.6-14.4; scenario I) and 17.6 (13.1-23.7; scenario II) among men, and between 1.1 (0.7-1.7; scenario I) and 1.8 (1.2-2.9; scenario II) among women; which implies declines of 58% for men and 84% for women (baseline). The peak of the inverse u-shaped age pattern of alcohol-attributable mortality (currently at around age 65) is expected to shift towards older ages, and an additional hump in the age pattern is projected that moves towards higher ages over time, and is more extended in the cohort scenario.

Conclusions: Alcohol-attributable mortality in France is expected to further decline in the coming decades, accompanied by age pattern changes. However, France's levels are not expected to reach the current lower levels in Italy and Spain for 15 years or more. Our results point to the value of implementing preventive policy measures that discourage alcohol consumption among people of all ages, but especially among adolescents.

Key words: age-period-cohort analysis, alcohol, cohort, projections, forecasting.

Background

Alcohol consumption is a major public health issue in Europe (1-3), where the levels of both alcohol consumption and attributable mortality are the highest worldwide (2). As alcohol consumption has a marked impact on overall mortality levels and trends (4), understanding how this impact will develop in the future is relevant for public health professionals and policy-makers aiming to reduce alcohol-attributable mortality, and, consequently, the impact of alcohol on overall mortality. However, there is a lack of knowledge about future trends in alcohol-attributable mortality.

When estimating future alcohol-attributable mortality, it is essential to understand past trends, which differ widely across European countries depending on their drinking cultures. Alcohol-attributable mortality has been gradually decreasing in Southern Europe since around the 1970s, but the long-term trends in other European countries have been more irregular (5, 6). In examining past trends in alcohol-attributable mortality, birth cohorts must be taken into account (5, 6). Birth cohort differences in the adoption of unhealthy lifestyles, including of heavy drinking, are often attributed to certain birth cohorts facing similar contextual situations at different ages than other birth cohorts. In addition, we know that alcohol use in younger adulthood is associated with overall drinking patterns over the life course (7), and with the development of alcohol-related problems (8, 9). Thus, when forecasting alcohol-attributable mortality, it may be useful to take birth cohorts into account.

Despite the important role birth cohorts play in determining alcohol-attributable mortality trends, only one previous study barely touched upon this dimension when discussing future levels of alcohol-attributable mortality (10). By assuming age effects and cohort effects to be constant over time, which is arguable over the short term, it has been projected that alcohol-attributable mortality will decline moderately in Sweden between 2015 and 2025 (10). Other projections of alcohol-attributable mortality failed to simultaneously account for both period and cohort effects. Sheron et al. (11, 12) used linear extrapolation techniques to project alcohol-attributable liver deaths in the United Kingdom up to 2030, while also applying past time trends from other European countries to the United Kingdom. Thus, projections of future alcohol-attributable mortality are currently available for two countries only, and for relatively short time periods. It should also be noted that in addition to being based on arguable assumptions, these results were not provided disaggregated by age group.

We aim to forecast overall and age-specific alcohol-attributable mortality in France by sex over a long period (2014-2050) using age-period-cohort modelling, while including different likely scenarios for the period and cohort dimensions. To do so, we have used a methodology that can be applied to other European countries.

We have chosen to focus on France for several reasons. First, even though alcohol consumption has declined in France in recent decades (2, 13), the country's current levels of alcohol consumption are still high. Moreover, France has higher levels of alcohol-attributable mortality than most other Western European countries (4, 14). According to recent estimates for France, 13% of deaths among men and 5% of deaths among women are attributable to alcohol (15). Second, there are public health concerns about the current and the future impact of the drinking habits of younger generations. Although overall consumption levels among young people in France have been declining moderately over time (16, 17), there is evidence that drunkenness increased among 18-25-year-olds from 2005 to 2014 (18), while stagnating or moderately declining among 15-year-olds (17). Finally, in order to carefully study past trends and to adequately capture cohort effects, information about long-term trends in alcohol-attributable mortality are needed. However, because of changes in the International Classification of Diseases (ICD) (19), these trends cannot be directly estimated from cause-of-death data from the international WHO Mortality Database. More detailed national cause-of-death data is therefore required.

Methods

Setting and study population

For the total population of men and women in France aged 25-90, we studied past trends in overall and age-specific alcohol-attributable mortality (1979-2014), and estimated future overall and age-specific alcohol-attributable mortality (2015-2050).

Data

We used detailed cause-of-death data by single year of age and sex for the 1979-2014 period from Inserm CépiDc (20). In line with previous studies, alcohol-attributable mortality was defined as the sum of deaths from the main causes wholly-attributable to alcohol (mental and behavioural disorders due to alcohol use, alcoholic liver disease, and alcohol poisoning) and

liver cirrhosis deaths (ICD-9 codes: 291, 303, 571, and E860-E866; ICD-10 codes: F10, G31.2, K70, K73, K74, and X45), as similarly done in previous studies (21, 22). We used the corresponding population data from the Human Mortality Database to estimate alcohol-attributable mortality rates (23).

Approach

We applied a generalized methodology to forecast (age-specific) alcohol-attributable mortality that uses age-period-cohort modelling and includes different likely scenarios for the period and cohort dimensions. A crucial part of this methodology is the careful assessment of past trends prior to the formulation of the assumptions for the baseline projection and the likely scenarios based on observed data. In the remainder of the methodology section, we will describe the methodology used to study past trends (age-period-cohort modelling), report the resulting past trends, and describe the methodology and assumptions used to estimate future alcohol-attributable mortality levels and trends (projection methodology).

Age-period-cohort modelling

We estimated yearly sex-specific age-standardized alcohol-attributable mortality, using the total French population of 2014 as the standard. We modelled alcohol-attributable mortality by means of age-period-cohort (APC) modelling,

$$\log \mu_{x,t}^{\text{alc}} = \alpha_x + \kappa_t + \gamma_{t-x}$$

where $\mu_{x,t}^{\text{alc}}$ are alcohol attributable mortality rates by age (x) and year (t). The parameters α_x, κ_t, and γ_{t-x} capture the age pattern, the overall time trend (period), and the cohort patterns, respectively. We assume that alcohol attributable deaths follow a Poison distribution.

To deal with the linear dependency between period and birth cohort (age = period – cohort) in the age-period-cohort modelling, we used the approach by Cairns et al. (24), which is implemented in the Stochastic Mortality Modelling (*StMoMo*) package (25) in R (26). This approach allows to clearly distinguish between period, birth cohort and the linear trend shared between period and birth cohort (drift) by applying a set of constraints to the cohort parameter, which entirely moves the shared linear trend between period and cohort (drift) to the period parameter. The period parameter thus captures the entire linear time trend (= includes the drift), while the cohort parameter captures the cohort variations from this overall trend (see (24) for further details). To ensure the robustness of the cohort estimates, we

excluded from the model the first and the last five birth cohorts, which were highly uncertain (wide prediction intervals) due to the reduced number of available data points (see Figure S1). This resulted in the inclusion of the cohorts born between 1894 and 1984.

Past trends

Alcohol-attributable mortality was clearly declining in France (1979-2014), but with two distinct trends: 1) a pronounced decline from 1979 to 1992; and 2) a slower decline from 1992 to 2014, especially among men (Figure 1).

< Figure 1 around here >

When looking at the period trend in our APC model, we see that the decline was larger among women than among men (see Figure 2). When examining the general decline in alcohol-attributable mortality over time, we observe that alcohol-attributable mortality increased among the cohorts born before 1955, then decreased among the cohorts born between 1955 and 1975, and increased for the more recent birth cohorts (Figure 2).

< Figure 2 around here >

Projection methodology

Based on the past trends analysis, we formulated a baseline projection and two likely scenarios. The baseline projection used common settings in age-period-cohort mortality projections and in general (mortality) forecasting. That is, we assumed that the birth cohort parameter was constant at the mean observed over the past period (10, 27). For the period parameter, we considered the trend for the most recent period (1992-2014), or the period after the clear trend break (11, 28).

Scenarios I (period) and II (cohort) account for likely changes in the period and the cohort dimension, respectively, relative to the baseline projection. In scenario I (period), we assumed a more pronounced decline in alcohol-attributable mortality than in the past period, given the possibility that favourable contextual or policy changes will affect the drinking behaviour of people in all age groups. We did so by forecasting that the past mortality trend will continue over the whole period (1979-2014). In scenario II (cohort), we assumed that the increase in mortality among the most recent cohorts (as seen in Figure 2) will also have negative effects on mortality in the subsequent birth cohorts, given the possibility that negative changes in drinking behaviour (and especially binge drinking) will continue across generations of young

people. We did so by allowing the cohort parameter to gradually converge towards the mean, instead of being fixed at the mean.

For each scenario, we forecasted the period and cohort parameter by using autoregressive integrated moving average (ARIMA) time series models. We selected the best ARIMA model based on the corrected Akaike's information criterion (AICc) (29) and the Hyndman-Khandakar algorithm (30). For the implementation of the algorithm, we used the *auto.arima* function from package *forecast* in R (26). See Table 1 for further details on the specific time series choices for the different scenarios; and Figure 3 for a graphical visualization of the forecasted period and cohort parameters.

We projected age-specific alcohol-attributable mortality rates up to 2050 for the baseline and the two scenarios, and estimated the respective 95% prediction intervals by performing 10,000 simulations. The projected rates were subsequently age-standardized using the total French population of 2014 as the standard.

< Table 1 around here >

< Figure 3 around here >

Results

The results showed that the age-standardized alcohol-attributable mortality rates will continue to decline for both men and women, albeit at different speeds depending on the period and cohort assumptions (Figure 4, Table S1 for the prediction intervals).

The baseline scenario projected a decline in age-standardized alcohol-attributable mortality, by deaths per 100,000, from 34.7 in 2014 to 14.7 (prediction interval: 11.2-19.6) in 2050 among men and from 9.9 in 2014 to 1.6 (1.0-2.4) in 2050 among women; or by 58% among men and 84% among women. The gender gap in alcohol-attributable mortality is projected to narrow over time in absolute terms, from 25 deaths per 100,000 in 2014 to 13 in 2050 (baseline scenario).

Scenario I (favourable period change) obviously resulted in larger declines and lower future age-standardized alcohol-attributable mortality in 2050: 10.5 (7.6-14.1) among men and 1.1 (0.7-1.7) among women. Scenario II (unfavourable cohort change) resulted in smaller declines and higher future levels in 2050: 17.6 (13.1-23.7) among men and 1.8 (1.2-2.9)

among women. As scenario II estimated higher mortality for the currently young generations only, but cohort mortality that is almost identical to the baseline projection (same period assumptions) in the long run (e.g., cohorts born in 2020), the overall estimates from the baseline projection and from scenario II tended to converge in the long run (Figure S2).

< Figure 4 around here >

Whereas in 2014, an inverse u-shaped age pattern of alcohol-attributable mortality was observed with a peak at around age 65, this peak is projected in each projection scenario to occur at higher ages among men up to about 2040, and among women at least up until 2050, which results in a linear increase with age for women in 2050 (Figure 5). Furthermore, a second sharp peak in the age pattern, which occurs at higher ages in later years, was observed. This peak was especially visible in the baseline projection and period scenario, in which the cohort parameter was set to the mean observed over the past period, in line with common settings in age-period-cohort mortality projections (10, 27). In the cohort scenario, the peak was more extended and more realistic, as here it was assumed that cohort mortality would gradually decline towards the mean.

< Figure 5 around here >

Discussion

Summary of results

Alcohol-attributable mortality was clearly declining among the French population aged 25-90 in the 1979-2014 period, with a deceleration of the decline from 1992 onwards. In 2014, the age-standardized rates, in deaths per 100,000, were 34.7 among men and 9.9 among women. Over the 2014-2050 period, the age-standardized alcohol-attributable mortality rates are projected to further decline by 58% for men and 84% for women (baseline). This implies a range in 2050, in deaths per 100,000, of between 10.5 (7.6-14.4; scenario I period) and 17.6 (13.1-23.7; scenario II cohort) among men, and between 1.1 (0.7-1.7; scenario I period) and 1.8 (1.2-2.9; scenario II cohort) among women. The peak of the inverse u-shaped age pattern of alcohol-attributable mortality (currently at around age 65) is expected to shift towards older ages, and an additional hump in the age pattern is projected that moves towards higher ages with time, and is more extended in the cohort scenario.

Reflection on data

In line with previous research, we used the main causes of death wholly-attributable to alcohol, supplemented with liver cirrhosis mortality, to estimate alcohol-attributable mortality (21, 22). The selected causes of death wholly-attributable to alcohol and liver cirrhosis (F10, G31.2, K70, K73, K74, and X45) represent >90% of the total deaths wholly-attributable to alcohol in France (22). Data for the remaining very specific causes of death wholly attributable to alcohol (31) were not available to us. Also the inclusion of liver cirrhosis mortality as a whole, which is mostly – but not always - driven by alcohol (6), was necessary as it was not possible to build coherent time trends purely for alcoholic liver cirrhosis. Overall, our estimate of alcohol-attributable mortality underestimates total alcohol-attributable mortality (22) because alcohol has a notable impact on other causes as well, such as ischemic diseases, cancers, and injuries (15, 31, 32). The extent of this underestimation in 2010 for France was estimated to be around 58% relative to estimates using attributable fraction methods, and between 27% (women) and 42% (men) relative to estimates from approaches using underlying and contributory causes of death (22). Therefore, the results of this paper on alcohol-attributable mortality levels should be interpreted as strictly referring to past and future mortality due to causes wholly-attributable to alcohol and liver cirrhosis.

The past and future time trends in alcohol-attributable mortality are, however, much less affected by our estimation. First, the past mortality trends from the selected causes of death, and especially liver cirrhosis, followed past overall alcohol consumption trends (33). Second, our method for estimating alcohol-attributable mortality seems to have a rather minor effect on time trends if we compare our data to the Global Burden of Diseases (GBD) estimates, which are based on population attributable fraction approaches (34). That is, the overall decline in alcohol-attributable mortality between 1990 and 2013 among men is 40.5% in the GBD estimates (4), and 41.7% in our study (36.5% and 47.3% for women, respectively). Therefore, our estimates of the past and future alcohol-attributable mortality decline can be considered good approximations of the overall decline in alcohol-attributable mortality in relative terms.

Explanation of results

The projected future decline in alcohol-attributable mortality is based on the extrapolation of past declines in alcohol-attributable mortality. These past declines in alcohol-attributable mortality can be mainly attributed to declines in overall alcohol consumption in France, from 19.4 litres of pure alcohol consumption per capita and year in 1979 to 12.0 in 2014 (35). These declines were driven by an overall reduction in daily wine consumption (2, 13) in a context of societal and economic changes (e.g., urbanization and increased female employment) (36). In that sense we assume that societal and economic change will lead to a continued decline in alcohol-attributable mortality in the future.

Our age-period-cohort analysis however also revealed a potential important deviation from the overall decline. That is, the most recent birth cohorts showed relatively higher alcohol-attributable mortality than their older counterparts. This relates as well to trends in alcohol consumption. Alcohol consumption among adolescents and young adults have also been moderately declining over time (16, 17), and therefore contributed as well to the observed decline in alcohol-attributable mortality over time. However, recent trends for drunkenness suggested increases among 18-25-year-old from 2005 to 2015 (18), and a stagnation or a moderate decline among 15-year-olds (17). These somewhat contrasting trends among young individuals (overall consumption, and patterns of drinking) seem to indicate a further decline in alcohol consumption with potential increases in riskier drinking patterns. We incorporated this potential increase in riskier drinking patterns in our cohort scenario, leading to – still – a

general decline in alcohol-attributable mortality but to elevated risks among younger birth cohorts and – as a result – a changing age pattern of alcohol-attributable mortality.

Despite the overall expected further decline in alcohol-attributable mortality, it might take some time before France reaches the levels currently observed in countries with similar drinking cultures (i.e., Spain and Italy) (37). According to our baseline projection for men, and using the same definition for alcohol-attributable mortality, France will not reach Spain's current levels (22.0 deaths per 100,000) until 2032, and will not reach Italy's current levels (17.5 deaths per 100,000) before 2040 (see Figure S3). Thus, even though alcohol-attributable mortality is expected to further decline in France, it will not decrease to the current levels in these neighbouring countries in the next decade.

In addition to a further decline in alcohol-attributable mortality, we predict a changing age pattern. In particular, we project that the peak of the inverse u-shaped age pattern of alcohol-attributable mortality (currently at around age 65) will shift towards older ages. For men, this seems to be a temporal phenomenon only (up to about 2040); whereas for women it lasts at least up until 2050, with the peak expected to occur at age 85. For example, the cohorts born around 1955 (aged 70 in 2025 and aged 85 in 2040), and especially the women in these cohorts, are at higher risk of alcohol-attributable mortality than other observed cohorts (Figure 3), as the observed age patterns show (Figure 5). In both cases, this is entirely explained by the cohort effects. Thus, these relative changes in age patterns are not observed in the very long term, when cohort differences tend to be zero (see Figure S4).

Furthermore, the additional humps in the projected age pattern can be entirely explained by cohort effects. That is, for each subsequent period, this hump occurs at a higher age (at age 42 for 2025, at age 57 for 2040, at age 67 for 2050), at least for the baseline projection and the period scenario. The birth cohorts causing this pattern are the youngest birth cohorts we observed; i.e., those born in the early 1980s. The finding that alcohol-attributable mortality is higher among the younger generations than among the preceding generations could be explained by the higher alcohol consumption levels among the generations born in the 1980s and early 1990s (18). For the baseline projection and the period scenario this represents a very abrupt peak, mainly because mortality for the younger observed cohorts is higher than the average level, and because we assumed that the younger cohorts will have the same cohort mortality as the average level of the previous cohorts, as commonly done (10). In our cohort scenario, we instead adopted a more gradual change of the cohort parameter, which is likely

to result in an extended hump, and reflects the decline in alcohol use observed among the generations born in late 1990s and 2000s (17).

Appraisal of the methodology

To forecast (age-specific) alcohol-attributable mortality, we applied a methodology that uses age-period-cohort modelling and includes different likely scenarios for the period and cohort dimensions.

Our main rationale for applying an age-period-cohort (APC) projection methodology was that previous research demonstrated that the birth cohort dimension has clear added value in describing and understanding past alcohol-attributable mortality trends (5, 6). Moreover, in previous forecasts of alcohol-attributable mortality (10) and of smoking-attributable mortality (27), APC projection was applied using this same rationale. Our "explanation of results" section shows the added value of including the cohort dimension when forecasting alcohol-attributable mortality, as cohort effects were found to have a substantial impact on the projected age pattern in alcohol-attributable mortality at the population level.

To deal with the linear identification problem in the APC modelling we applied the approach developed by Cairns et al. (24), which allowed us to straightforward allocate all the linear trend (drift) in the period parameter, leaving the cohort parameter as purely non-linear. Other approaches presented in the literature deal with the linear identification problem in other ways (38-41), but generally provide similar results when identifying non-linear birth cohort effects, as non-linear effects are identifiable. One could therefore also use a different APC model as part of our general projection methodology.

In contrast to the only previous projection of alcohol-attributable mortality that included the cohort dimension (10), we considered different assumptions for both period and birth cohort based on a careful study of past trends. Whereas the assumption of the period had an effect on the overall levels (in this study, lower mortality levels), the assumption of the cohort had an effect on both the overall levels (in this study, higher mortality levels) and the age pattern of alcohol-attributable mortality. The application of our approach allowed us to provide new insights into the importance of the assumptions for both overall and age-specific future alcohol-attributable mortality estimates. In particular, our results showed that the use of a constant cohort pattern, which is often recommended in the literature, may result in an abrupt – and unlikely – hump in the projected age pattern. Thus, for future age-period-cohort

projections, we recommend that more realistic assumptions are used for the continuation of the cohort parameter. To make such assumptions, a careful study of past trends is essential.

Our age-period-cohort approach, which used different assumptions for the period and cohort dimensions, can be generalized and applied to other populations. But to make logical assumptions for the projection and achieve realistic results for the future, examining past trends for the population under study is crucial.

Conclusions

In conclusion, alcohol-attributable mortality in France is expected to further decline in the coming decades, although France is not expected to reach the current lower levels of neighbouring countries with similar drinking cultures within the next 10 years. Furthermore, the peak of the inverse u-shaped age pattern of alcohol-attributable mortality (currently at age 65) is expected to shift towards older ages because alcohol-attributable mortality is higher among cohorts born around 1955 than among the other observed cohorts (except the male cohorts born in the early 1980s).

Given its profound effects on future mortality trends and the unfavourable age patterns for current generations, health policy-makers should seek to prevent elevated alcohol-attributable mortality in the medium term by tackling alcohol consumption among adolescents (cohort measures). In addition, the implementation of preventive policy measures that affect people in all age groups (period measures; i.e., taxation) (42, 43) could positively contribute to alcohol-attributable mortality declines in the short term.

List of abbreviations

APC: age-period-cohort

GBD: Global Burden of Disease

HBV: Hepatitis B virus

HCV: Hepatitis C virus

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and material

The data were obtained from the following sources: Inserm CépiDc (contact persons: Mireille EB, Grégoire Rey) and Human Mortality Database (publicly available at www.mortality.org).

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

All authors designed the study. STL and AB carried out the empirical analyses. STL drafted the manuscript. FJ aided in drafting the manuscript and critically reviewed the manuscript. All authors aided interpreting the results, and approved the final manuscript.

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Figures and tables

Figure 1. Age-standardized alcohol-attributable mortality (ages 25-90) in France, 1979-2014, by sex

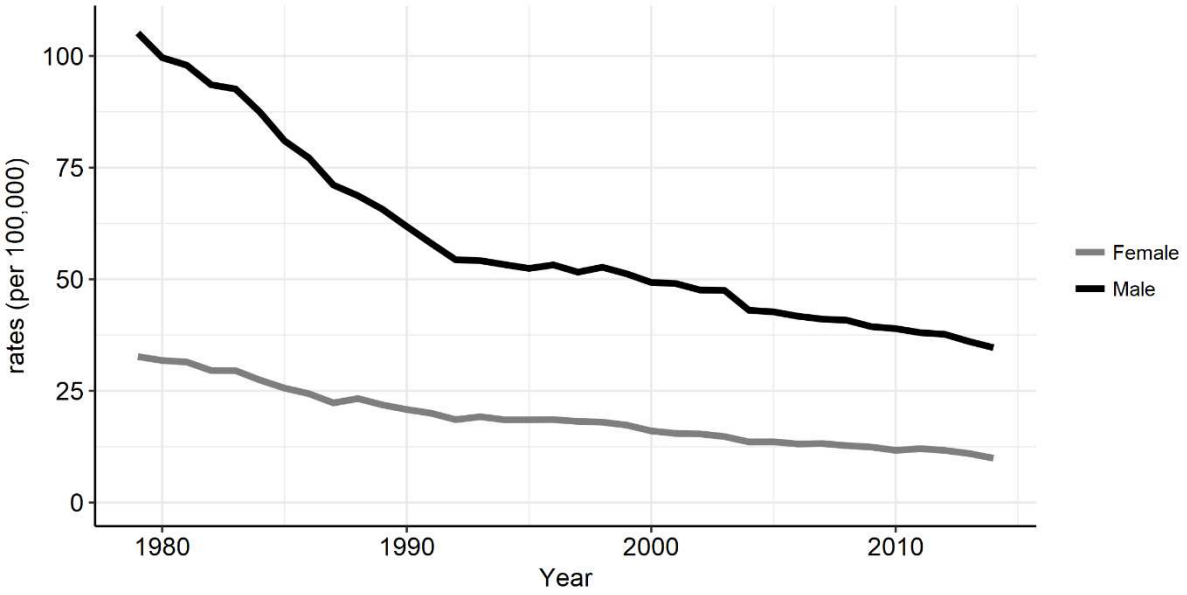


Figure 2. Period and (non-linear) birth cohort effects of alcohol-attributable mortality in France (ages 25-90, 1979-2014), by sex

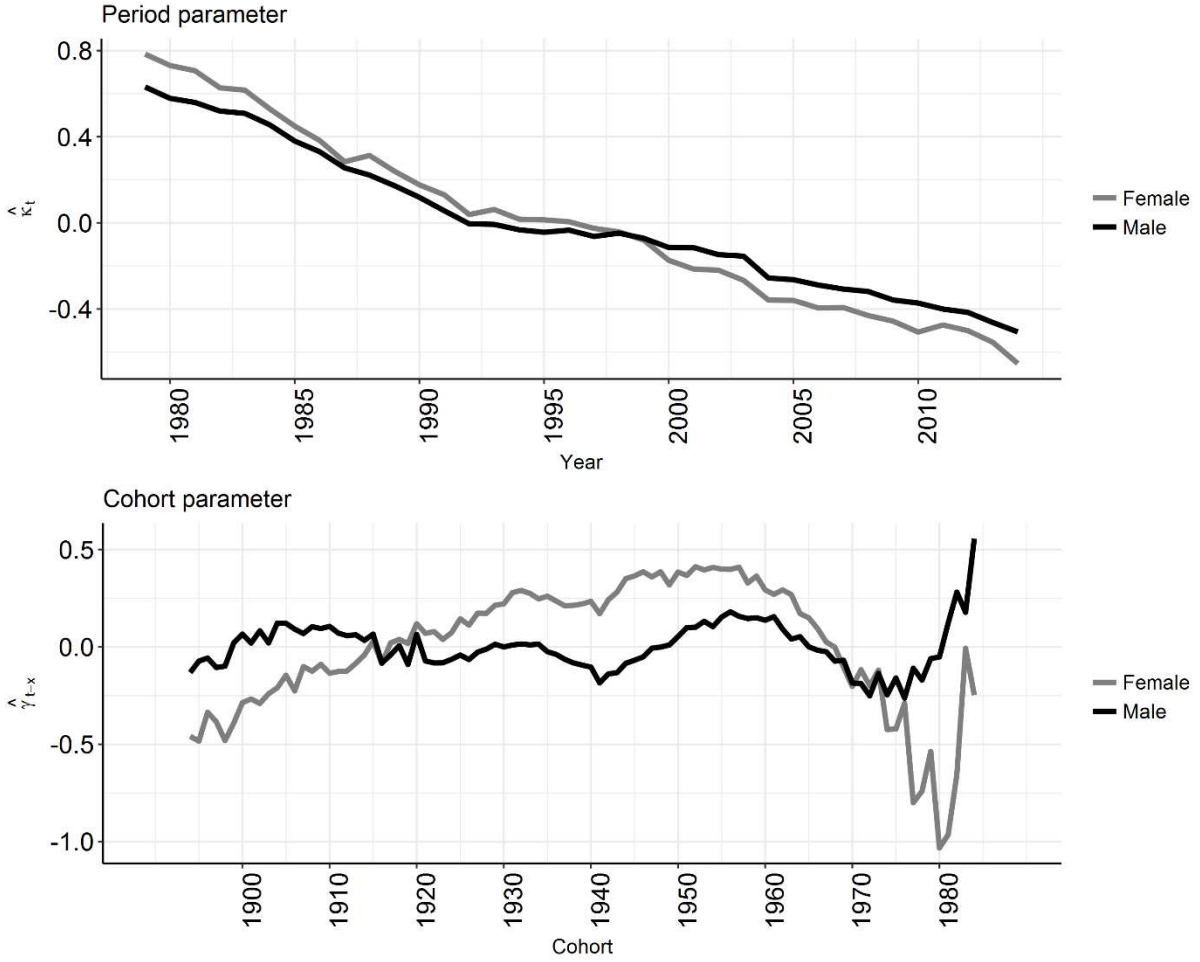


Table 1. Summary of scenarios and time-series specifications for the projection of the period and cohort parameters

Projection	Period parameter (κ_t)	Time series specification period	Cohort parameter (γ_{t-x})	Time series specification cohort
Baseline	1992-2014	ARIMA(0,1,0)	Men: constant along the mean (0). Women: constant along the mean for the last 10 cohorts (-0.56).	ARIMA(0,0,0)
Scenario I (period)	1979-2014	ARIMA(0,1,0)	Men: constant along the mean (0). Women: constant along the mean for the last 10 cohorts (-0.56).	ARIMA(0,0,0)
Scenario II (cohort)	1992-2014	ARIMA(0,1,0)	Men: gradually converging towards the mean. Women: same pattern as for men, but shifted downwards based on the differences in the mean between men and women (last 10 birth cohorts).	ARIMA(1,0,2)

* For women, unlike as for men, the average for the most recent birth cohorts is substantially lower than the overall average (zero). In that case, we assumed the mean to be the mean over the last 10 birth cohorts.

Figure 3. Alcohol-attributable mortality in France (ages 25-90): Age, period, and cohort parameters and projections of period and cohort parameters, by sex

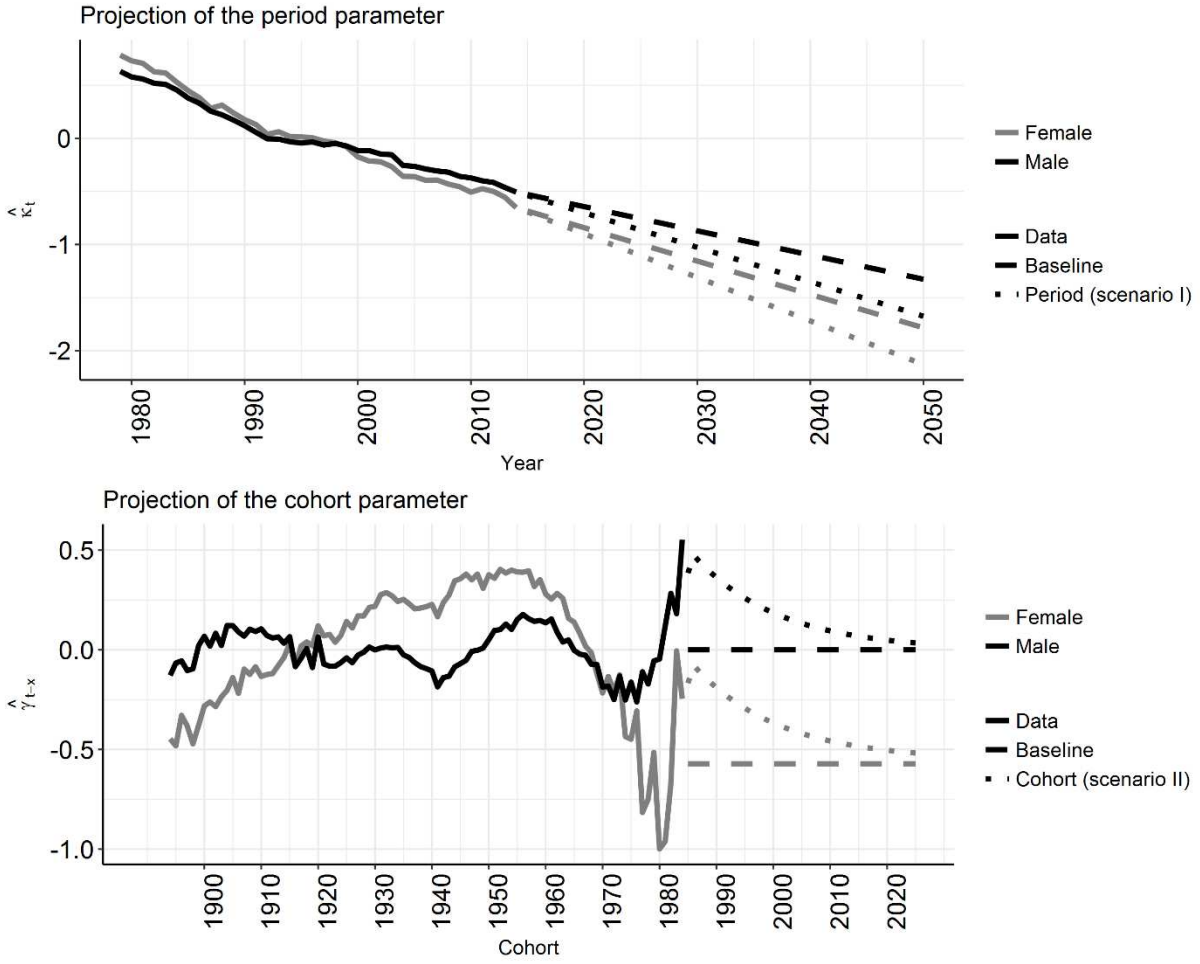


Figure 4. Age-standardized alcohol-attributable mortality rates (ages 25-90) in France (1979-2014 data; 2015-2050 projection), by sex

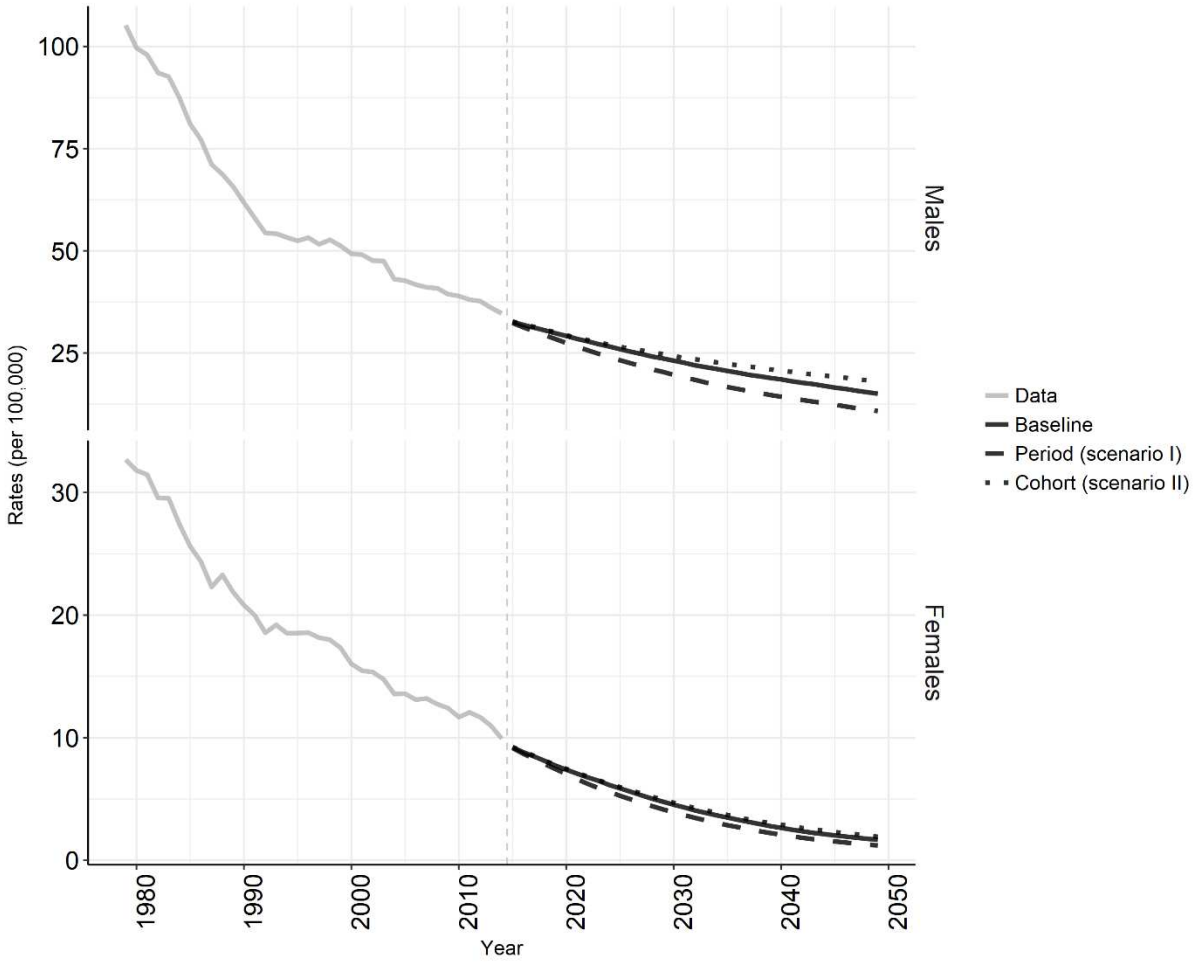
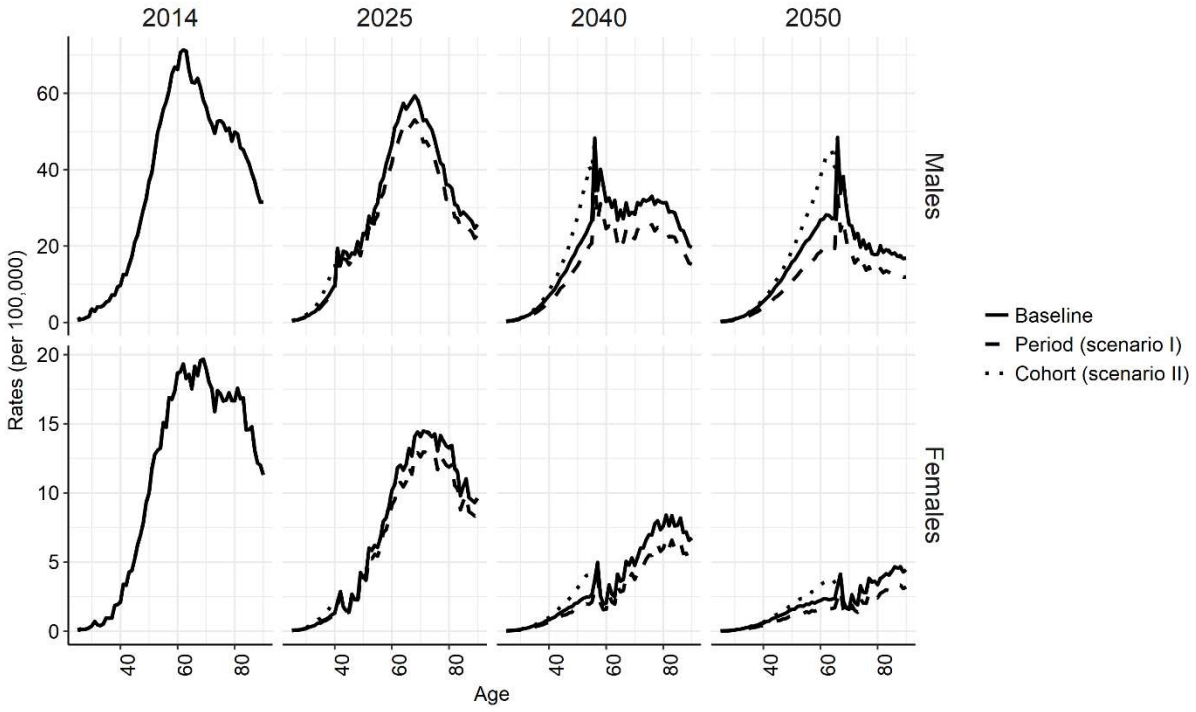
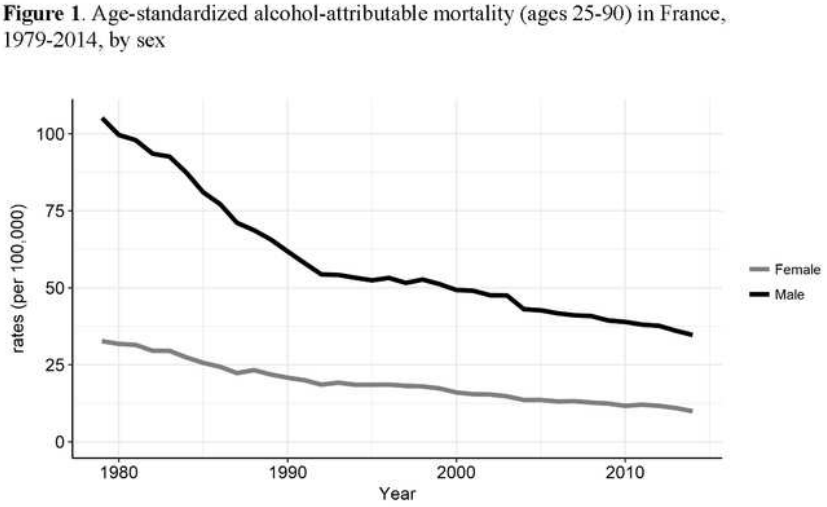


Figure 5. Observed (2014) and projected (2025, 2040, 2050) age-specific alcohol-attributable mortality rates (25-90) in France, by sex



Figures



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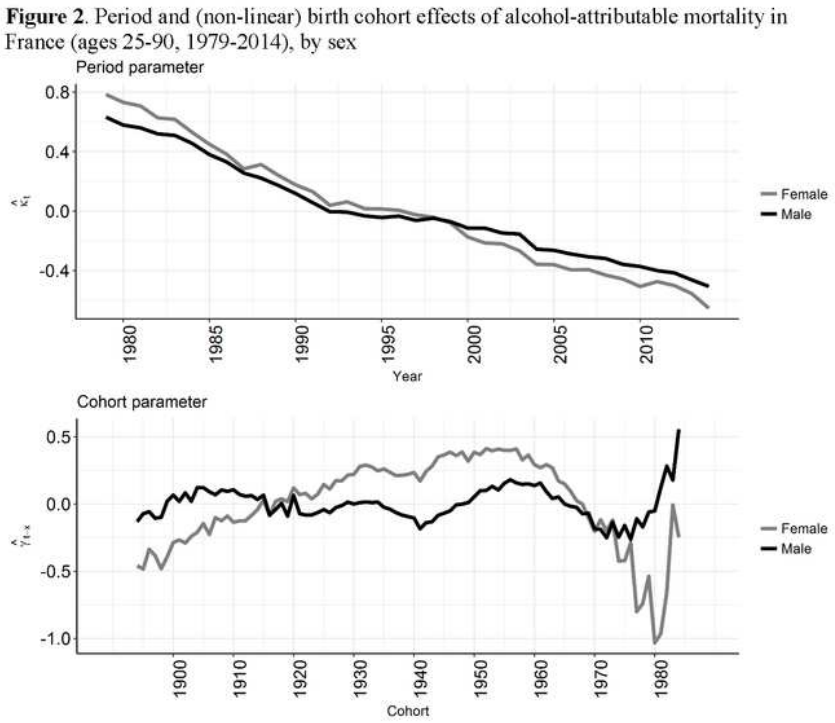

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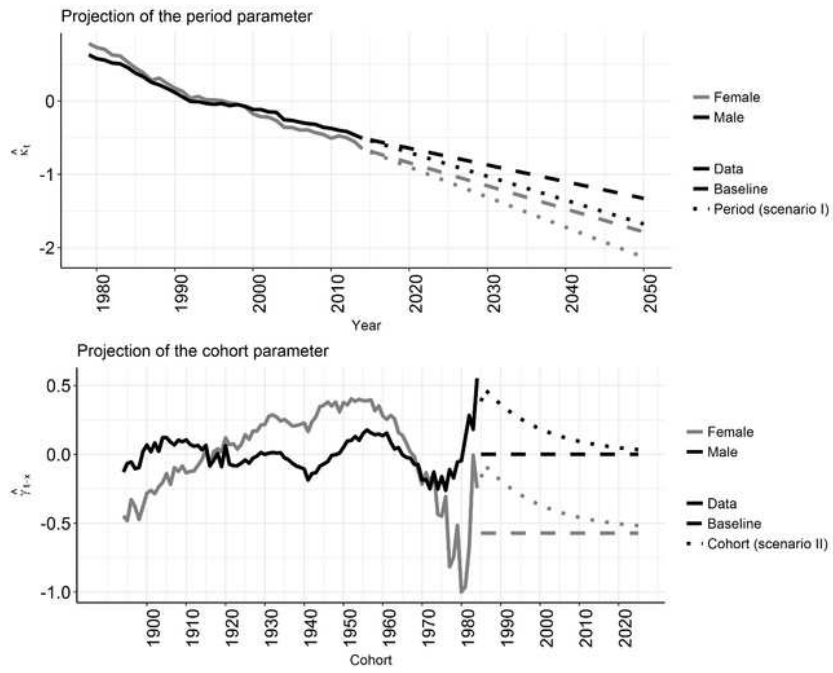

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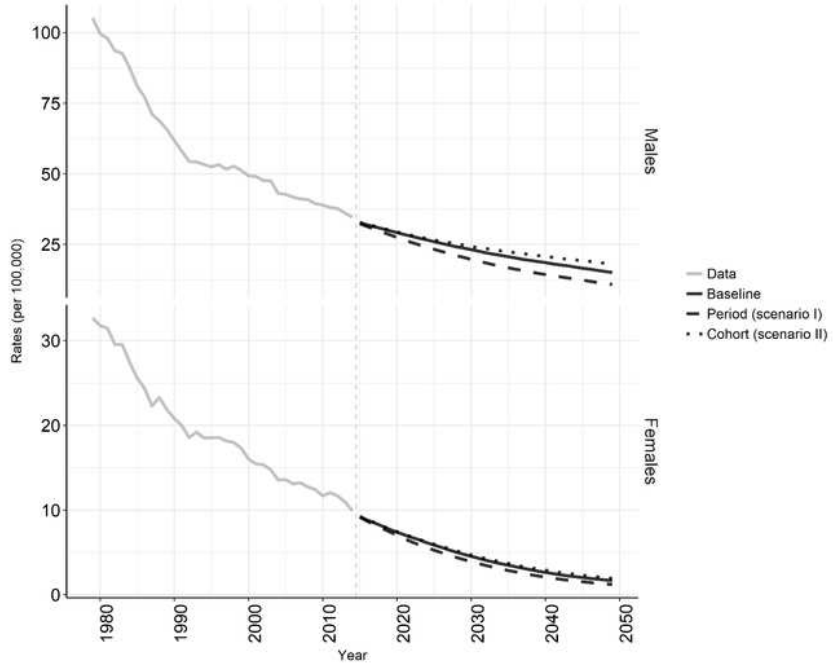

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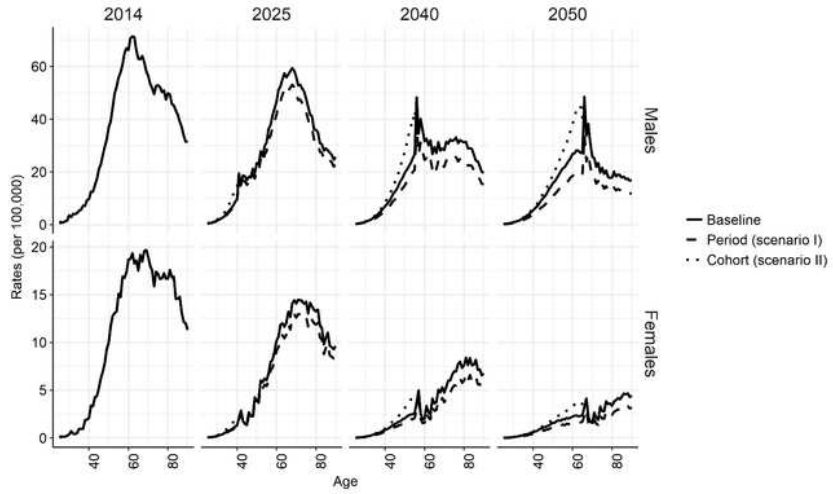

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