Forecasting Dementia Mortality among Older Adults in Low Mortality Countries

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Short abstract

Evidence on temporal trends in dementia mortality in low-mortality countries remains limited, and there is considerable uncertainty about its trajectory over the coming decades. While most studies point to a continued decline in mortality, others warn of potential increases due to worsening population health and lifestyle factors. This uncertainty highlights the need for further research on national trends in dementia mortality. This study aims to analyze future trends in dementia mortality in 21 low-mortality countries up to 2050, using probabilistic projection methods. The future dementia age-specific mortality rates were projected using the Compositional Data Analysis (CoDa) model, an extension of the Lee-Carter model. Its great advantage is that it ensures consistency between mortality rates due to dementia and total mortality rates in the projections. The results reveal a wide diversity in future dementia mortality trends across the studied nations. Although most countries are projected to experience an overall increase in dementia mortality, some, including Australia, Belgium, France, Italy, Poland, and Spain, show signs of stabilizing overall dementia mortality levels. Crucially, the projected rise in dementia mortality is primarily driven by significant increases in age-standardized rates among the oldest age groups (80 years and over). In contrast, younger cohorts (60-79 years) generally exhibit stable or even slightly declining age-specific mortality rates. These findings are essential for guiding public health strategies aimed at reducing the prevalence of dementia and mitigating its increasing impact on older populations.

INTRODUCTION

According to the Global Burden of Disease study on the global, regional, and national burden of Alzheimer's disease and other dementias, 1990–2019 (Li et al., 2022), the incidence and prevalence of Alzheimer's disease and other dementias increased by 147.95% (from 2.92 million to 7.24 million) and 160.84% (from 19.79 million to 51.62 million), respectively. Increases were observed in both men and women, consistently over the study period but more serious in countries with a high sociodemographic index, although age-standardized rates in Australasia, high-income North America and Western Europe declined slightly. Alzheimer Europe (2020) estimated, based on prevalence rates from previous studies, that the EU28 countries had 8,885,101 people living with dementia in 2018, with 16,276,070 expected to have the condition by 2050. As a percentage of the population, this represents 1.73% in 2018, compared with 3.28% in 2050. However, important differences across gender and age groups were noted. Notably, the incidence of dementia doubles approximately every 5 years up to the age of 75-79, and it grows at a slower pace thereafter.

These rising prevalence rates are mirrored by trends in dementia-related mortality, reflecting a broader transformation in the causes of death in ageing societies. In recent decades, low-mortality countries have experienced significant shifts in the distribution of causes of death. Notably, there has been a sustained decline in mortality from cardiovascular diseases, accompanied by an increase in deaths linked to conditions associated with advanced ages, such as dementia and other neurological disorders (Vallin & Meslé, 2004, 2006; Pritchard et al., 2004; Mackenbach et al., 2014). This rise in dementia-related mortality has been particularly pronounced in countries like Finland, Iceland, Malta, the Netherlands, Spain, Sweden, and the United Kingdom. Consequently, the proportion of deaths attributed to mental and neurological diseases has risen substantially, from less than 5% in the early 1970s to over 10% among women in several countries today. Some scholars have interpreted these trends as indicative of a new phase in the epidemiological transition, with early commentators even warning of a potential pandemic of mental disorders and disabilities (Gruenberg, 1978; Olshansky & Ault, 1986; Kramer, 1980). While the notion of a distinct new stage in the epidemiological transition remains contested (Santosa et al., 2014), it is clear that the growing contribution of dementia to overall mortality rates is significant. Indeed, dementia is now ranked among the top 10 causes of death for men and is among the top 5 for women in many low-mortality countries (Mackenbach et al., 2014). This underscores the importance of understanding dementia as a key factor in contemporary mortality patterns.

More recently, however, mortality rates due to dementia in some low-mortality countries have either stabilized or begun to decrease (Prince et al., 2016). While no single risk factor fully explains these trends, increased educational attainment across successive cohorts has been identified as a significant contributing factor. Higher education levels are associated with better cognitive function and greater cognitive reserve, both of which are considered protective factors against the development of dementia (Schrijvers et al., 2012; Qiu et al., 2013; Prince et al., 2016; Takasugi et al., 2021; Taudorf et al., 2021).

Despite these promising developments, the evidence regarding time trends in dementia-related mortality remains limited, and considerable uncertainty about its trajectory in the coming decades. While many studies offer an optimistic outlook, suggesting that both the prevalence and mortality rates for dementia-related conditions may follow recent stabilizing or decreasing patterns, this optimism is tempered by the complexity of underlying factors and potential variability across regions. Age-specific prevalence and mortality rates for dementia are expected to remain stable or decline. Prince et al. (2016) even argue that current forecasts may be conservative, particularly for low- and middle-income countries, as they do not fully account for the potential benefits of effective public health interventions. However, other studies offer a more cautionary view, warning that dementia-related mortality could rise in the coming years due to worsening population health driven by deleterious lifestyle habits such as physical inactivity, poor diet, alcohol consumption, obesity and diabetes (Livingston et al 2020).

Given the uncertainties surrounding future trends in dementia-related mortality, there is an urgent need for further research into national-level patterns, particularly in low-mortality countries where dementia accounts for a growing share of overall deaths. While several studies have addressed this issue (REFS), many rely on deterministic models that do not fully account for the inherent uncertainty in future projections of dementia trends. Accurate projections can guide strategies aimed at reducing dementia prevalence and mitigating its societal and healthcare burden in the decades to come.

This study aims to analyze future trends in dementia mortality in 21 low-mortality countries up to 2050, using probabilistic projection methods.

DATA AND METHODS

Mortality Information

Life tables were sourced from the Human Mortality Database, and the World Health Organization provided the number of deaths by cause, sex, and age group. Because dementia mortality occurs predominantly at older ages, the analysis focused on individuals aged 60 years and older. The dementia-related causes of death categories included Alzheimer's disease (ICD-10 G30), other degenerative diseases of the nervous system not elsewhere classified (ICD-10 G31), and other dementias (ICD-10 F01-F03). Missing information on age and sex was distributed according to the observed structure for deaths with declared age and sex.

The analysis included 21 countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Poland, Spain, Sweden, Switzerland, the United Kingdom, and the United States of America. The selection of these countries occurred qualitatively, ensuring the chosen set included countries with diverse socioeconomic conditions and mortality levels. Information for Australia (2005) was unavailable, so linear interpolation between subsequent years imputed it.

Methods

The age-specific dementia deaths from the life table is the input for estimating the CoDa model. This function is obtained by multiplying the number of deaths from all causes by age group from the life table by the proportion of deaths attributable to each specific cause within the corresponding age group.

Several countries reported the number of deaths by cause aggregated for ages 85 years and older in some years of the historical series (Canada, 2000–2022; Czech Republic, 1994; Denmark, 1997–2000; Finland, 1996–2021; France, 2016–2020; Germany, 2017–2020; Ireland, 2016–2020). This subset represented approximately 14% of the total observations. To address this, probabilistic imputation, incorporating period and country effects, estimated age-specific mortality rates for the two oldest age groups (90–94 years and 95 years and older).

Compositional Data Analysis (CoDA) Model

The age-specific dementia deaths were forecasted using the Compositional Data Analysis (CoDA) model, an extension of the Lee-Carter model designed for probabilistic mortality rate projections. The Lee-Carter model (1992) integrates a demographic framework with time-series forecasting methods, relying on historical trends to predict future mortality. While several studies recognize this model's accuracy and relatively straightforward method for modeling mortality rates, projected cause-specific mortality rates do not necessarily equal the projected all-cause mortality rate. This inconsistency can lead to overestimating future mortality (Wilmoth, 1995), posing challenges for accurate long-term forecasting.

The CoDA framework models the evolution of mortality using an approach similar to Lee-Carter, specifically by applying it to the death distribution function ($d_{t,x}$). This function represents the distribution of deaths within a synthetic cohort for a given year, and crucially, its values sum to the radix of the life table across all ages. Compositional data represent parts of a whole and always sum to a constant. For dt,x, what truly matters are its relative proportions to the whole, rather than the absolute values themselves. The CoDA model can be expressed as:

$$d_{t,x} = \alpha_x \oplus (k_t \odot \beta_x) \oplus \epsilon_{t,x}$$

Here, α_x represents the average age pattern of mortality over time. β_x describes how mortality at each age x responds to changes in the overall mortality level, while k_t is the temporal component capturing the overall mortality level in a specific year t. The ⊕ (perturbation) and ⊙ (scaling) operators, intrinsic to CoDA, ensure that addition and multiplication operations in the transformed space respect the compositional nature of the data. The estimation of these parameters, k_t and β_x , is typically performed via a rank-1 approximation (like, Singular Value Decomposition in traditional Lee-Carter) of the data matrix in the CoDA space.

After estimating the overall mortality level, the structural break test was applied to analyze if there was any significant structural change in the historical series considered. Subsequently, the overall mortality level was forecasted using a time series model (*Auto Regressive Integrated Moving Average*) and corrected it by the jump-off. The future number of dementia deaths is ultimately calculated from the estimated parameters and the projected overall mortality level; this involves reversing the CoDA transformations via a closing procedure to ensure projections maintain their compositional form and sum to the initial life table radix (l_0).

The models were adjusted using the *MortalityForecast* package developed by Pascariu (2019) for the R language.

Comparability

To ensure comparability with other studies projecting dementia mortality, number of deaths by age group and cause of death were transformed these counts into age-specific mortality rates, applying standard life table relationships (Preston, 2000). Additionally, to facilitate comparisons over time and across countries with varying age structures, age-standardized mortality rates were also calculated. A reference population, defined as the mean between the observed value for 2011 and the projected value for 2030 for the EU-27 and EFTA countries, served for standardization.

Sensitivity Analysis

Two sensitivity analyses were conducted to assess the CoDA model's performance in projecting dementia mortality. The first analysis evaluated the model's predictive accuracy by re-estimating it with a shortened time series and comparing the projected values with observed mortality between 2016 and 2019. The second analysis examined the impact of including COVID-19 years by re-estimating the model while excluding data from 2020 onwards and comparing the resulting projections with those from the full model that incorporated the COVID-19 period. Both sets of results were also compared with projections generated by alternative models, including the log-linear extrapolation method and the original Lee-Carter model.

Uncertainty Analysis

The CoDA model provided probabilistic projections for the number of deaths by cause based on the life table. Consequently, uncertainty in both the age-specific and the age-standardized mortality rates stemmed from the uncertainty associated with the projected number of deaths in the life table. Monte Carlo simulations were used to derive confidence intervals, under the assumption that mortality rates followed a truncated normal distribution with a lower bound at zero.

RESULTS

Recent Trends in Dementia Mortality (2000-2019)

The age-standardized dementia mortality rate exhibits substantial variation across low-mortality countries (Figure 1). Countries such as the Czech Republic, Japan, and Poland consistently report the lowest rates for both sexes, whereas Finland displays the highest rates for both men and women. All countries have experienced increases in dementia mortality over time. Poland, France, Spain, and Belgium show the smallest increases, while Finland, the United States, the UK, the Netherlands, and Germany demonstrate the most pronounced increases.

Generally, dementia mortality is significantly higher among women than men, with Finland, the United States, the Netherlands, and Switzerland exhibiting the largest disparities. Conversely, Japan is the sole country where dementia mortality consistently remains higher for men than for women over time.

While dementia mortality levels differ between countries, the age-specific mortality profiles are remarkably similar (Figures 2 and 3). Dementia mortality rises sharply between ages 60 and 84, after which it tends to plateau. Mortality rates have increased across all age groups over time, as evidenced by the upward shift in the age-specific mortality curves (from blue to red lines in Figures 2 and 3). Notably, in several countries—including Poland, Austria, Denmark, Germany, Japan, and Norway—dementia mortality has become increasingly concentrated among the oldest age groups.

Estimation of CoDa parameters

The CoDA model projects age-specific dementia mortality rates by incorporating three main components: the average age pattern of mortality (αx), the age-specific rate of change relative to the overall mortality trend (βx), and the general level of mortality over time (κt).

The average age structure of dementia mortality (αx) reflects the historical pattern observed across countries (Figure 1A in Appendix). It follows an inverted U-shape, with mortality steadily increasing from age 60 to around age 85, then slightly declining at older ages. Some countries, such as Austria, the Czech Republic, Germany, Japan, and Poland, display a more uniform age structure.

The overall level of mortality (κt), a latent measure of general mortality risk by dementia from age 60 onwards, has increased in most countries, although the intensity of this increase varies (Figure 3A in Appendix). Exceptions include Ireland (both sexes), men in Belgium, Norway, and Finland, and women in Austria, Sweden, and the UK, where mortality levels have decreased. These trends were projected using a linear time-series model, assuming the continuation of past trends into the future. Table 1 in the Appendix shows a structural break only for women in Australia, likely due to mortality variations during the COVID years. Since the study conducts a sensitivity test for the inclusion of pandemic years, it does not correct the historical series for this break; instead, it tests its effects later.

The βx parameter quantifies how mortality at each age x responds to changes in the overall mortality level (Figure 2A in Appendix). For countries experiencing an increase in the overall mortality level, positive βx values indicate a rise in dementia mortality within age group x. Conversely, negative βx values suggest that even as the overall dementia mortality for the population aged 60 and older increases, that specific age group experiences reductions in dementia mortality. Generally, in countries with increasing overall mortality, younger age groups, particularly those aged 60 to 64 (extending up to 75 for countries like France and Poland), show negative βx values. This indicates a decrease in dementia mortality for these groups, while dementia mortality for other age groups increases throughout the observed period. It is also notable that the βx parameter generally increases with age, signifying that dementia mortality has grown more pronounced in older age groups.

In countries where the overall mortality level decreases, positive βx values indicate a reduction in mortality for age group x. Conversely, negative βx values signify an increase in dementia mortality for that specific age group, despite a general decline in dementia mortality for the 60 and older population. For instance, among men in Belgium (a country with decreasing overall dementia mortality), the βx parameter is positive for ages 60 to 74, indicating a reduction in dementia mortality for these age groups during the observed period. However, for ages above 75, the βx parameter is negative, suggesting an increase in dementia mortality within these older age groups. Overall, in countries with decreasing overall dementia mortality, the βx parameter is generally negative and decreases with age, indicating that dementia mortality increased for older age groups in these countries.

Age-Specific Dementia Mortality Rates

Based on these parameters, it is possible to project age-specific dementia mortality rates (Figures 4A to 11A in Appendix). Among the youngest age group (60–64), rates remain relatively stable over time, with slight declines observed for men in Canada, Denmark, Finland, France, Germany, Ireland, Italy, New Zealand, Norway, Poland, Spain, Sweden, and Switzerland; and for women in Austria, Belgium, Canada, the Czech Republic, Japan, Italy, Finland, France, Germany, New Zealand, Norway, Poland, Spain, and Switzerland. Thus, no major changes in dementia mortality are expected for this age group in the coming decades.

For individuals aged 65–79, future changes in mortality rates are also relatively modest. Countries such as Australia, the Czech Republic, Ireland, Italy, Japan, the Netherlands, Sweden, the United Kingdom, and the United States show slight increases in dementia mortality for both sexes, while Poland, Spain, Finland, and France exhibit slight decreases across these age groups.

In contrast, starting at ages 80-84, a clear upward trend in dementia mortality rates is evident for most countries. The magnitude of this increase grows with age and reflects the combined effects of the βx and κt parameters. The most notable increases occur in Austria, Finland, the Czech Republic, Germany, New Zealand (especially among men), and Norway (among women).

Regarding sex differences, the predicted age-specific rates for women are higher than for men in most of the countries, although differences are not statistically significant except for the highest age group (95+). Finland and Japan are anomalies regarding the predicted sex differences with statistically significant higher mortality rates for men until age 80-84.

Age-Standardized Dementia Mortality Rates

Overall, all countries are projected to experience rising dementia mortality, with increases in age-standardized rates for both sexes (Figure 4; for other models see figures 12A and 13A in the Appendix). Countries with smaller projected increases include Australia, Belgium, France, Italy, Poland, and Spain. Meanwhile, larger increases are seen in the Czech Republic, followed by other countries such as Austria, Finland, Germany, Norway, and the UK.

Interestingly, the sharp rise in age-standardized dementia mortality in these latter countries is almost entirely driven by significant increases among the oldest age groups (85+). For example, Austria shows relatively stable mortality rates—or even slight declines—among younger age groups (60–79), but a marked increase among those aged 85 and over.

Sensitivity Analysis

The first sensitivity analysis aims to assess the predictive performance of each model used in projecting dementia mortality rates. To do so, age-specific projected rates are compared with observed rates from 2016 to 2019. Overall, the three models show good predictive accuracy, with mean square error (MSE) values close to zero (Table 1). However, the CoDA model, which produces more conservative estimates, shows slightly lower predictive performance compared to the others. It is also observed that the oldest age groups (85 years and over) tend to have higher MSE values, as do men compared to women.

The second sensitivity analysis aims to assess the impact of including the years 2020 to 2022—marked by changes in mortality patterns due to the COVID-19 pandemic—on projections of dementia mortality. Overall, incorporating the full historical series, including the pandemic years, results in slightly lower projected dementia mortality rates (Figure 5). However, this difference is not statistically significant. In addition, no substantial differences are observed by sex or by the models used.

DISCUSSION

This study highlights significant variability in dementia mortality trends across low-mortality countries, both historically and in future projections. Future projections generated by the CoDa model reflect the diversity of past trends, with most low-mortality countries expected to see an overall increase in dementia mortality. While all examined countries have seen increases in age-standardized dementia mortality over time, the rate of increase varies considerably. Notably, the Czech Republic, Japan, and Poland have consistently reported the lowest age-standardized rates, with Poland, France, Spain, and Belgium showing the smallest historical increases. Conversely, Finland, the United States, the UK, the Netherlands, and Germany experienced the most pronounced increases. Our projections indicate that most countries will continue to see a rise in age-standardized dementia mortality, with Austria, Finland, the Czech Republic, and Germany projected for the largest increases. Critically, these overall increases are primarily driven by a substantial rise in dementia mortality among individuals aged 80 and over, while younger age groups (60–64 and 65–69) show either stable rates or slight declines, with the exception of women in New Zealand (65-69) and both sexes in the US.

While some studies lean towards an optimistic outlook for future dementia trends (Prince et al., 2016), our findings suggest a more heterogeneous future, where significant increases in dementia mortality for the very old will likely drive up overall burdens in many countries. Our findings resonate with the broader discourse on shifting mortality patterns in high-income countries, where a decline in cardiovascular deaths has coincided with a rise in conditions associated with advanced age, such as dementia (Vallin & Meslé, 2004, 2006; Pritchard et al., 2004; Mackenbach et al., 2014). The observed historical increases in dementia mortality across most countries align with initial concerns about dementia's growing contribution to overall mortality, echoing early warnings of a potential "pandemic" of mental disorders (Gruenberg, 1978; Kramer, 1980). However, our study also captures the more recent nuances reported by Prince et al. (2016) and others, where some countries exhibit stabilizing overall dementia mortality levels. This aligns with the hypothesis that factors like increased educational attainment and improved cognitive reserve may offer protective effects (Schrijvers et al., 2012; Qiu et al., 2013; Prince et al., 2016).

The Compositional Data Analysis (CoDA) model provides a coherent framework for understanding these trends, particularly the redistribution of mortality across age groups. Unlike deterministic models, CoDA inherently accounts for the compositional nature of life table deaths, ensuring that age-specific projections remain consistent with overall mortality. Additionally, the detailed age-specific insight offers a more nuanced understanding than studies solely focused on overall trends. However, this study has a few limitations that you should consider. First, the historical series for each country differs, which might affect the comparability of the results. Second, the reliance on ICD-10 coding restricts the historical data available, as earlier ICD-9 classifications do not allow for clear distinctions between dementia categories (Quan et al., 2005). This shortens the historical series, preventing a longer-period sensitivity analysis. Finally, the CoDA model, while robust for handling compositional data, comes with its own methodological assumptions and constraints. Specifically, the model primarily relies on extrapolating observed historical trends and does not inherently incorporate alternative future scenarios or exogenous factors beyond the data's historical patterns.

Implications for Public Health and Policy

The projected increase in dementia mortality across most low-mortality countries, especially the dramatic rise among the oldest age groups, presents a substantial public health challenge. This finding underscores the urgent need for proactive planning in healthcare systems to accommodate the growing burden of dementia, particularly in countries projected for the largest increases like Austria, Finland, the Czech Republic, and Germany. Policymakers must anticipate increased demands for specialized dementia care services, long-term care facilities, and palliative care tailored for very elderly populations. The sustained, and in some cases declining, mortality rates among younger age groups (60-79) suggest that interventions focused on delaying onset or preventing dementia earlier in life may be having some effect. This highlights the importance of continuing public health initiatives promoting cognitive health and potentially expanding educational attainment, as identified in existing literature, to further bolster cognitive reserve. Ultimately, these projections serve as an important tool for national health authorities to refine their strategies for dementia prevention, care, and resource allocation, fostering more resilient and prepared healthcare systems for an aging population.

CONCLUSION

This study, employing the CoDA model, provides probabilistic projections of dementia mortality, revealing a complex and varied future across 21 low-mortality countries. While most countries face a projected increase in age-standardized dementia mortality, particularly among the oldest age groups (80+), some demonstrate stable overall mortality levels. These findings underscore the ongoing epidemiological shift towards dementia as a leading cause of death, particularly impacting the very elderly. The growing concentration of dementia mortality in advanced ages necessitates urgent and tailored public health and policy responses. Governments and healthcare systems must strategically plan for increased demand for dementia care services, resource allocation, and support for aging populations. Addressing existing sex disparities and investing in preventive measures that promote cognitive health across the lifespan will also be critical. Ultimately, accurate and coherent projections, like those presented here, are indispensable tools for developing evidence-based strategies to mitigate the societal burden of dementia in the coming decades.

REFERENCES

Alzheimer Europe. Dementia in Europe Yearbook 2019: Estimating the prevalence of dementia in Europe. (Alzheimer Europe, Luxembourg, 2020).

Bergeron-Boucher, M. P., Canudas-Romo, V., Oeppen, J., & Vaupel, J. W. (2017). Coherent forecasts of mortality with compositional data analysis. *Demographic Research*, *37*, 527-566.

Gruenberg EM: Epidemiology of senile dementia. Adv Neurol 1978, 19:437–457. Epub 1978/01/01.

Kjærgaard, S∅ ren, et al. "Forecasting causes of death by using compositional data analysis: the case of cancer deaths." *Journal of the Royal Statistical Society: Series C (Applied Statistics)* (2019).

Kramer M: The rising pandemic of mental disorders and associated chronic diseases and disabilities. Acta Psychiatr Scand 1980, 62(Suppl. 285):282–297.

Lee, Ronald D.; Carter, Lawrence R. Modeling and forecasting US mortality. Journal of the American statistical association, v. 87, n. 419, p. 659-671, 1992.

Meslé F, Vallin J: Diverging trends in female old-age mortality: the United States and the Netherlands versus France and Japan. Popul Dev Rev 2006,32(1):123–145.

Livingston, G. *et al.* Dementia prevention, intervention, and care: 2020 report of the Lancet Commission. *Lancet* **396**, 413-446, https://doi.org/10.1016/S0140-6736(20)30367-6 (2020).

Li, X. *et al.* Global, regional, and national burden of Alzheimer's disease and other dementias, 1990–2019. *Frontiers in Aging Neuroscience* **14**, https://doi.org/10.3389/fnagi.2022.937486 (2022).

Lloyd, C.D., Pawlowsky-Glahn, V., and Egozcue, J.J. (2012). Compositional data analysis in population studies. Annals of the Association of American Geographers 102(6): 1251–1266. doi:10.1080/00045608.2011.652855.

Oeppen, J. (2008). Coherent forecasting of multiple-decrement life tables: A test using Japanese cause of death data. Paper presented at the European Population Conference 2008, Barcelona, Spain, July 9–12, 2008.

Olshansky, S. J. & Ault, A. B. The fourth stage of the epidemiologic transition: The age of delayed degenerative diseases. *The Milbank Memorial Fund Quarterly* **64**, 353-391 (1986).

Pritchard C, Baldwin D, Mayers A: Changing patterns of adult (45–74 years) neurological deaths in the major Western world countries 1979–1997. Public Health 2004, 118(4):268–283. Epub 2004/05/04.

Prince, M., Ali, G. C., Guerchet, M., Prina, A. M., Albanese, E., & Wu, Y. T. (2016). Recent global trends in the prevalence and incidence of dementia, and survival with dementia. *Alzheimer's research & therapy*, *8*, 1-13.

Qiu C , Von Strauss E , Bäckman L , Winblad B , Fratiglionis L ((2013)) Twenty-year changes in dementia occurrence suggest decreasing incidence in central Stockholm, Sweden. Neurology 80: , 1888–1894.

Quan, H., Sundararajan, V., Halfon, P., Fong, A., Burnand, B., Luthi, J. C., ... & Ghali, W. A. (2005). Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Medical care*, *43*(11), 1130-1139.

Santosa, A., Wall, S., Fottrell, E., Högberg, U., & Byass, P. (2014). The development and experience of epidemiological transition theory over four decades: a systematic review. *Global health action*, *7*(1), 23574.

Schrijvers EMC , Verhaaren BFJ , Koudstaal PJ , Hofman A , Ikram MA , Breteler MMB ((2012)) Is dementia incidence declining? Trends in dementia incidence since 1990 in the Rotterdam Study. Neurology 78: 1456–1463.

Vallin J, Mesle F: Convergences and divergences in mortality. A new approach to health transition. Demographic Res 2004, 2:11–44. SPECIAL COLLECTION 2, ARTICLE

Taudorf, L., Nørgaard, A., Waldemar, G., & Laursen, T. M. (2021). Mortality in dementia from 1996 to 2015: a national registry-based cohort study. *Journal of Alzheimer's Disease*, *79*(1), 289-300.

Takasugi T., Tsuji T., Hanazato M., Miyaguni Y., Ojima T., Kondo K. (2021). Community-level educational attainment and dementia: a 6-year longitudinal multilevel study in Japan. BMC geriatrics, 21(1), 661. doi:10.1186/s12877-021-02615-x

Wilmoth, John R. Are mortality projections always more pessimistic when disaggregated by cause of death? Mathematical Population Studies, v. 5, n. 4, p. 293-319, 1995.

FIGURES

Figure 1. Observed Age-Standardized Dementia Mortality Rates – Low mortality countries, both sexes (2000, 2010 and 2019)

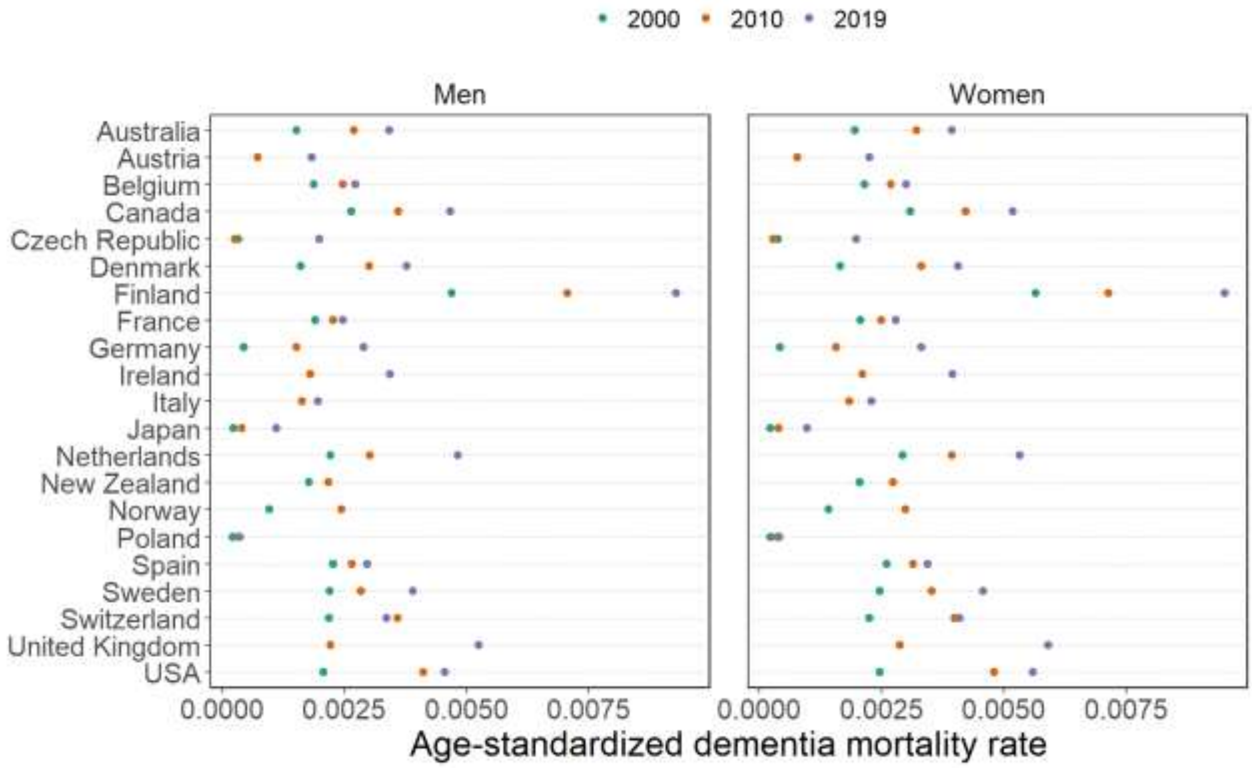


Figure 2. Observed Age-Specific Dementia Mortality Rates – Low mortality countries, men

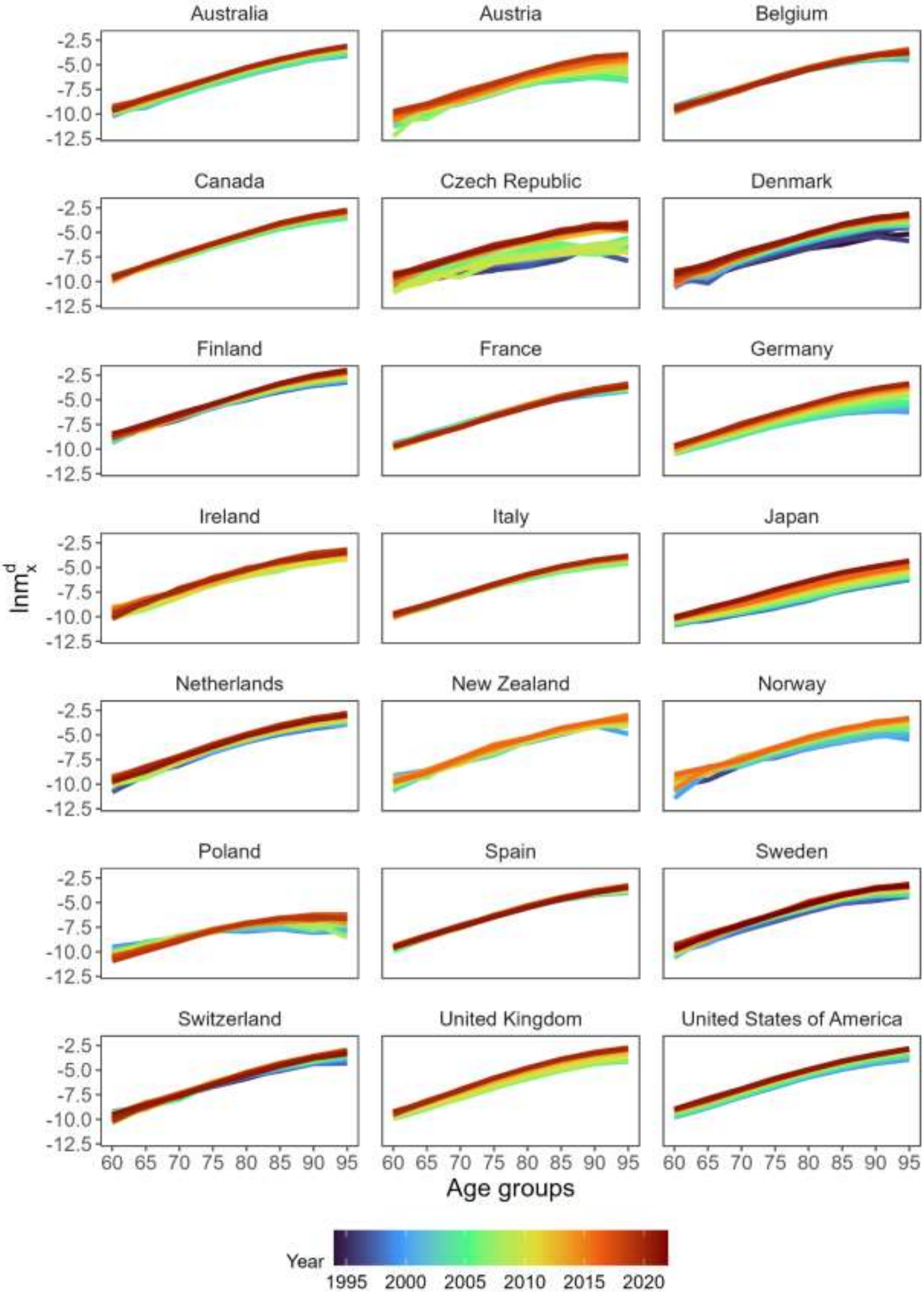


Figure 3. Observed Age-Specific Dementia Mortality Rates – Low mortality countries, women

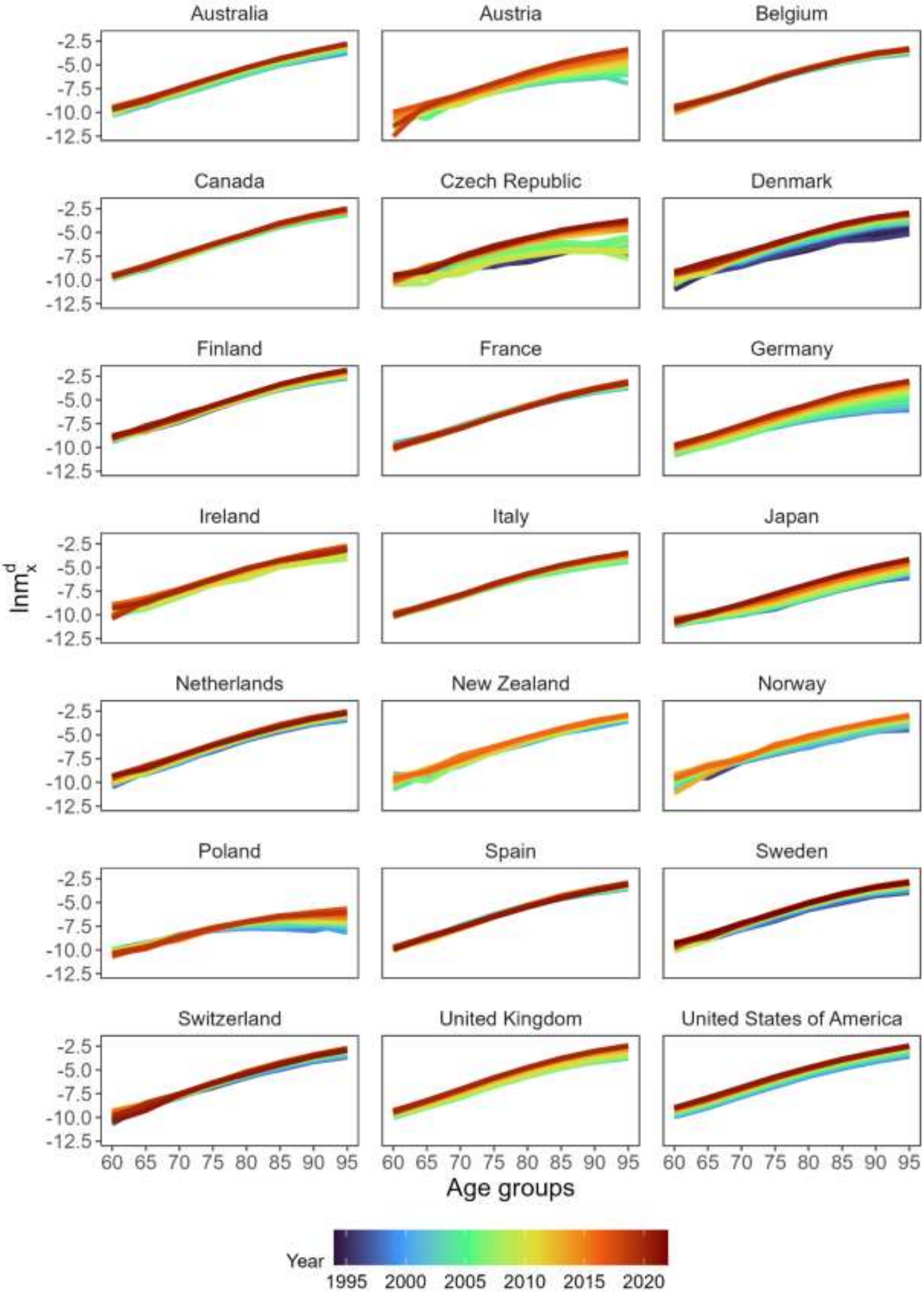


Figure 4. Age-Standardized Dementia Mortality Rates – Low mortality countries, both sexes (observed and forecasted up to 2050)

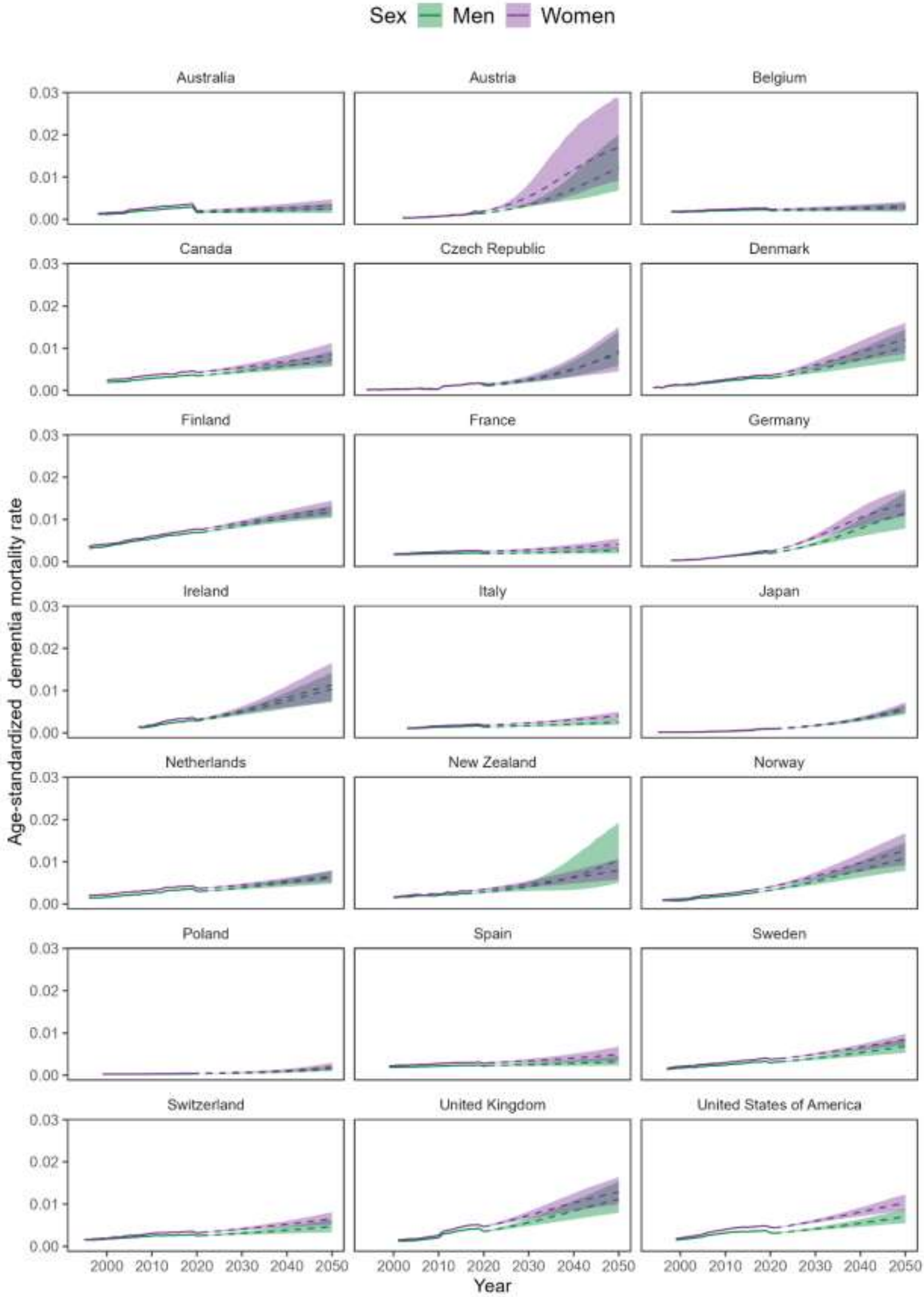
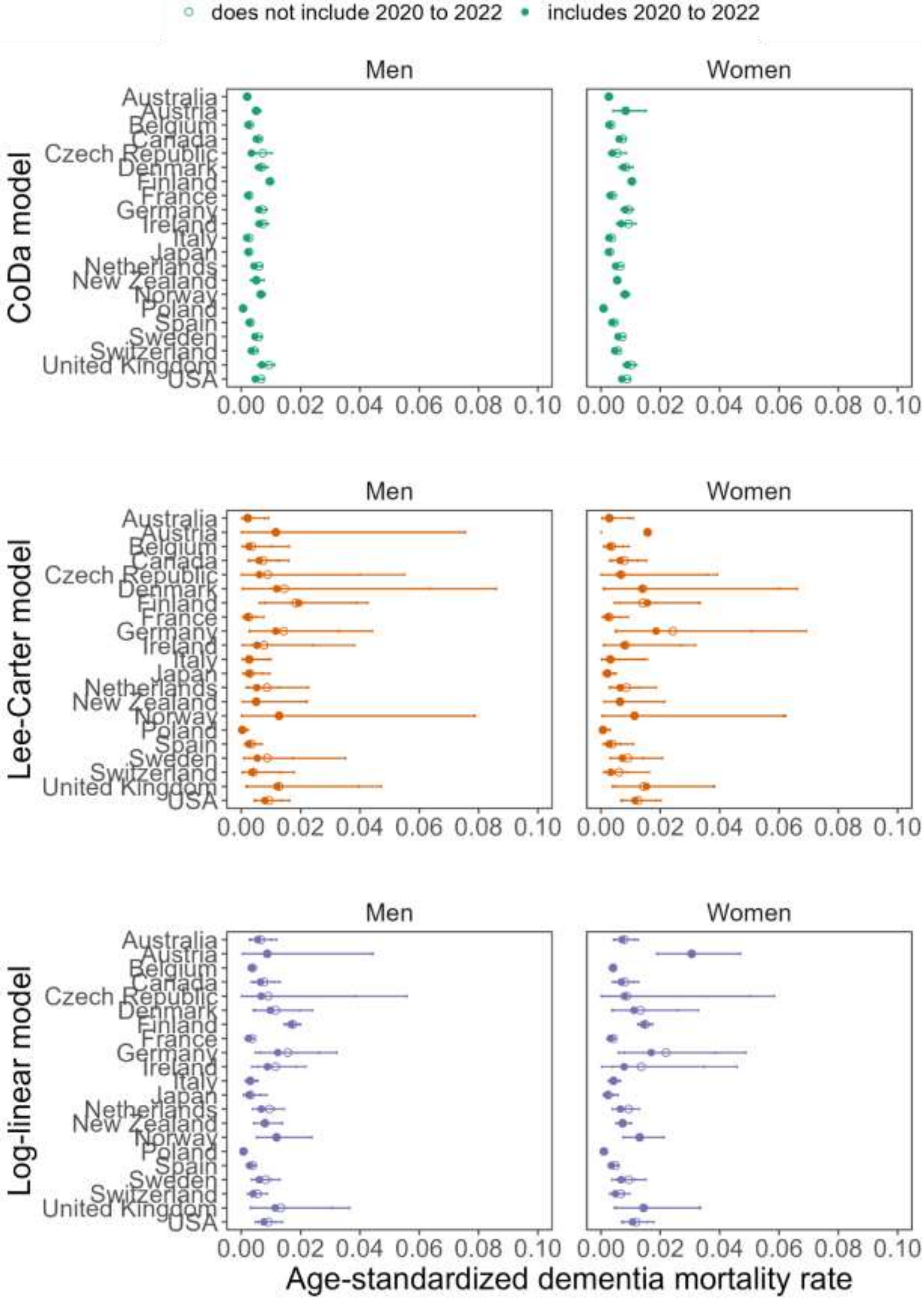


Table 1. Mean Square Error (MSE*100) of Age-Specific Dementia Mortality Projections by Model, Age Group, and Sex (2016-2019)

	Men			Women		
Age group	**Arima**	**Lee-Carter**	**CoDa**	**Arima**	**Lee-Carter**	**CoDa**
60-64 years old	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
65-69 years old	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
70-74 years old	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
75-79 years old	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
80-84 years old	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001
85-89 years old	0.0002	0.0003	0.0004	0.0002	0.0003	0.0003
90-94 years old	0.0010	0.0014	0.0017	0.0012	0.0023	0.0024
95 years old or more	0.0045	0.0065	0.1452	0.0066	0.0133	0.1144
Total	0.0007	0.0010	0.0184	0.0010	0.0020	0.0147

Figure 5. Comparison of Projected Age-Standardized Dementia Mortality Rates in 2035: Full Historical Series vs. Excluding 2020-2022 - – Low mortality countries, both sexes



APPENDIX

Table 1A. Chow Test Results for Structural Breaks in the Overall Mortality Level (κt) Series – Low mortality countries, both sexes

	Women		Men	
	P-valor	Sig.	P-valor	Sig.
Australia	0.0783	*	0.4518	NS
Austria	0.5797	NS	0.7859	NS
Belgium	0.3163	NS	0.2014	NS
Canada	0.7627	NS	0.7512	NS
Czech Republic	0.2771	NS	0.1698	NS
Denmark	0.4168	NS	0.3681	NS
Finland	0.4652	NS	0.1209	NS
France	0.4296	NS	0.6361	NS
Germany	0.4016	NS	0.4437	NS
Ireland	0.6456	NS	0.6381	NS
Italy	0.6456	NS	0.6686	NS
Japan	0.3437	NS	0.6929	NS
Netherlands	0.2536	NS	0.1989	NS

Figure 1A. Average Age Pattern of Dementia Mortality (αx) estimated by CoDA model – Low mortality countries, both sexes

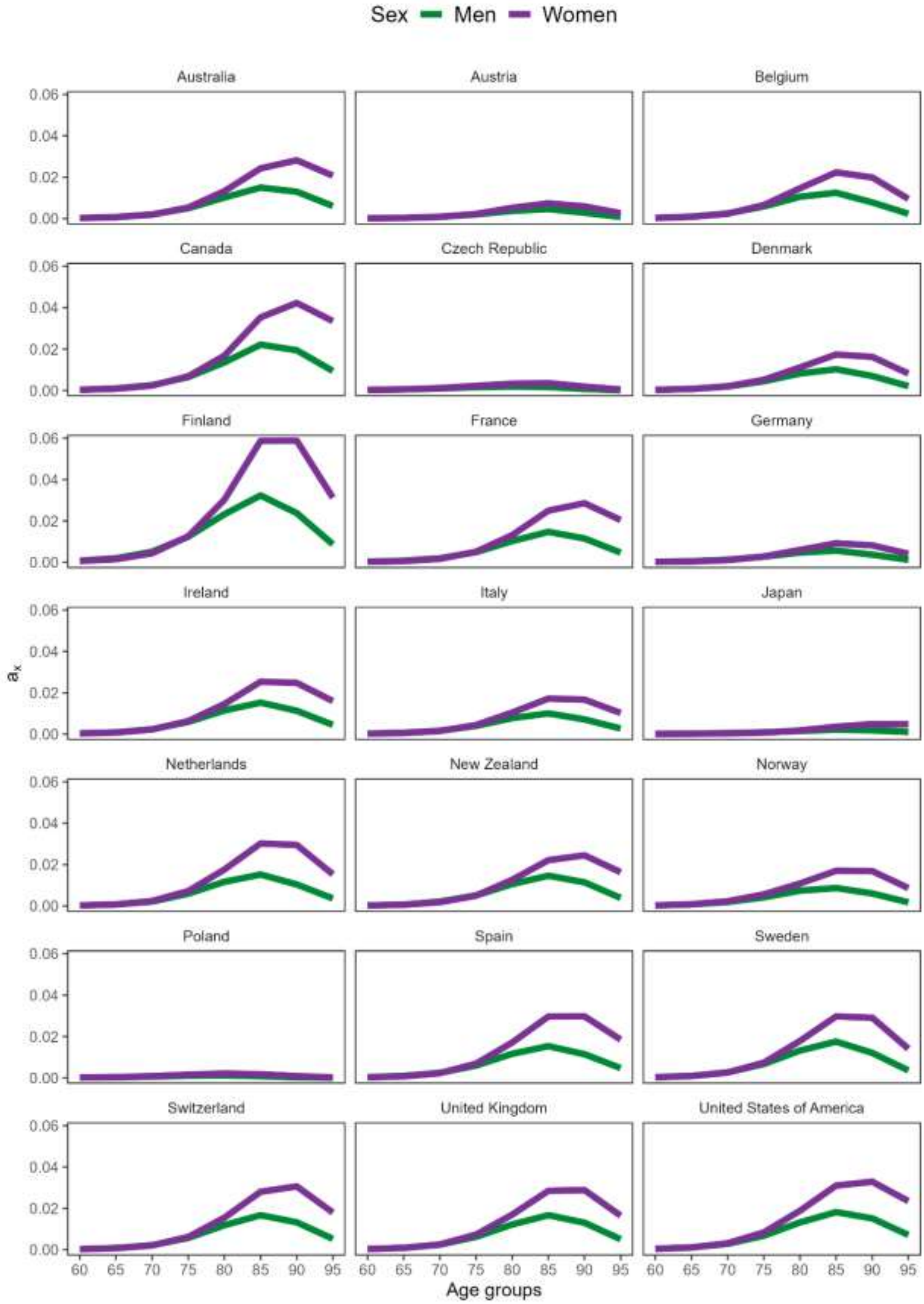


Figure 2A. Age-Specific Sensitivity to Changes in Overall Dementia Mortality (βx) estimated by CoDA model – Low mortality countries, both sexes

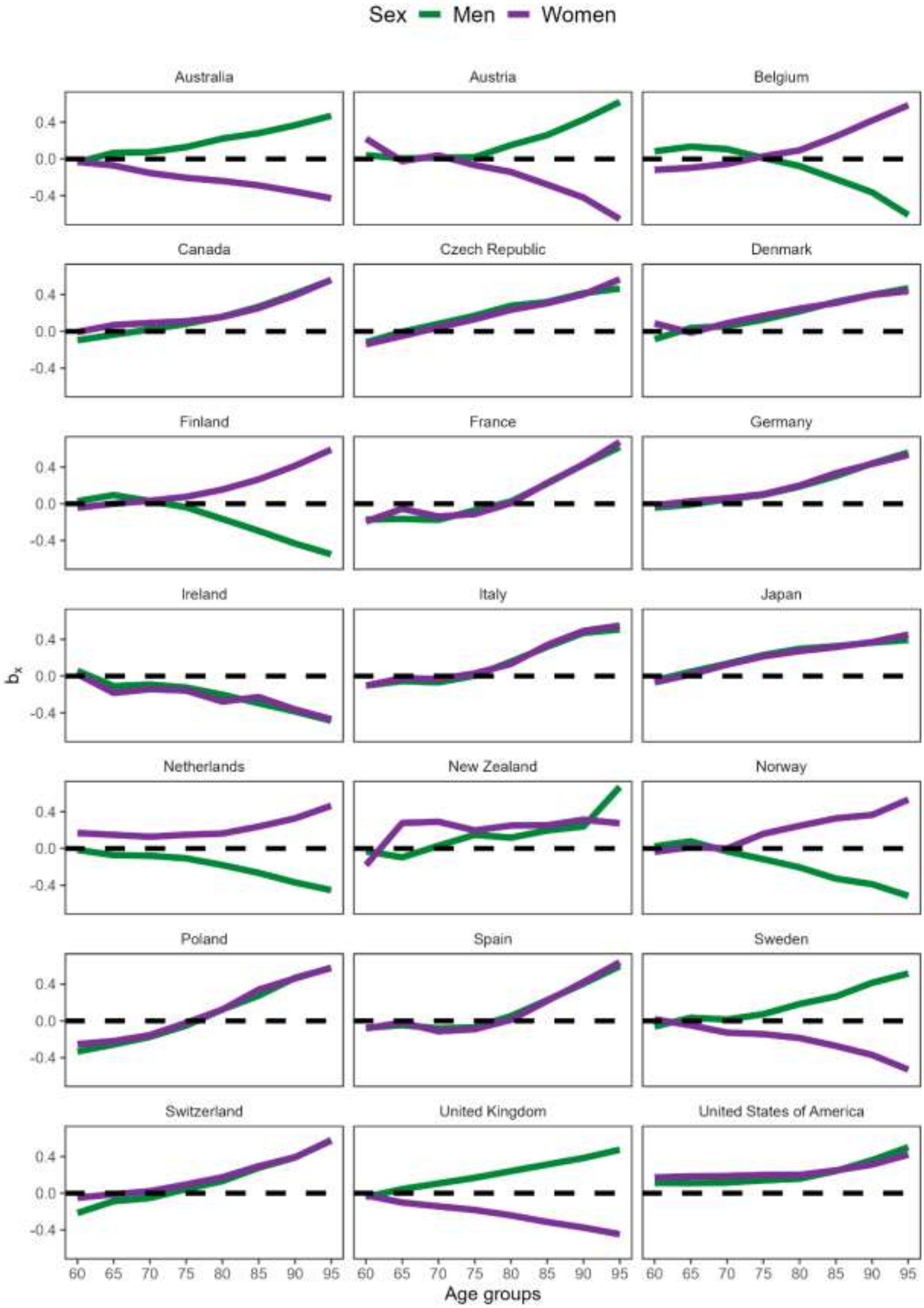


Figure 3A. Observed and Projected Overall Level of Dementia Mortality (κt) estimated by CoDA model – Low mortality countries, both sexes

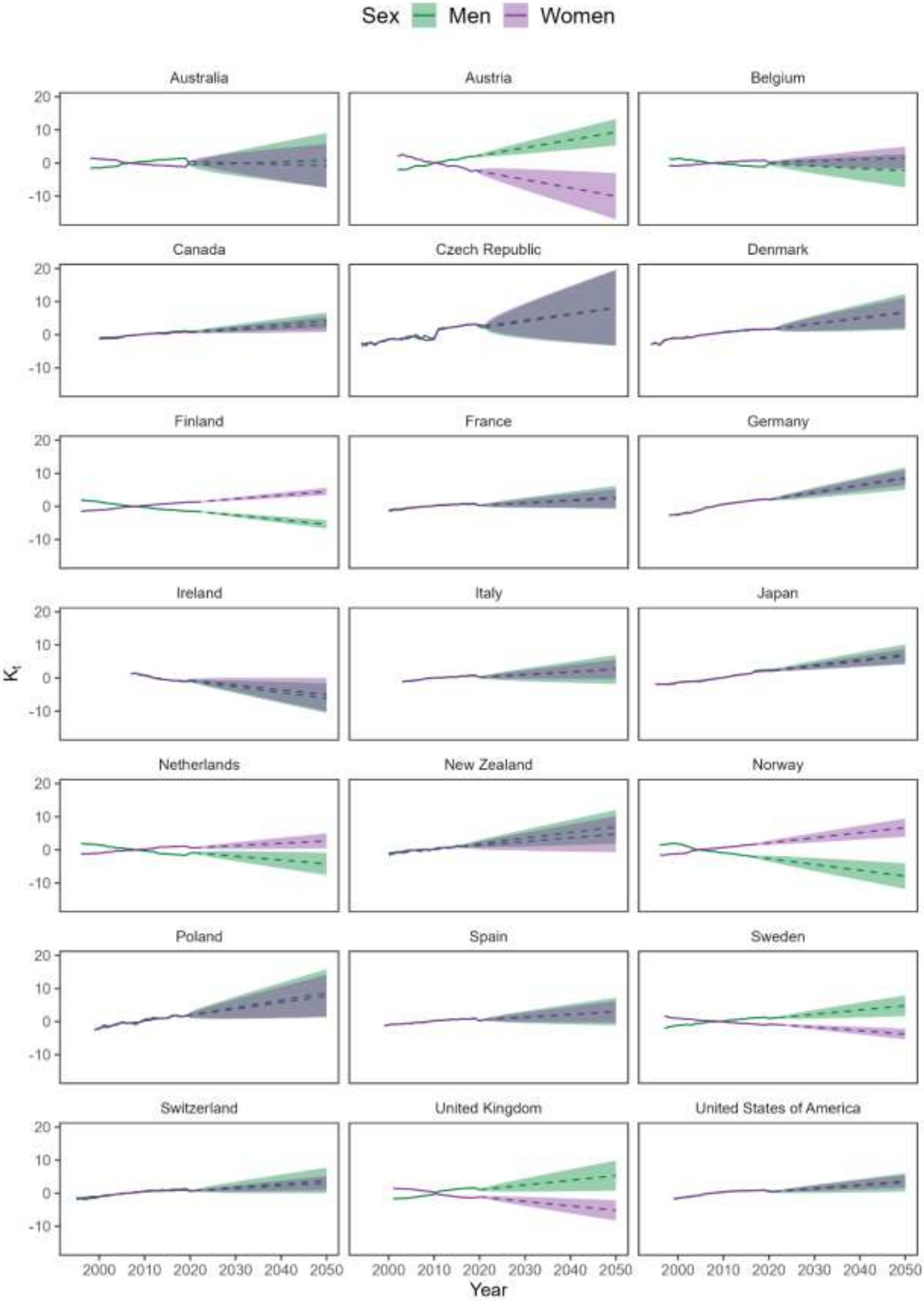


Figure 4A. Dementia Mortality Rates from 60 to 64 years old – Low mortality countries, both sexes (observed and forecasted up to 2050)

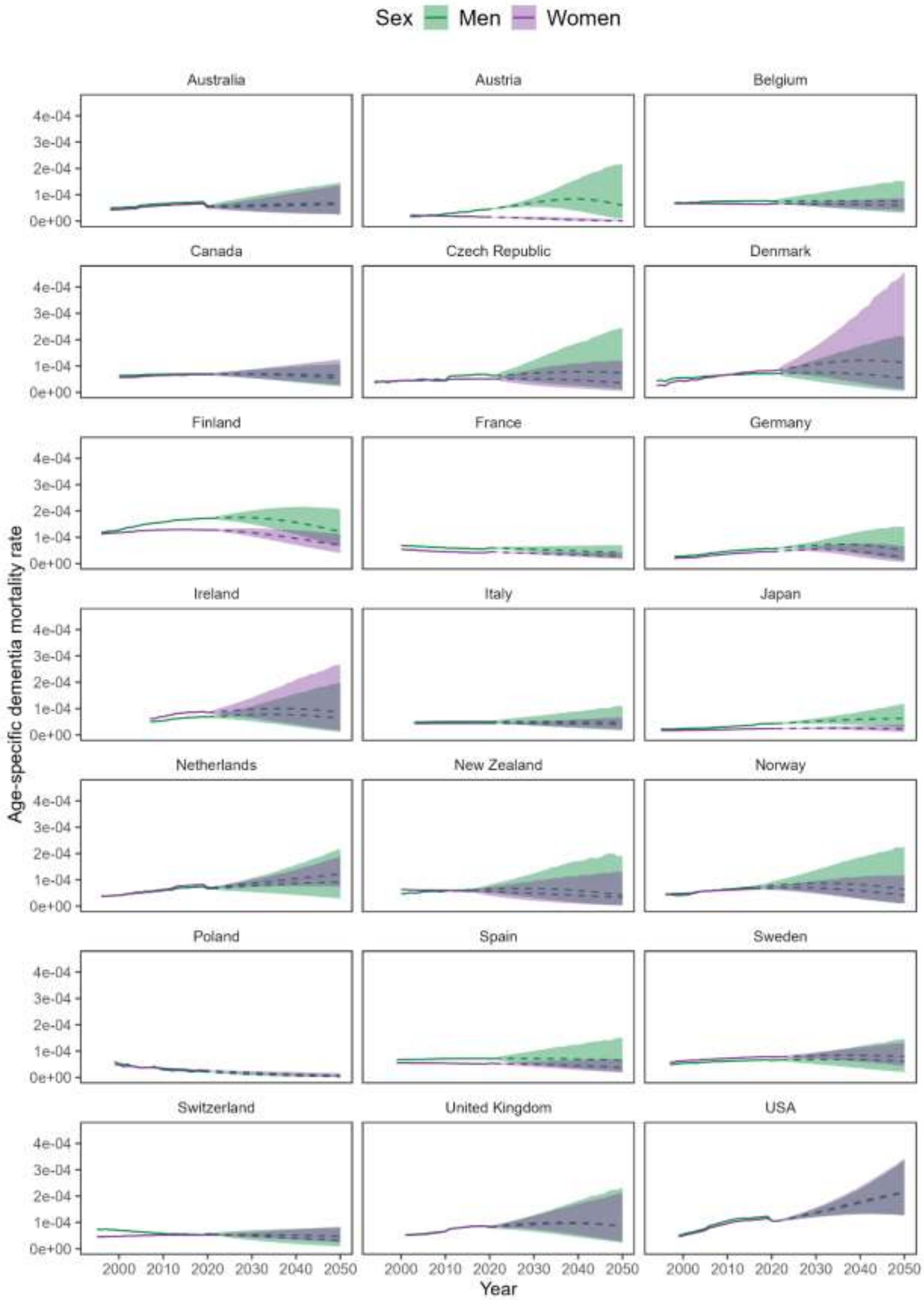


Figure 5A. Dementia Mortality Rates from 65 to 69 years old – Low mortality countries, both sexes (observed and forecasted up to 2050)

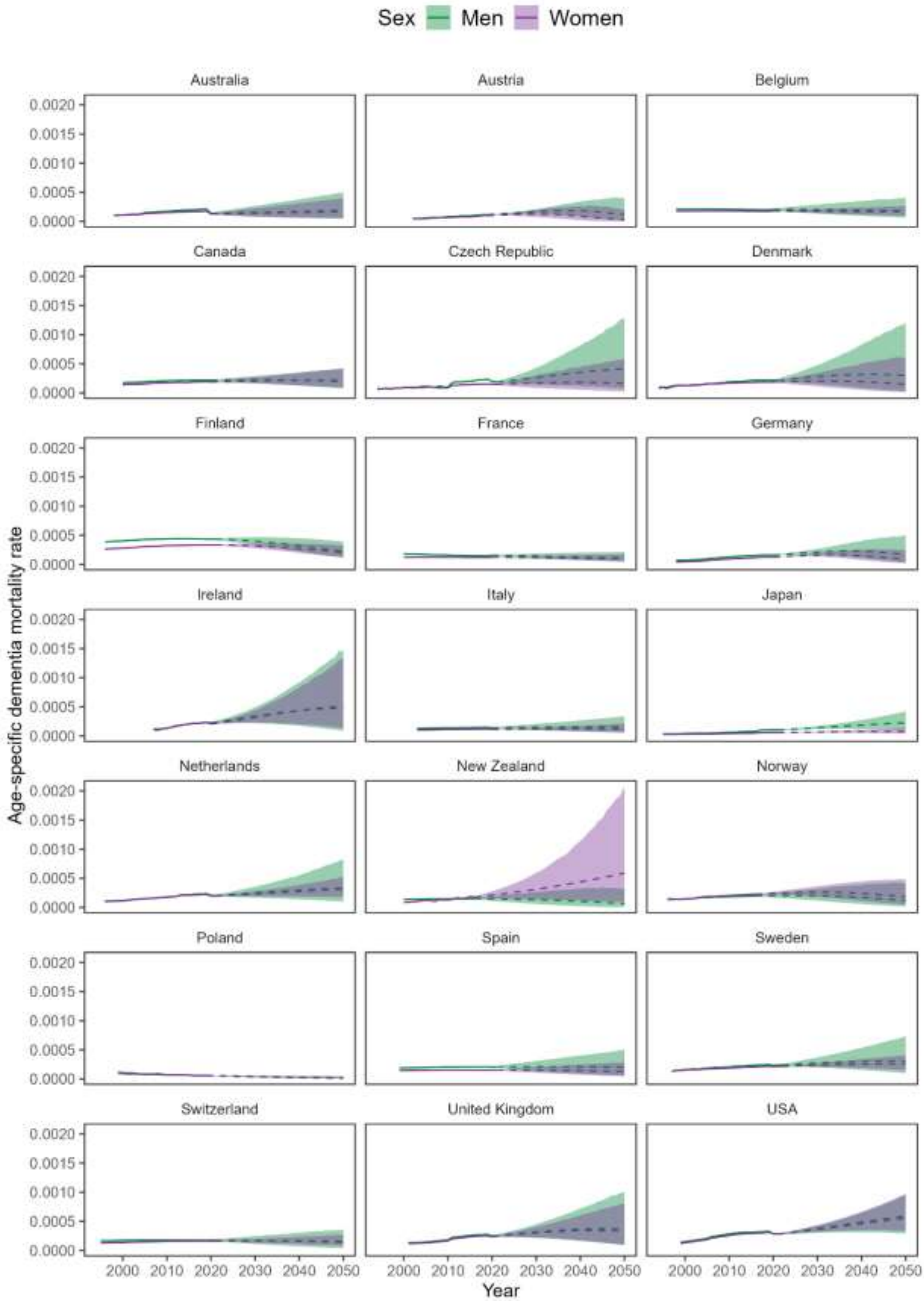


Figure 6A. Dementia Mortality Rates from 70 to 74 years old – Low mortality countries, both sexes (observed and forecasted up to 2050)

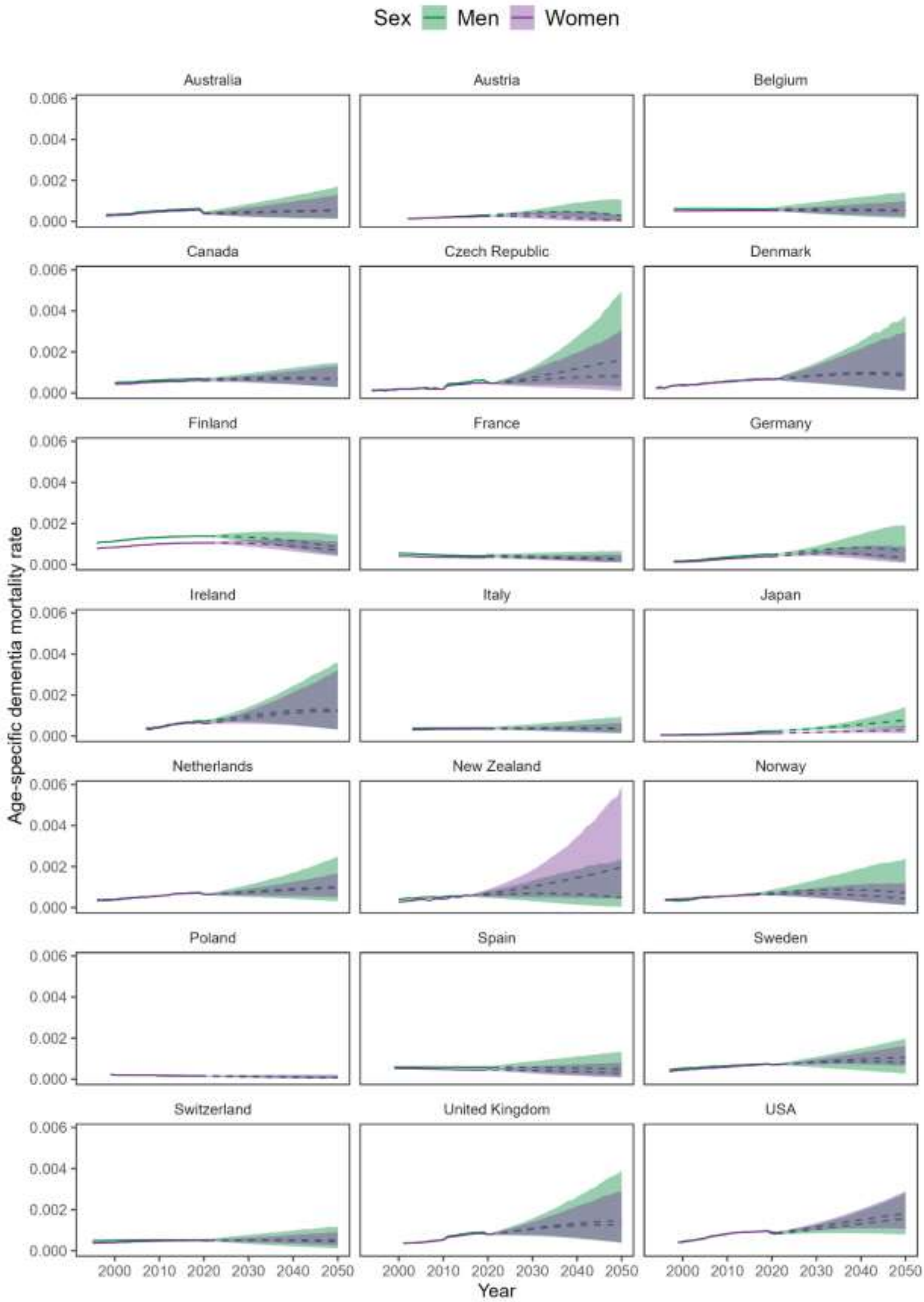


Figure 7A. Dementia Mortality Rates from 75 to 79 years old – Low mortality countries, both sexes (observed and forecasted up to 2050)

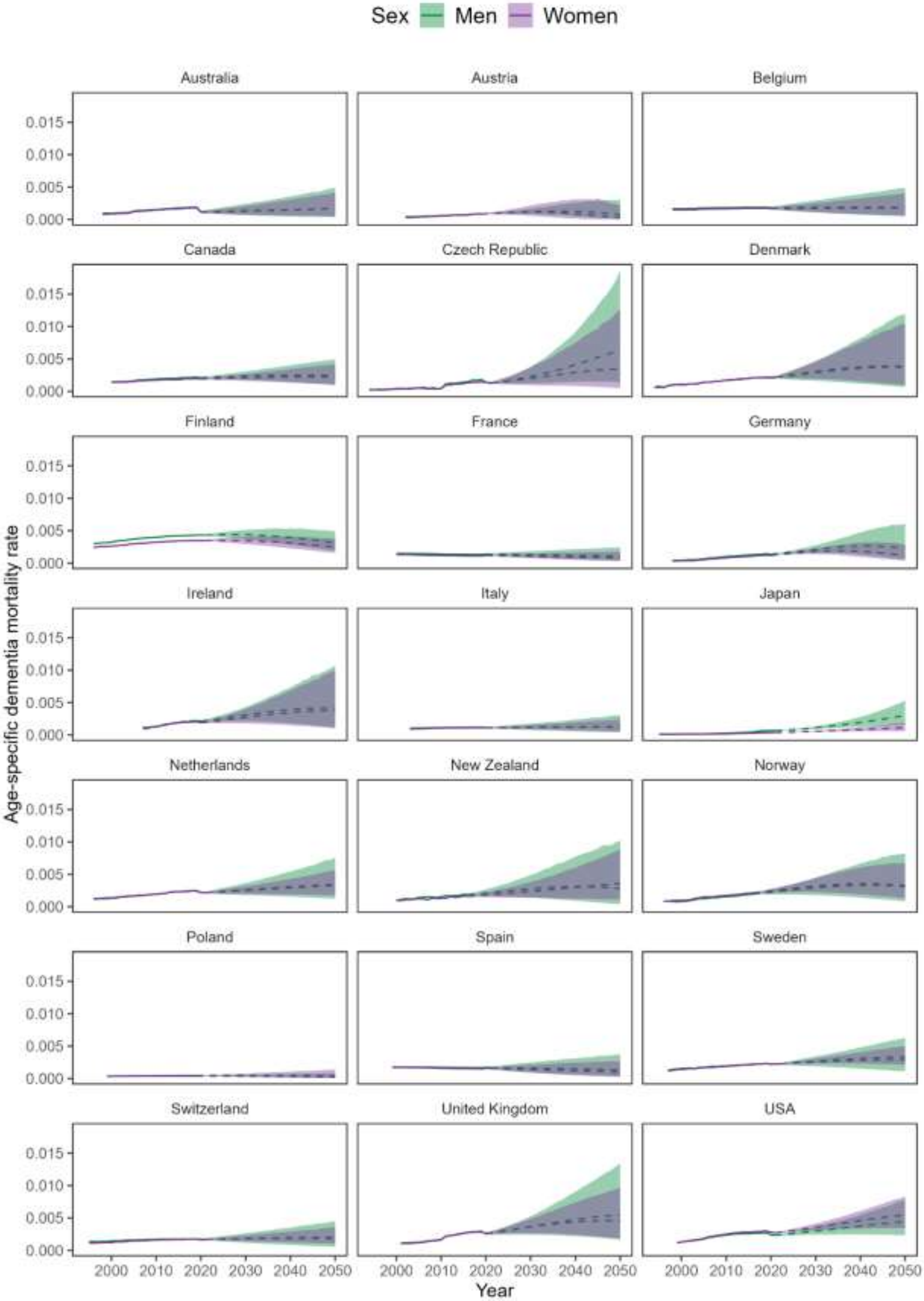


Figure 8A. Dementia Mortality Rates from 80 to 84 years old – Low mortality countries, both sexes (observed and forecasted up to 2050)

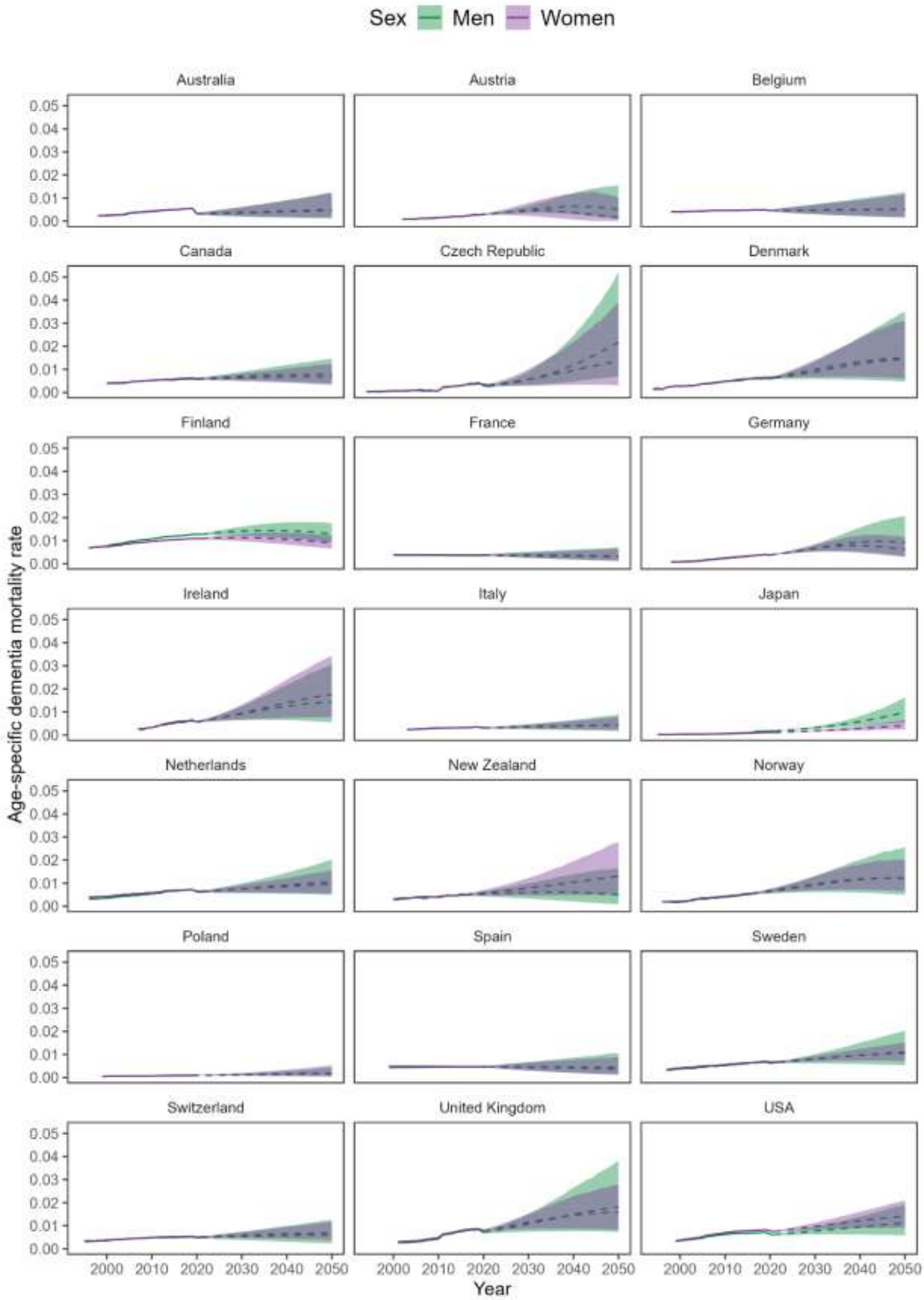


Figure 9A. Dementia Mortality Rates from 85 to 89 years old – Low mortality countries, both sexes (observed and forecasted up to 2050)

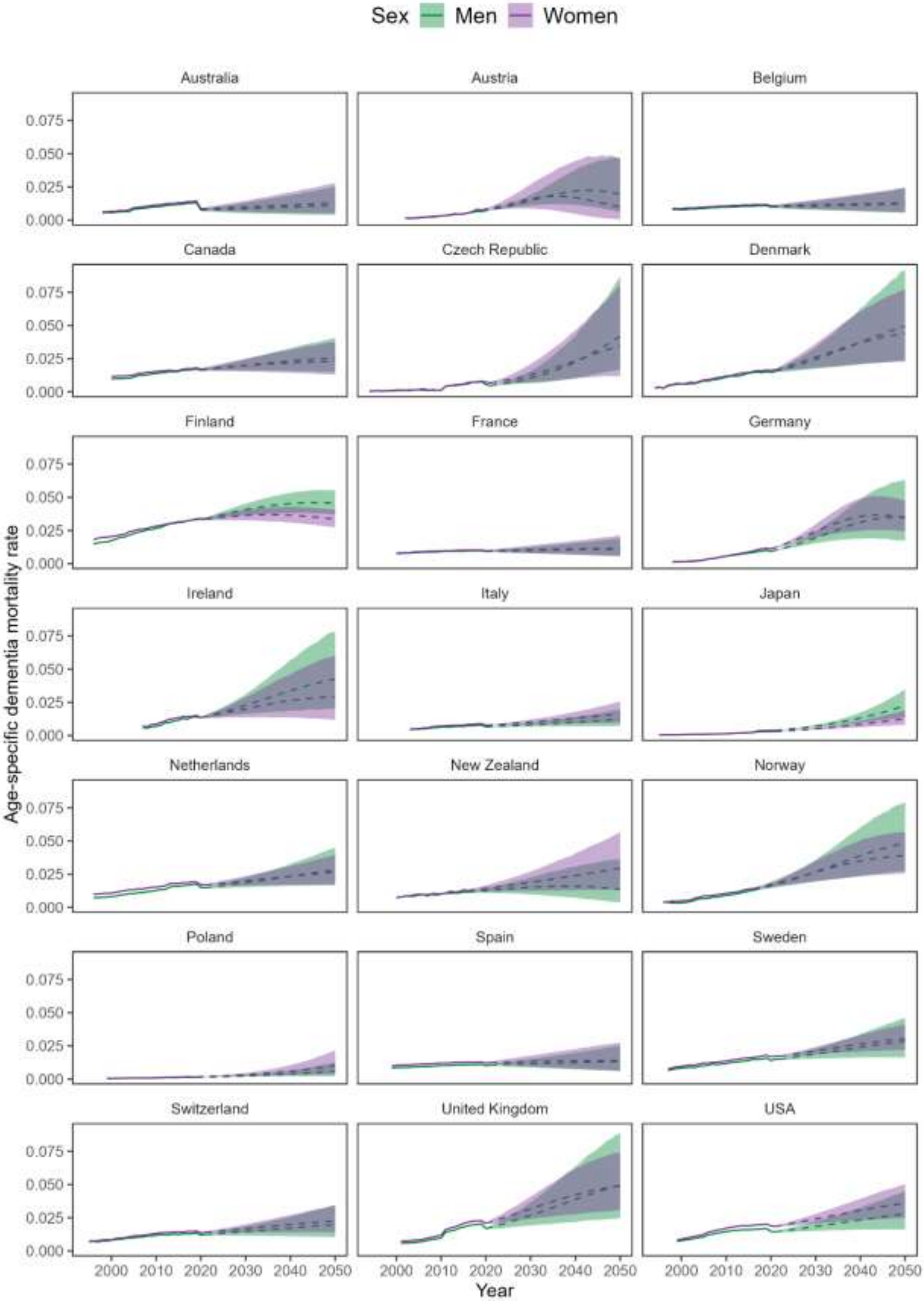


Figure 10A. Dementia Mortality Rates from 90 to 94 years old – Low mortality countries, both sexes (observed and forecasted up to 2050)

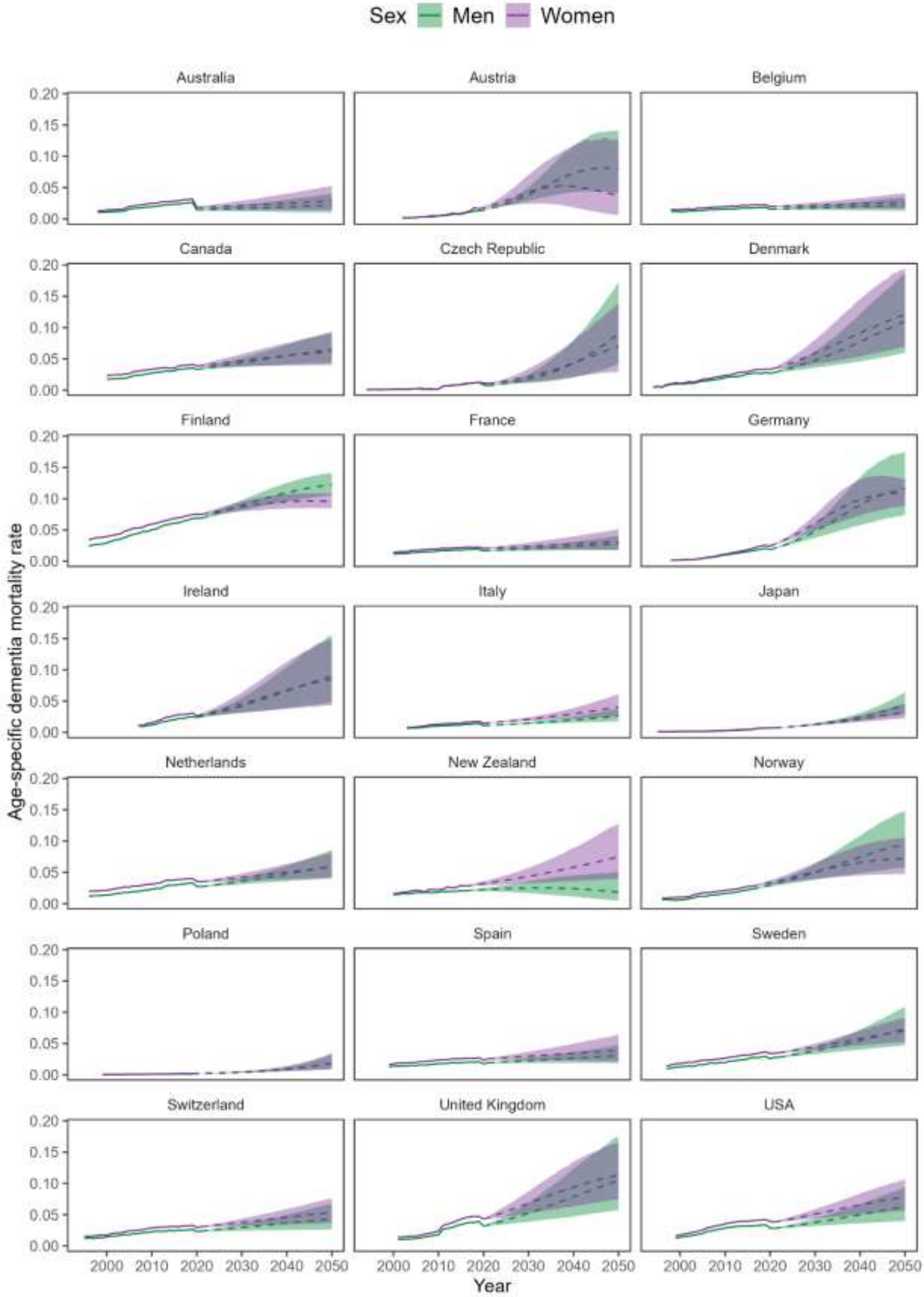


Figure 11A. Dementia Mortality Rates over 95 years old – Low mortality countries, both sexes (observed and forecasted up to 2050)

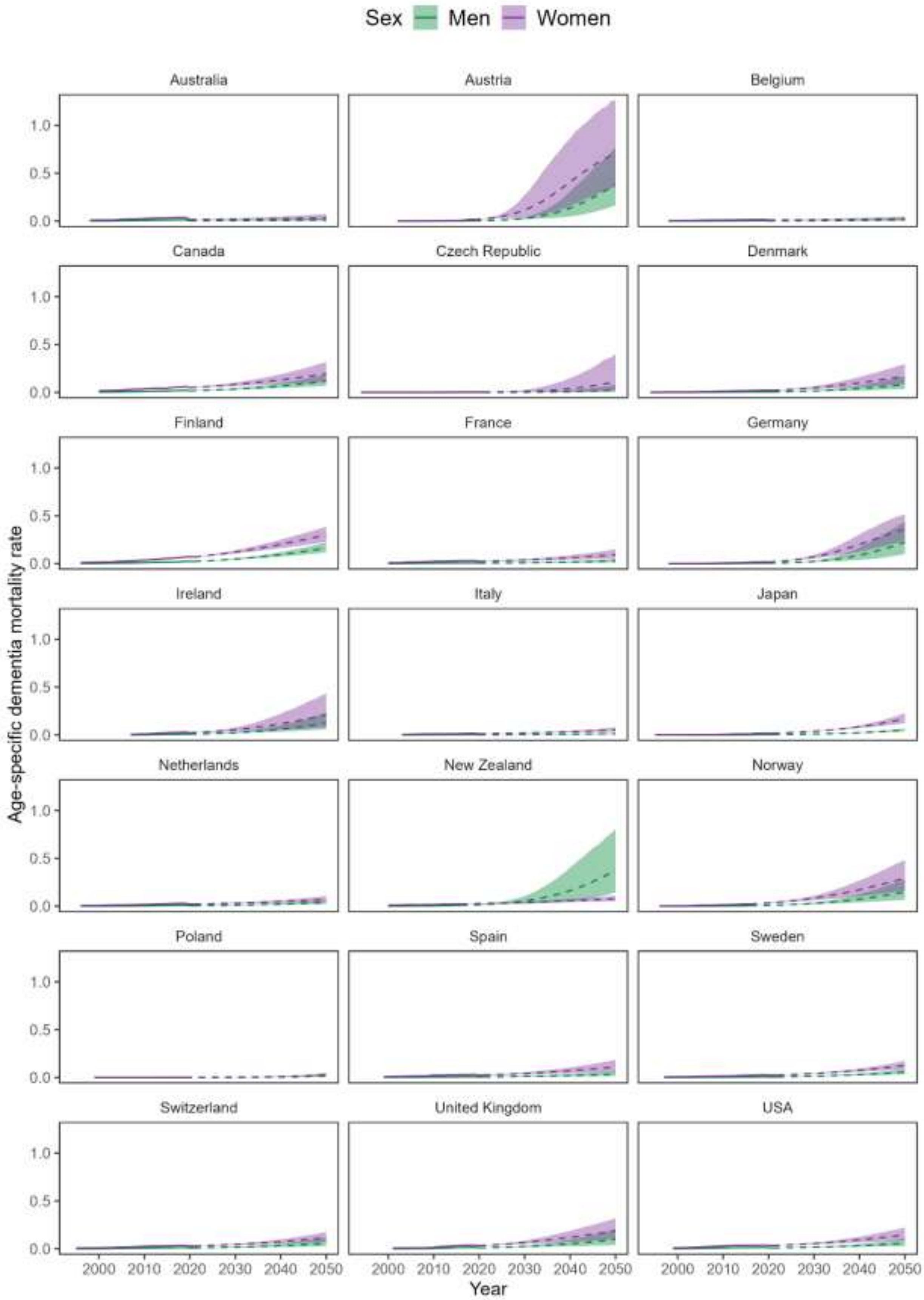


Figure 12A. Age-Standardized Dementia Mortality Rates using 3 different forecasting models – Low mortality countries, men (observed and forecasted up to 2050)

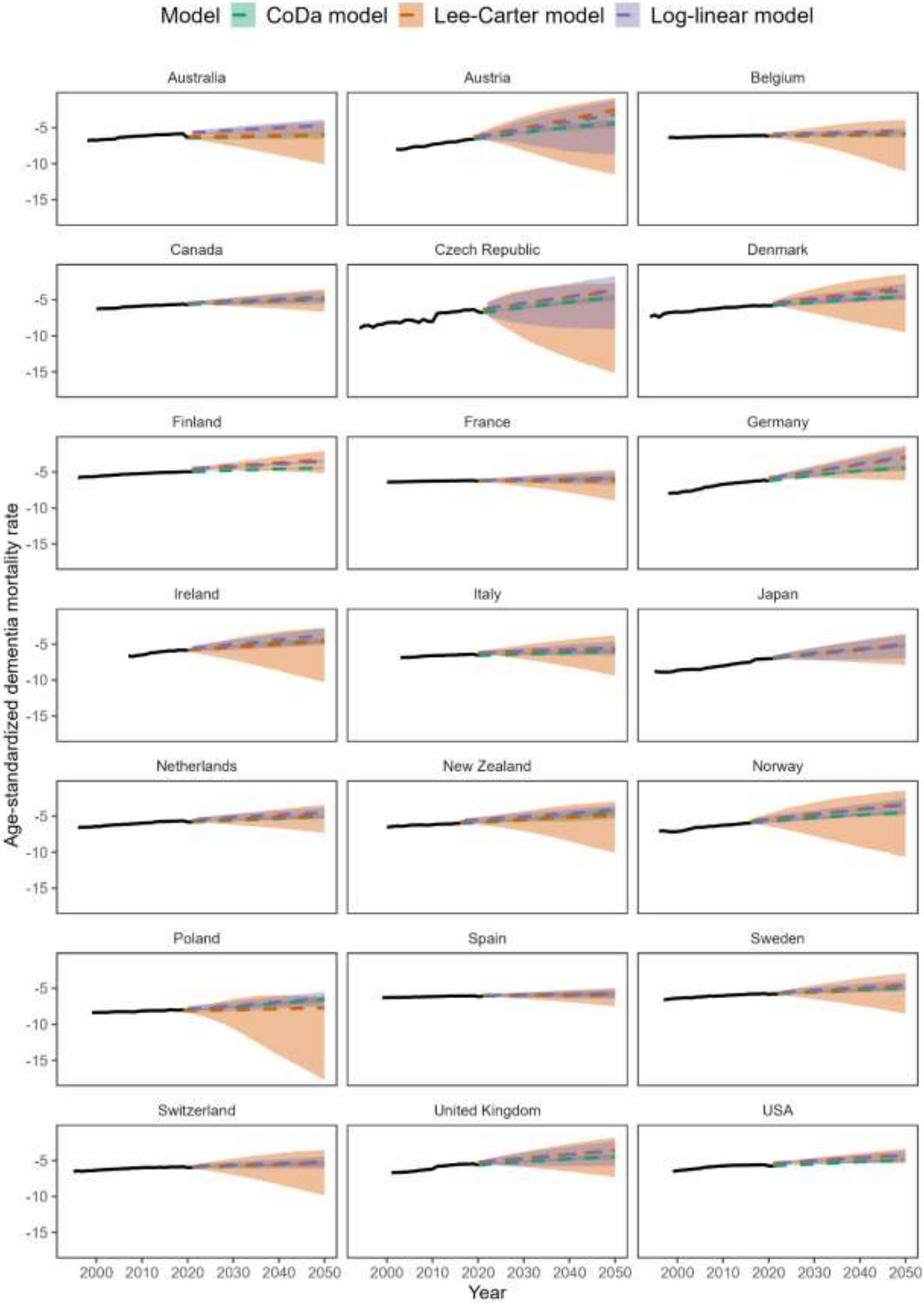


Figure 13A. Age-Standardized Dementia Mortality Rates using 3 different forecasting models – Low mortality countries, women (observed and forecasted up to 2050)