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International excess mortality

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This working paper was originally issued in October 2023. This version corrects a minor typo in Section 3.7.

Summary

In response to the COVID-19 pandemic, the CMI has been publishing weekly analysis of excess mortality in England & Wales and the United Kingdom in its “mortality monitor”. Excess mortality is defined as the difference between actual and expected mortality.

This paper extends that analysis to other countries, based on the “short-term mortality fluctuations” (STMF) dataset from the Human Mortality Database (HMD), which includes weekly deaths and mortality rates for 38 international territories (of which we include 24 in the analysis).

Method

We calculate approximate age-standardised mortality rates (ASMRs) for 24 of the 38 international territories covered by the STMF and use these to calculate weekly excess mortality and cumulative excess mortality. The measure of expected mortality (in the calculation of excess mortality) is set as the fitted ASMR in 2019 based on the trend in annual ASMRs for the period 2010 to 2019 (except for four territories for which we use a shorter period to 2019*) and allowing for a seasonality effect using weekly ASMRs in the same period.

Results

When we compare weekly excess mortality for the 24 international territories we observe:

- A clear “first wave” peak can be seen in the second quarter of 2020 for Belgium, England & Wales, France, Italy*, Netherlands, Scotland, Spain, Sweden, Switzerland and the USA*. The highest peak is for Spain with 148% excess weekly mortality (i.e. mortality more than twice as high as expected) in week 14 of 2020.
- Eastern European territories (Bulgaria, Czech Republic, Lithuania, Poland, Russia and Slovakia) tended to have relatively low excess mortality in the second quarter of 2020.
- High excess mortality can be observed for several countries in early 2021, including Bulgaria, Czech Republic, England & Wales, Lithuania, Poland, Slovakia and the USA*. High excess mortality can also be observed for several territories at the end of 2021, including Bulgaria, Czech Republic, Lithuania, Netherlands, Poland, and Slovakia.
- Excess mortality in 2022 was low in most territories. The only countries with a large excess mortality peak in 2022 are Bulgaria, Israel, Republic of Korea and Spain.

When we compare cumulative excess mortality for the 24 international territories we observe:

- England & Wales has the third highest cumulative excess mortality to the end of 2022 of the western Europe territories, measured from week 10 of 2020. The only western Europe territories with higher cumulative excess mortality are Austria and Italy*. The high cumulative excess mortality for Austria is due to consistent but relatively low excess mortality, whereas high cumulative excess mortality for Italy* is due to a very high level of excess mortality during 2020.
- Most western Europe territories had significant excess mortality to the end of 2020.
- Most western Europe territories have experienced higher than expected mortality since week 26 of 2021. Excess for England & Wales is the third highest for western Europe and Nordic territories.

* Results for Australia, Italy, New Zealand and the USA are based on expected mortality calculated using a different, shorter, baseline than that used for all other territories, due to data not being available for these territories from the start of 2010.

Contents

Reliances and limitations

The purpose of this paper and the accompanying spreadsheets is to analyse international mortality in light of the pandemic, using the Human Mortality Database's short-term mortality fluctuations dataset.

The CMI aims to produce high-quality outputs and takes considerable care to ensure that its research and the accompanying documentation are accurate. However, in respect of this paper:

- We rely on data published by HMD which we have not independently verified.
- Therefore, we cannot guarantee its accuracy (see the Disclaimer on the last page of this document).
- We have also applied judgement to:
  - the territories selected for analysis;
  - the periods used to analyse mortality;
  - the methods used to analyse mortality; and
  - how we have illustrated the results.

1. Introduction

In response to the COVID-19 pandemic, the CMI has been publishing weekly analysis of excess mortality in England & Wales and the United Kingdom in its "mortality monitor". Excess mortality is defined as the difference between actual and expected mortality (where expected mortality is generally a pre-pandemic view). This paper extends that analysis to other countries, based on the "short-term mortality fluctuations" (STMF) dataset from the Human Mortality Database (HMD) which includes weekly deaths and mortality rates for 38 international territories.

In this paper, our approach typically focuses on "Age Standardised Mortality Rates" (ASMRs). ASMRs are a weighted average mortality rate for a population, weighted by a "standard" population. The standard population used in this paper (and used in other CMI analyses) is the European Standard Population 2013. The advantage of analysing ASMRs compared to crude mortality rates is that ASMRs do not reflect the actual age profile of a population, which allows for fairer comparison of mortality between different populations that may have different age profiles. For example, a younger population will typically have fewer deaths than an older population, so comparing ASMRs for the two populations allows for a fairer comparison of the mortality characteristics of the two populations. As the age profile of populations will also typically change over time, using ASMRs also allows for a fairer comparison of mortality over time.

1.1 Contents

The main body of this paper is organised in the following sections:

1. This introduction.
2. A summary of the HMD STMF data used and considerations when using this data.
3. The methods used.
4. The results of the analysis, including weekly excess mortality and cumulative excess mortality for 24 international territories.

Supplementary material is provided in the following appendices:

1. A summary of the 38 territories included in the HMD STMF dataset.
2. Analysis testing the appropriateness of the European Standard Population 2013 for calculating ASMRs for the 24 international territories.
3. Comparing the approach used in this paper with the approach used in the CMI mortality monitor.
4. Charts showing weekly ASMRs for the 24 international territories.
5. Charts showing seasonality factors applied to reduce the seasonal effects on mortality for the 24 international territories.
6. Charts showing crude annual ASMRs and fitted mortality trend lines for the 24 international territories.
7. A description of the Tableau data visualisation accompanying this paper.

1.2 TAS compliance

This paper is intended to translate publicly available demographic information published by the Human Mortality Database into indicative mortality measures to illustrate recent mortality experience in 24 international territories. The paper is intended for use by actuaries and other parties interested in detailed mortality statistics and is for information only.

The paper complies with the principles in the Financial Reporting Council's Technical Actuarial Standard "TAS 100: General Actuarial Standards". Any person using this paper should exercise judgement over its suitability and relevance for their purpose.

1.3 Acknowledgements

This Working Paper was jointly produced by the CMI Mortality Projections Committee and members of the CMI Executive Committee. The members involved are Cobus Daneel (Chair of Mortality Projections Committee), Steve Bale, Darryl Brundle, Piero Cocevar, Susan Hanlon, Jonathan Hughes, Stuart McDonald, Steven Rimmer, Neil Robjohns and Brian Sewell.

2. Data

This section describes the dataset used for the analysis presented in this paper and notes points to consider when interpreting the results due to differences in the data for different territories. Section 2.1 provides an overview of the dataset, Section 2.2 outlines data features of note, and Section 2.3 describes which territories we have analysed and the rationale for the choice of territories analysed.

2.1 Overview

In response to the COVID-19 pandemic, the Human Mortality Database (HMD) now publishes a new short-term mortality fluctuations (STMF) dataset[1]. The STMF dataset includes weekly death counts and weekly mortality rates (annualised by HMD) by gender (male and female) and age band (ages 0-14, 15-64, 65-74, 75-84 and 85+) for 38 international territories. The territories in the STMF dataset (including the period of available data for each) are shown in Appendix 1: Territories in the HMD STMF dataset.

HMD has obtained data from a range of sources (for example, the Office for National Statistics for data for England & Wales). The source data is available in a variety of formats and covers different time periods and age ranges, which HMD has transformed to create a dataset that is as consistent as possible between territories. Some of the issues with transforming the data into consistent formats are discussed in Section 2.2. We consider the methods used by HMD to transform the data to be appropriate, but we note that results in this paper are reliant on the methods used by HMD to construct the dataset.

The data series is updated regularly by HMD. We have used data downloaded from HMD's website on 20 June 2023 for the analysis in this paper.

2.2 Data variations between territories

As noted above, the format of the source data underlying the HMD STMF dataset varies by territory. We note several features that should be considered when interpreting results.

Date recorded for death – registration or occurrences

Date of death is recorded on an occurrence basis for most territories used in this analysis. The only exceptions are England & Wales and Scotland, where date of death is recorded on a registration basis.

- For England & Wales we have made an estimate of weekly deaths on an occurrences basis. This based on the HMD data but with an adjustment to allow for registration delays, described in Section 3.
- The adjustment is based on our previous analysis comparing death registration and death occurrences in the mortality monitor for week 33 of 2023. That analysis suggests that the difference between mortality on registrations and occurrences basis was unusually large in December 2022 due to larger than usual registration delays at that time.
- No adjustment has been made to the results for Scotland, as comparable analysis is not available.

HMD has consciously chosen to collect data primarily using deaths recorded on an occurrence basis to reduce the impact of fluctuations in deaths recorded on a registration basis (for example, due to closures of registration offices on public holidays).

We note that the occurrences data does not appear to make any estimate for deaths that have occurred but not yet been reported and so more recent data may be incomplete. We have therefore restricted our analysis to cover the period to the end of 2022 to reduce the impact of late-reported deaths, though the possibility of incomplete data should be considered when interpreting the results.

[1] https://www.mortality.org/Data/STMF
Data source: Human Mortality Database (HMD). Max Planck Institute for Demographic Research (Germany), University of California, Berkeley (USA), and French Institute for Demographic Studies (France).

Period covered by weekly deaths

The majority of territories report data for weeks ending on a Sunday. England & Wales reports for weeks ending on a Friday, and Canada and the USA report for weeks ending on a Saturday. We do not believe this feature materially impacts the results, but we note it here for completeness.

Age bands

For some territories (Australia, Canada, Germany, Israel, New Zealand), data is not available in the standard age bands that HMD reports data for in the STMF dataset. The USA reports data that requires age band splitting only for years prior to 2020. Consequently, the data underlying results for the USA is inconsistent pre- and post-2020. For these territories, HMD has made an assumption about the split of deaths by age in order to distribute the deaths into the age bands that it uses. For example, the source data for Germany includes a group for ages 0-29, which is then allocated by HMD into the 0-14 and 15-64 age bands.

We do not believe this is a material concern for the territories used in this working paper as the approach adopted by HMD appears reasonable, however we stress that the distribution of deaths by age for these territories is approximate.

Gender

Data for the USA is not split by gender for years prior to 2020. For these years, HMD have estimated the distribution of deaths by gender using a method similar to that used for age band. Consequently, the data underlying results for the USA is inconsistent pre- and post-2020.

Period of data

As discussed further in Section 3, in this analysis we calculate a baseline for expected mortality in 2020, 2021 and 2022 based on data from 2010 to 2019, where this is possible. We are able to do this for 31 territories in the dataset, which have data available from week 1 of 2010. For the other territories the trend is based on data starting at the earliest possible calendar year. We note that the difference in the period used to calculate the expected baseline should be considered when comparing results and we have shown an asterisk against the territories which do not have data from 2010.

Frequency of updates to source data

The source data for different territories is updated at different frequencies. Further, source data for different territories is considered “final” (and therefore not revised) at different points. Analysis of mortality using datasets obtained from the HMD website at different points may therefore be different as the revised data may have:

- Changed data for the period 2010-2019, and therefore changed the expected mortality measure.
- Changed data for 2020-2022, and therefore changed the actual mortality analysed.

Deaths not assigned to a specific week

EuroStat notes that Sweden has “reported a number of deaths where the week of death is unknown”. The HMD data for Sweden does not include these deaths in their dataset. We have made an approximate allowance for these deaths in the results for Sweden, based on another data source as discussed further in Section 3. Deaths where the week is unknown account for around 3% of total Swedish deaths on average.

Further information

HMD has published two documents on its website which provide further information on the STMF dataset:

- A note providing an overview of the data and methods[2].
- A note setting out territory-specific information on the source data and modifications made by HMD[3].

As noted in the above guidance notes published by HMD, the accuracy and completeness of data varies materially by territory.

[2] https://www.mortality.org/File/GetDocument/Public/STMF/DOC/STMFNote.pdf
[3] https://www.mortality.org/File/GetDocument/Public/STMF/DOC/STMFmetadata.pdf

2.3 Territories included in our analysis

The analysis in this paper uses data for 24 of the 38 international territories included in the STMF dataset. These 24 territories were selected based on the following criteria:

- Generally, territories must have data starting from week 1 of 2010. As noted above, 31 of the 38 territories have data for this period. We have also included Australia, Italy, New Zealand and the USA in the analysis using a shorter period for calculating the expected baseline measure of deaths (with the period depending on availability of data for those territories) as we believed the results of these territories would still provide an informative comparison with England & Wales. However, we stress that the data period used to calculate the expected measure of mortality differs and hence comparisons should be made with caution.
- Including a mixture of territories with either similar economic characteristics to the UK or territories that covered a wide range of locations across the world. This was a subjective decision, with the primary aim of restricting the territories analysed to 24 for ease of presentation in this report, although further information on why certain territories were excluded is included in.

3. Methods and assumptions

This section outlines the methods and assumptions used to calculate weekly excess mortality.

We calculate weekly excess mortality as the difference between actual and expected mortality in a given week, allowing for seasonality and using “age-standardised mortality rates” (ASMRs). Age-standardising leads to fairer comparisons between territories and over time compared to using unadjusted deaths or crude mortality rates, as ASMRs mitigate the impact of populations having different sizes or average ages or gender splits.

3.1 Overview

The approach we have taken for the analysis in this paper is to:

- Calculate annualised ASMRs for each week and territory, using the HMD STMF data series. This gives a measure of actual mortality. We calculate a single ASMR for the entire population of each territory, and do not include analysis by gender or age band in this paper.
- Calculate ASMRs for each year and territory, as the average of the annualised weekly ASMRs calculated above for the year.
- Calculate our measure of expected mortality for each week and territory. This is the combination of two components:
  - An annual mortality rate. For 20 of the 24 territories analysed, we calculate this for each territory by fitting a log-linear model to the annual ASMRs for 2010 to 2019 and then use the fitted value for 2019. For Australia, Italy, New Zealand and the USA, where data is not available from 2010, we fit a log-linear model to the annual ASMRs from the earliest available full calendar year to 2019[4] and then use the fitted value for 2019.
  - A seasonality factor. We calculate this for each territory based on average weekly and total mortality for that territory.
- Calculate relative excess mortality for each week and territory as the percentage difference between the actual ASMR and expected mortality.
- Calculate cumulative relative excess mortality as the accumulation of relative excess mortality over time.

The following sections provide further details of each step.

3.2 Weekly ASMRs

The HMD STMF dataset includes annualised weekly crude mortality rates for each territory by gender and age band (0-14, 15-64, 65-74, 75-84 and 85+). We combine these into an approximate (as we cannot control for the age distributions within each age band i.e. within each age band each individual territory’s actual age distribution is used) weekly ASMR for each territory, using the 2013 edition of the European Standard Population (ESP).

The ASMR for week w, year y, and territory t is given by:

$$ASMR_{w,y,t} = \frac{1}{2}\left(\sum_a \left(R^{Male}_{a,w,y,t} \times \frac{ESP_a}{ESP_{total}}\right) + \sum_a \left(R^{Female}_{a,w,y,t} \times \frac{ESP_a}{ESP_{total}}\right)\right)$$

where:

- $R^{Male}_{a,w,y,t}$ is the annualised weekly mortality rate for males for age band a;
- $R^{Female}_{a,w,y,t}$ is the annualised weekly mortality rate for females for age band a;
- ESP_a is the total ESP for ages in age band a; and
- ESP_{total} is the total ESP for all ages.

We note that ESP may not be an appropriate population estimation for all territories analysed in this paper; particularly for territories with significantly different population structures to that assumed with ESP (e.g. for

[4] For Italy and New Zealand, we use data for 2011-2019, for Australia we use data for 2015-2019, and for the USA we use data for 2016-2019.

territories with relatively young or old populations). Appendix 2: Suitability of the European Standard Population includes further analysis considering the suitability of ESP for the territories analysed in this paper.

3.3 Annual ASMRs

The annual ASMR for a territory is calculated from the weekly ASMRs for that year. This means that the annual ASMRs are for periods of 364 or 371 days (52 or 53 weeks) and do not correspond exactly to calendar years.

As the weekly ASMRs are already annualised, the annual ASMR is the average of the weekly ASMRs.

$$ASMR_{y,t} = \sum_w ASMR_{w,y,t} \div NumWeeks_y$$

where $NumWeeks_y$ is the number of weeks in year y and can be 52 or 53.

3.4 Weekly expected mortality

Our measure of expected mortality is the combination of two components, one for annual mortality and one for seasonality.

Annual mortality

For each territory, we fit a log-linear trend to the annual ASMRs (described in Section 3.3) fitting to 2010-2019 for 20 of the territories, 2011-2019 for Italy and New Zealand, 2015-2019 for Australia, and 2016-2019 for the USA. We then use the fitted ASMR for 2019 as our measure of expected annual mortality in 2020, 2021 and 2022.

In more detail, we first find the values of a_t and b_t for each territory that minimises:

$$\sum_y \left(\log\left(ASMR_{y,t}\right) - (a_t + b_t y)\right)^2$$

where the sum is over the years from the start year to 2019.

We then calculate the fitted value for 2019 as:

$$ASMR_t^{Fitted2019} = \exp\left(a_t + b_t \times 2019\right)$$

Using fitted mortality in 2019 to inform expected mortality allows for differing mortality improvement trends prior to 2020 in the territories analysed and basing the fit on data for several years results in a measure of expected mortality that is less volatile than using a single year as a baseline.

We have used fitted mortality in 2019 for expected mortality in 2020, 2021 and 2022, rather than projecting the fitted model to those years. This means that the measure of expected mortality in 2020 to 2022 is identical.

Seasonality

As mortality varies within each year due to seasonal effects, such as temperature and the typical peak influenza season, we have incorporated an allowance for seasonality in the expected ASMR measure.

We calculate a seasonality factor $F_{w,t}$ for each territory and week number (from 1 to 52) as:

$$F_{w,t} = \frac{\sum_y ASMR_{w,y,t}}{\sum_y ASMR_{y,t}}$$

where the sums are over the same years (varying by country) used to fit the annual trend.

As a few years have 53 weeks, we cannot reliably calculate $F_{53,t}$ based on data so instead set $F_{53,t} = F_{52,t}$ for all territories.

Appendix 5: Seasonality factors shows the seasonality factors calculated for each territory.

Weekly expected mortality

We combine these two components and calculate expected mortality for 2020, 2021 and 2022 as:

$$ASMR_{w,t}^{Expected} = ASMR_t^{Fitted2019} \times F_{w,t}$$

3.5 Relative excess mortality

We calculate relative excess mortality for each week and territory as:

- $Excess_{w,y,t} = ASMR_{w,y,t} \div ASMR_{w,t}^{Expected} - 1$

We then calculate cumulative relative excess mortality for a given week as the sum of the relative excess mortality from a defined starting week to the given week, divided by 52 to give an annualised figure:

$$CumExcess_{w,y,t}^{start} = \frac{1}{52} \times \sum_{i=start}^{i=(w,y)} Excess_{i,t}$$

Where i indexes the week and the sum may span multiple years. For example, if the starting week is week 26 of 2021 and the cumulative relative excess is calculated for week 15 of 2022, then the sum would include weeks 26-52 of 2021 and weeks 1-15 of 2022.

3.6 Comparison to methods used in CMI mortality monitor

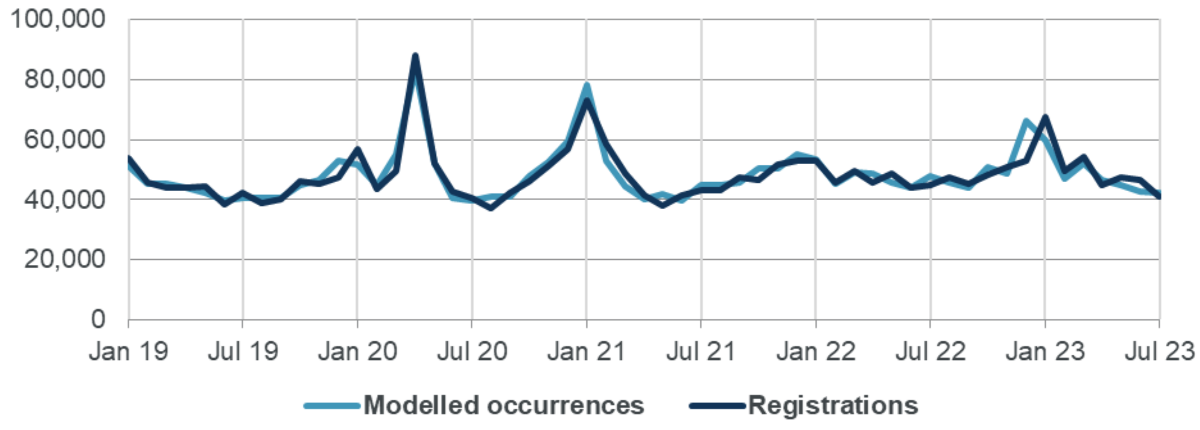
There are a number of differences in method between this analysis and that used in the CMI mortality monitor. These are discussed in Appendix 3: Differences to CMI mortality monitors.

3.7 Adjusting results for England & Wales

As discussed in Section 2, in a previous analysis we identified that there appeared to be an abnormal and significant delay in the registration of deaths in December 2022.

Chart 3A (replicated from the mortality monitor for week 33 of 2023, which includes further information on the data and methods used) compares monthly death registrations with our estimate of monthly occurrences. These estimated monthly occurrences are based on the number of occurrences registered by 31 July 2023 with an allowance for a typical historical pattern of monthly registration delays after that point. These estimates are necessarily uncertain, particularly for more recent periods where registration delays form a larger proportion of the estimate. Chart 3A shows that while estimated occurrences and registrations are generally broadly in line, estimated occurrences in December 2022 are significantly higher than registrations, while in January 2023 the opposite is true.

Chart 3A: Estimated occurrences and registrations



This greater delay in registrations means that excess mortality in December 2022 would be higher for England & Wales on an occurrences basis than on a registrations basis. We have therefore estimated weekly occurrences data for England & Wales so that results are more closely comparable with the other territories in the analysis – except Scotland.

We have estimated weekly occurrences for England & Wales by adjusting the weekly ASMRs for England & Wales in 2020, 2021 and 2022 by the ratio of the monthly modelled death occurrences to the monthly death registrations from Chart 3A. For weeks spanning two months we have used an average of the ratios for the two months, weighted by the number of days in each of the two months. We have not adjusted the weekly ASMRs for 2011 to 2019 as the relevant data is not readily available for 2011 to 2018, and the difference between registrations and occurrences over this relatively long time period would be expected to broadly cancel out, with little impact on the fitted ASMR for 2019.

3.8 Adjusting results for Sweden

As discussed in Section 2, Eurostat notes that that there are deaths in the Sweden dataset that are assigned to a year but not assigned to a specific week. This affects around 3% of Swedish deaths on average.

We have compared the weekly deaths in the HMD STMF dataset to weekly deaths published by Statistics Sweden to assess the proportion of deaths not assigned to a specific week for the average of 2015 to 2019 and for individual years 2020, 2021, 2022 and 2023[5]. This data is summarised in the Table 3.1 (excluding 2023). We are not aware of similar data for 2011 to 2014, or for individual years from 2015 to 2019.

Table 3.1: Total deaths and deaths not assigned to a specific week

	2015 to 2019	2020	2021	2022
Total deaths	90,509	96,950	88,566	90,881
Deaths not assigned to a specific week	2,056	2,663	2,951	3,605
Ratio of deaths not assigned to a specific week to total deaths	2.3%	2.7%	3.3%	4.0%

We have made an approximate allowance for these deaths not assigned to a specific week by making the following adjustments to the analysis:

- Increasing weekly ASMRs for the period 2011 to 2019 by the ratio of deaths not assigned to a specific week to total deaths for the average of 2015 to 2019 (2.3%). This adjustment therefore assumes that deaths not assigned to a specific week are distributed broadly evenly across 2015 to 2019, and the pattern for 2015 to 2019 is applicable to 2011 to 2014.
- Increasing weekly ASMRs for 2020, 2021 and 2022 by the ratio of deaths not assigned to a specific week to total deaths for the individual years. No allowance is made for week crossing multiple years (for example, week 53 of 2020 is uplifted by the ratio for 2020 only).

[5] https://www.scb.se/en/finding-statistics/statistics-by-subject-area/population/population-composition/population-statistics/pong/tables-and-graphs/births-and-deaths/preliminary-statistics-on-deaths/

4. Analysis

In this section we have included the following analyses:

- Section 4.1 shows relative excess mortality in 2020, 2021 and 2022 for each territory. This illustrates the degree to which weekly mortality rates deviated from expected mortality during different stages of the pandemic.
- Section 4.2 compares cumulative relative excess mortality for the territories. We show two measures:
  - starting from week 10 of 2020 - broadly the start of the COVID-19 pandemic in Europe and North America; and
  - starting from week 26 of 2021 – a period in which mortality in England & Wales was markedly less volatile than earlier in the pandemic.

4.1 Relative excess mortality

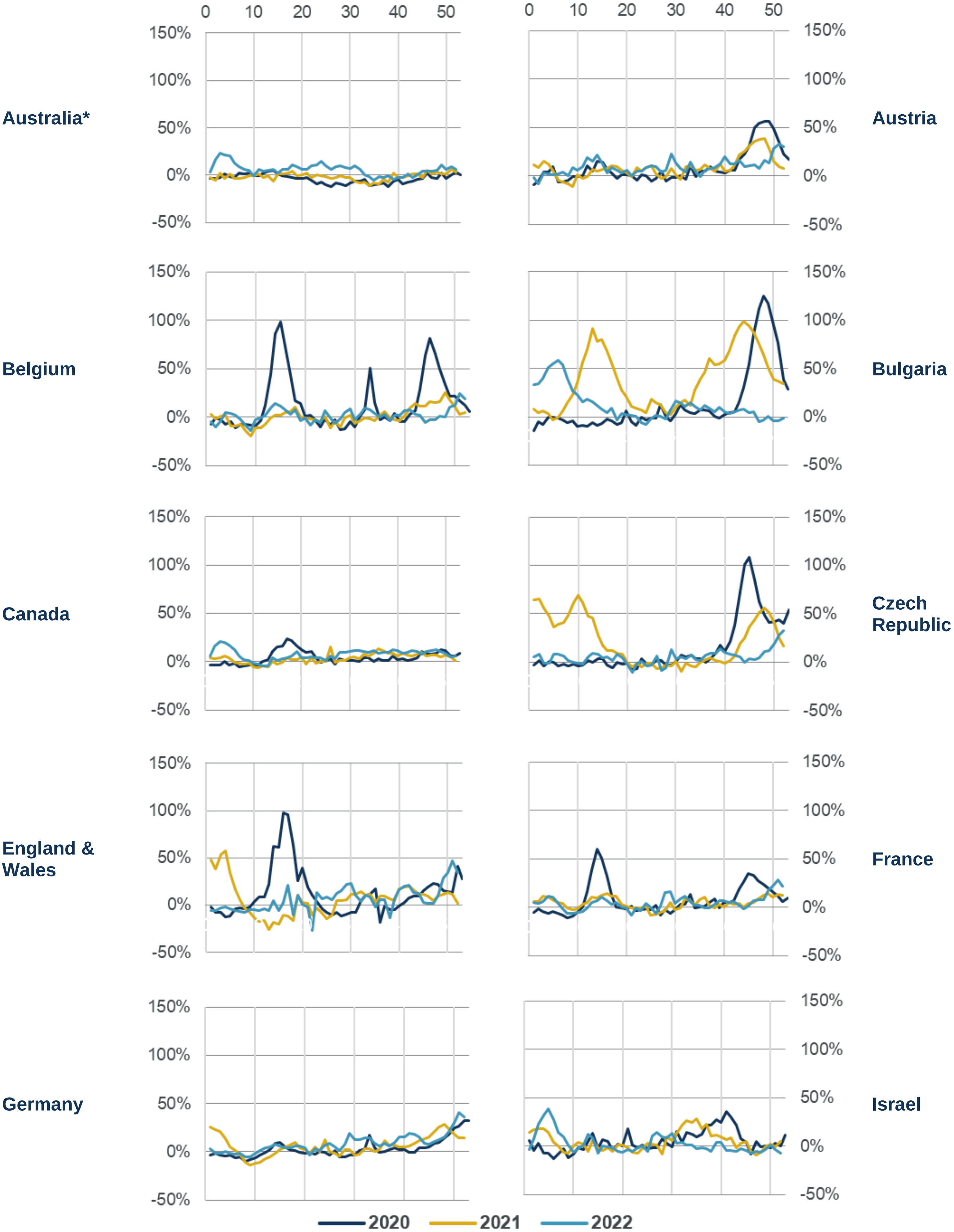
Chart 4A shows weekly relative excess mortality in 2020, 2021 and 2022 for each territory. Weekly ASMR charts in 2020, 2021 and 2022 for a given territory are shown in Appendix 4: Weekly ASMRs in 2010-2022. We stress that results are sensitive to the baseline chosen.

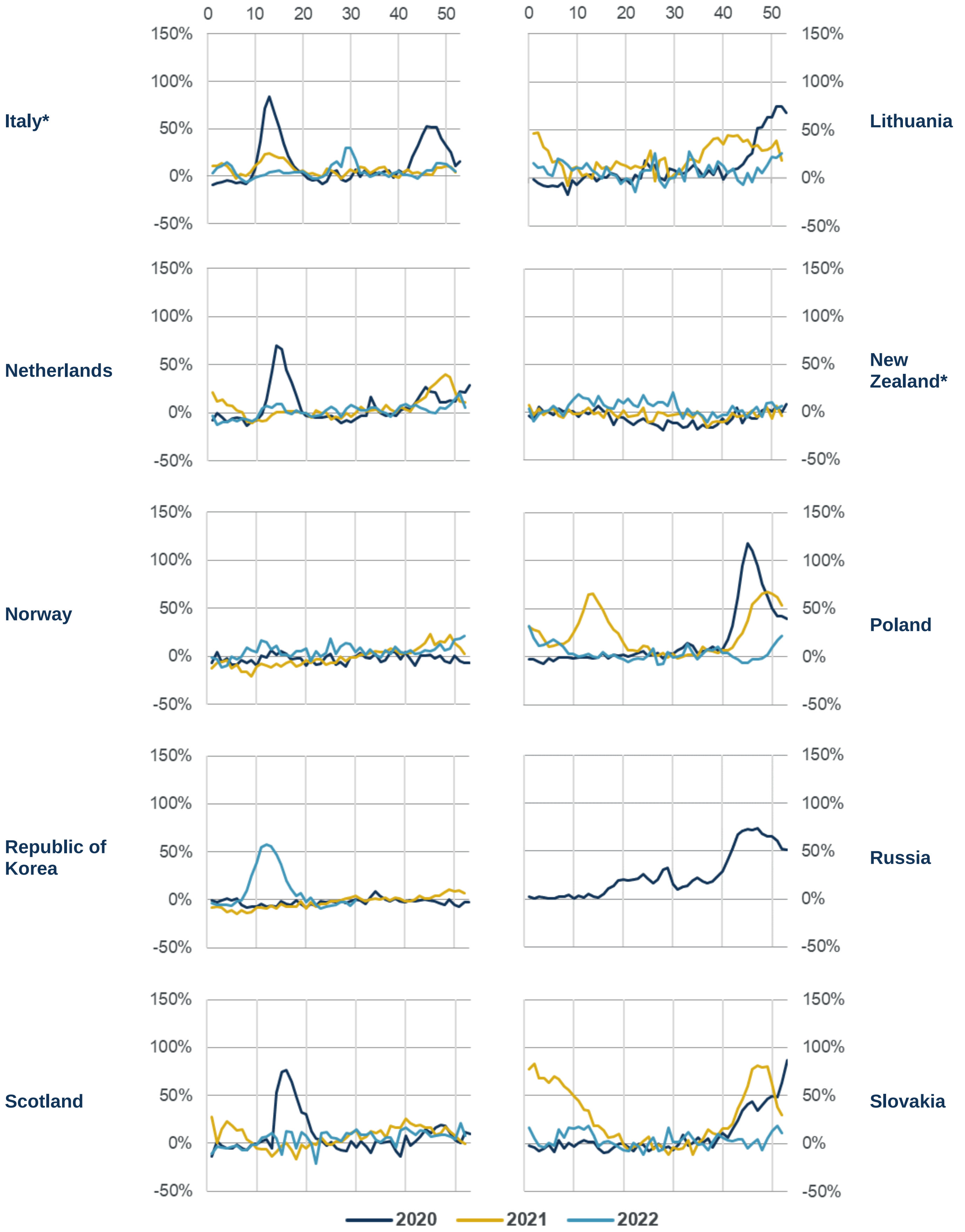
The chart shows:

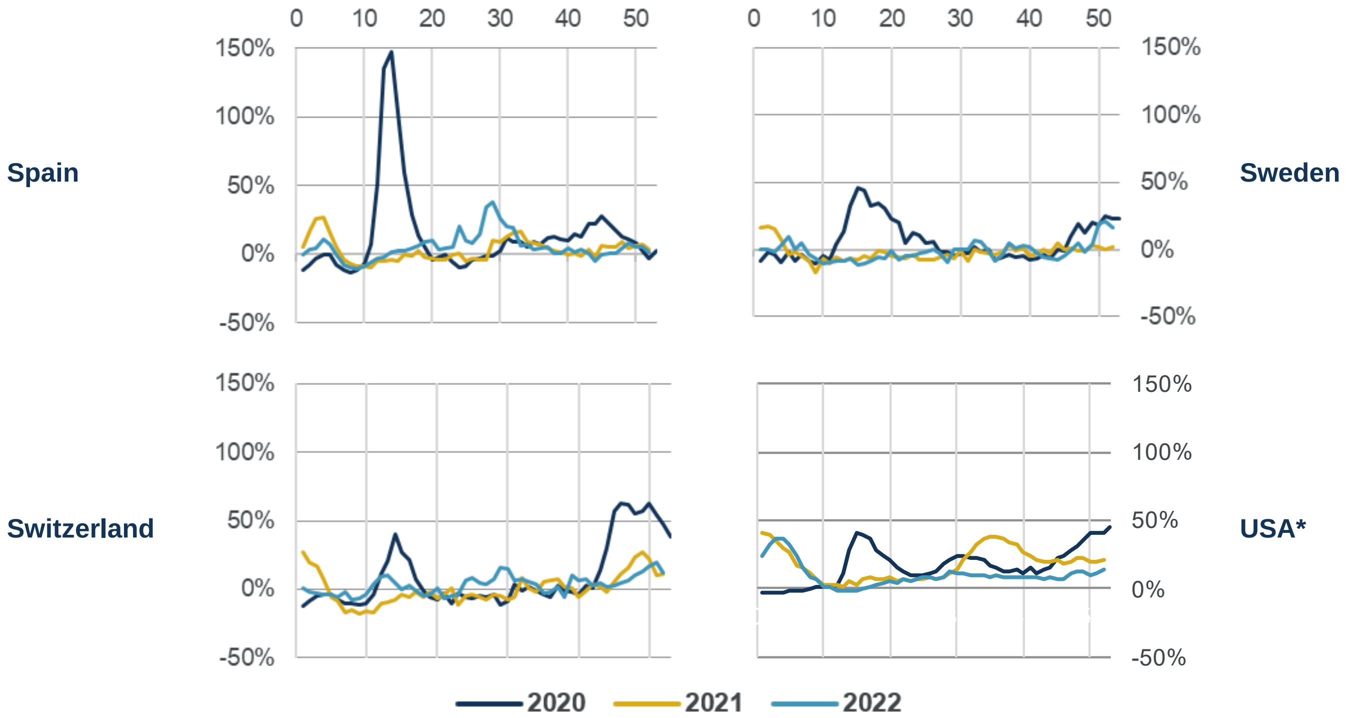
- A clear "first wave" peak can be seen in the second quarter of 2020 for Belgium, England & Wales, France, Italy*, Netherlands, Scotland, Spain, Sweden, Switzerland and the USA*. The highest peak is for Spain with 148% excess weekly mortality in week 14 of 2020.
- Eastern European territories (Bulgaria, Czech Republic, Lithuania, Poland, Russia and Slovakia) tended to have relatively low excess mortality in the second quarter of 2020. These territories instead experience higher excess mortality in later weeks of 2020. These territories also typically have two distinct peaks in 2021; one in early 2021 and one towards the end of the year.
- High excess mortality can be observed for several countries in early 2021, including Bulgaria, Czech Republic, England & Wales, Lithuania, Poland, Slovakia and the USA*. High excess mortality can also be observed for several territories at the end of 2021, including Bulgaria, Czech Republic, Lithuania, Netherlands, Poland, and Slovakia.
- Excess mortality in 2022 is typically low in all territories. The only territories with a large excess mortality peak in 2022 are Bulgaria, Israel and Republic of Korea.
- The three territories with the lowest peak weekly excess mortality in the territories analysed are New Zealand (+21%), Australia (+23%) and Norway (+23%).
- As discussed further in Section 4.2, Austria had the highest cumulative excess mortality from week 20 of 2020. However, the heights of the excess mortality peaks for Austria are relatively low compared to peak excess mortality observed for other territories. Instead weekly excess mortality for Austria is overall above 0% for all of 2020 to 2022, averaging weekly excess mortality of around 9%.
- Belgium shows an additional peak around week 33 of 2020, between the two peaks typically seen for most of Western Europe.
- Data is available for Russia up to the end of 2020 only. Excess mortality for Russia is low for the first 15 weeks of 2020. Between weeks 16 and 43 excess mortality increased, averaging excess mortality of 23% per week. After week 43 excess mortality increases significantly, reaching a peak of 74% and remaining high at the end of 2020.
- Australia* and New Zealand* show very low, or negative excess mortality in 2020 and 2021. Both territories have higher excess mortality in 2022, although the results are volatile.
- The USA* sees a number of excess mortality peaks throughout 2020 and 2021, although these peaks aren't as high as the peaks observed for western European territories (for example, England & Wales and Spain). The USA has an excess mortality peak in early 2022 (at a similar time to Canada, although the peak for USA is higher), which isn't typically observed for western European territories.

* Results for Australia, Italy, New Zealand and the USA are calculated using an expected mortality baseline that is calculated using a different data period than that used for all other territories, due to data being unavailable for these territories from the start of 2010.

Chart 4A: Annualised weekly excess mortality in 2020-2022 relative to the weekly projected 2019 ASMR




Italy*
Lithuania
Netherlands
New Zealand*
Norway
Poland
Republic of Korea
Russia
Scotland
Slovakia
0
10
20
30
40
50
150%
100%
50%
0%
-50%
2020
2021
2022


Spain
Sweden
Switzerland
USA*
0
10
20
30
40
50
150%
100%
50%
0%
-50%
2020
2021
2022

4.2 Cumulative relative excess mortality

In this section we show cumulative relative excess mortality starting from:

- week 10 of 2020 - broadly the start of the COVID-19 pandemic; and
- week 26 of 2021 – a period in which mortality in England & Wales was markedly less volatile than earlier in the pandemic.

Charts 4B and 4C show cumulative excess mortality by territory from week 10 of 2020. Chart 4B shows cumulative excess mortality for England & Wales compared to territories in western Europe. Chart 4C shows results for England & Wales compared to territories not in western Europe. England & Wales is shown in dark blue on both charts. Note that Charts 4B and 4C have different y-axis ranges.

Charts 4D and 4E show cumulative excess mortality from week 26 of 2021. Charts 4D and 4E again have different ranges.

Charts 4B and 4C show:

- Measured from week 10 of 2020, England & Wales has the third highest cumulative excess mortality to the end of 2022 of the European and Nordic territories. The only western Europe territories with higher cumulative excess mortality are Austria and Italy*. The high cumulative excess mortality for Austria is due to consistent but relatively low excess mortality, whereas the high cumulative excess mortality for Italy* is due to a very high level of excess mortality during 2020.
- Most western European territories had significant excess mortality to the end of 2022. The only two territories that did not are the two Nordic territories analysed – Norway and Sweden. Norway had relatively low excess mortality for the whole period, whereas Sweden saw excess mortality during 2020, which was offset by lower than expected mortality from the start of 2021.
- England & Wales is broadly in the middle of the other territories outside western Europe analysed, with Australia*, Canada, Israel, Republic of Korea and New Zealand* having lower cumulative excess mortality and the other territories having higher excess mortality. At the point at which data becomes unavailable for Russia, Russia had the highest cumulative excess mortality of all territories analysed.
- Of all territories analysed, Bulgaria had the highest cumulative excess mortality to the end of 2022 (+65%). Poland had the second highest cumulative excess mortality (+46%) and the USA had third highest (+45%).

Charts 4D and 4E show:

- Most western European territories have experienced higher than expected mortality since week 26 of 2021. England & Wales has the third highest cumulative excess mortality to the end of 2022 since week 26 of 2021 (with cumulative excess mortality for England & Wales 0.2% higher than for Scotland).
- England & Wales is broadly in the middle of cumulative excess mortality since week 26 of 2021 compared to the other territories. The relatively higher cumulative excess mortality in the other territories is typically caused by excess mortality peaks after week 26 of 2021 (for example, an excess mortality peak can be observed for Bulgaria, Poland and Slovakia at the end of 2021).
- The USA* has the third highest cumulative excess mortality since week 26 of 2021, with only Bulgaria and Lithuania having higher values.

* Results for Australia, Italy, New Zealand and the USA are calculated using an expected mortality baseline that is calculated using a different data period than that used for all other territories, due to data being unavailable for these territories from the start of 2010.

We present the cumulative excess mortality for each table at end of 2022 for each territory in Table 4.1, measured from week 10 of 2020 and from week 21 of 2021. Western European and Nordic territories are presented with dark blue text and all other territories with gold text.

Chart 4B: Cumulative excess mortality from week 10 of 2020 – Western European and Nordic territories

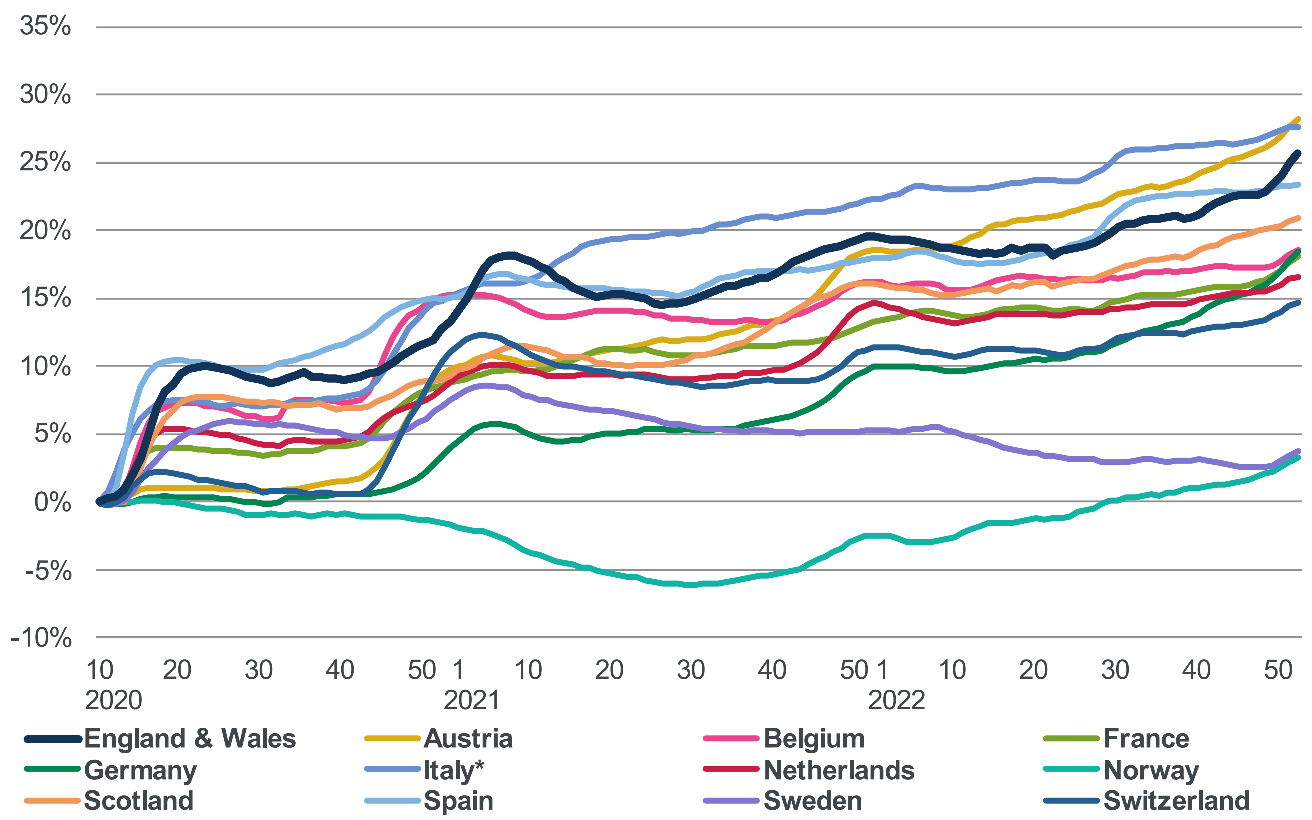


Chart 4C: Cumulative excess mortality from week 10 of 2020 – all other territories

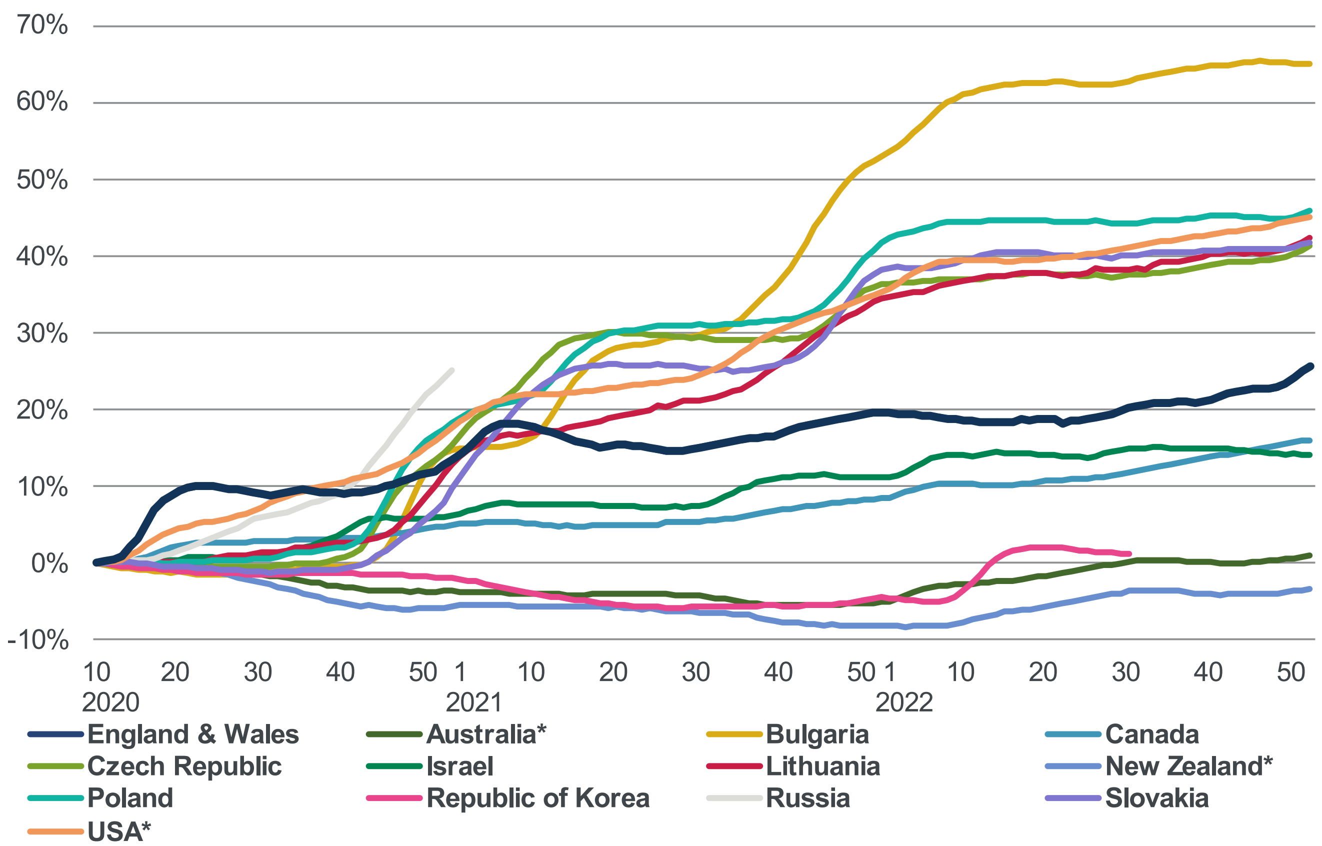


Chart 4D: Cumulative excess mortality from week 26 of 2021 – Western European and Nordic territories

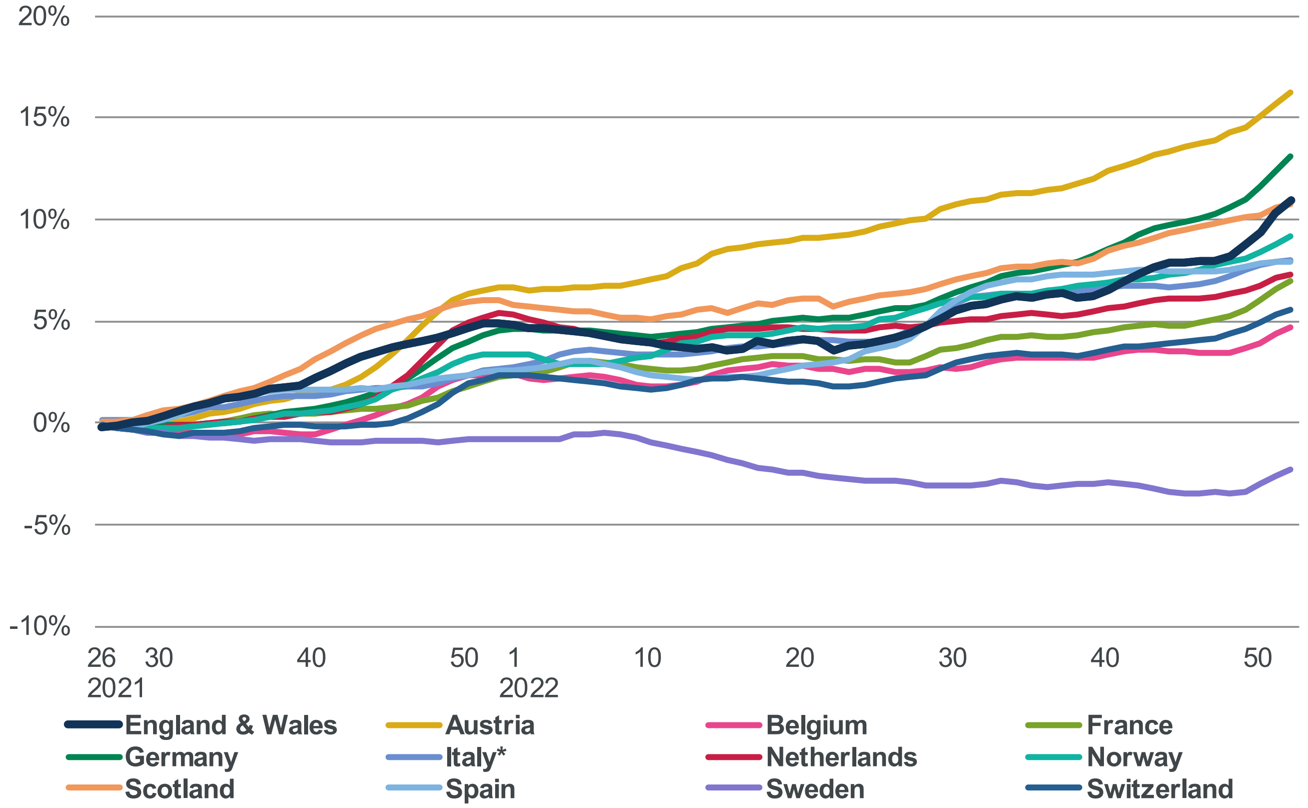


Chart 4E: Cumulative excess mortality from week 26 of 2021 – all other territories

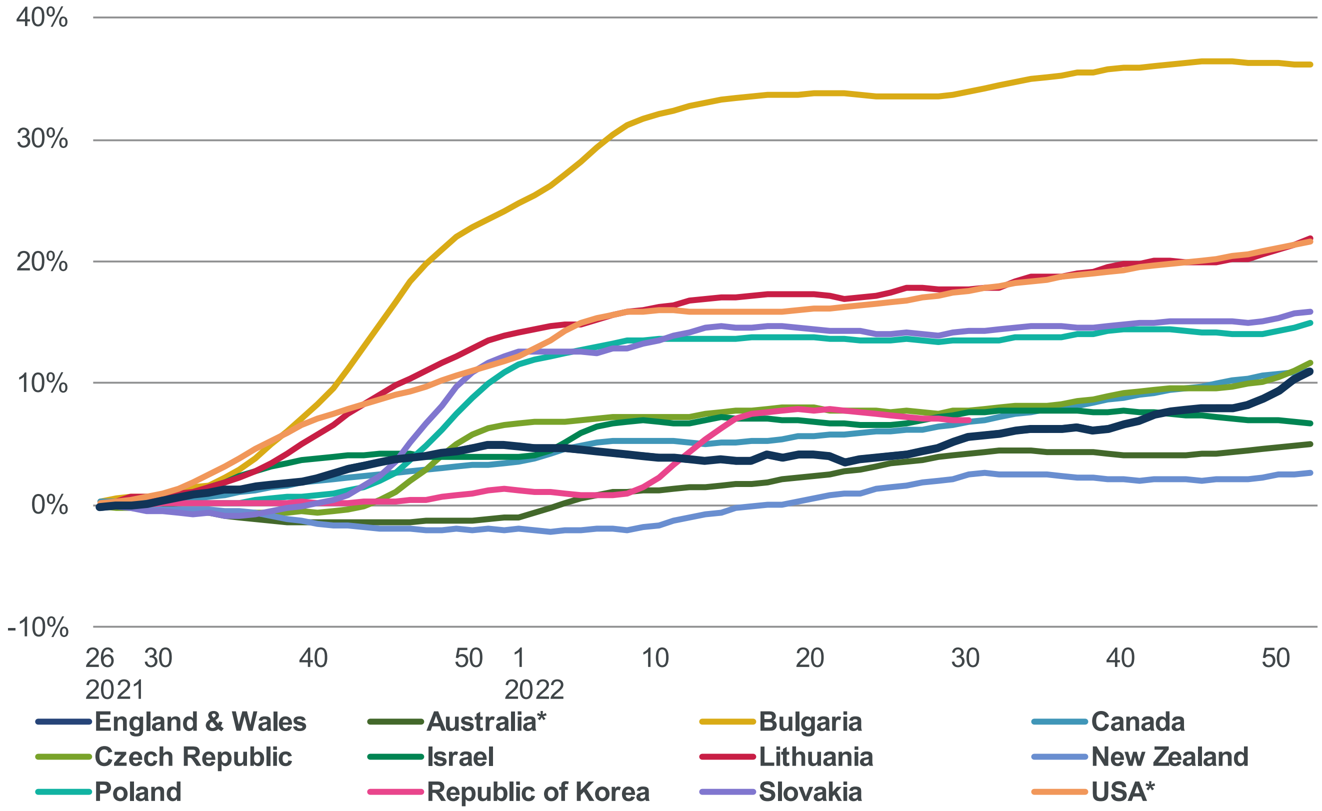


Table 4.1: Cumulative excess mortality at the end of 2022 from week 10 of 2020 and week 26 of 2021 for all territories analysed

Territory	Cumulative excess from week 10 of 2020	Cumulative excess from week 26 of 2021
Australia	+1%	+5%
Austria	+28%	+16%
Belgium	+19%	+5%
Bulgaria	+65%	+36%
Canada	+16%	+11%
Czech Republic	+41%	+12%
England & Wales	**+26%**	**+11%**
France	+18%	+7%
Germany	+18%	+13%
Israel	+14%	+7%
Italy	+28%	+8%
Lithuania	+42%	+22%
Netherlands	+17%	+7%
New Zealand	−4%	+3%
Norway	+3%	+9%
Poland	+46%	+15%
Republic of Korea	+1% [Data to week 30 of 2022 only]	+7% [Data to week 30 of 2022 only]
Russia	+25% [Data to end of 2020 only]	n/a [Data to end of 2020 only]
Scotland	+21%	+11%
Slovakia	+42%	+16%
Spain	+23%	+8%
Sweden	+4%	−2%
Switzerland	+15%	+6%
USA	+45%	+22%

References

Working Paper	Relevance to this paper	Relevant part of the reference
CMI Mortality monitors	Comparison of methods	Analysis of recent mortality in England & Wales

Appendix 1: Territories in the HMD STMF dataset

Table A1.1 shows the 38 territories included in the HMD STMF dataset, the period for which data was available (at the time when data was downloaded on 20 June 2023), whether the territory has data from 2010 in the STMF, and whether the territory was excluded for another reason. The 24 territories analysed in this paper are shown in bold.

Table A1.1: Territories in the HMD STMF dataset

Territory	Start of data	End of data	Data from 2010	Otherwise excluded
Australia	**Week 1 of 2015**	**Week 8 of 2023**	**No**	
Austria	**Week 1 of 2000**	**Week 22 of 2023**		
Belgium	**Week 1 of 2000**	**Week 20 of 2023**		
Bulgaria	**Week 1 of 2000**	**Week 17 of 2023**		
Canada	**Week 1 of 2010**	**Week 3 of 2023**		
Chile	Week 1 of 2016	Week 23 of 2023	No	
Croatia	Week 1 of 2001	Week 17 of 2023		Range of other Eastern Europe[6] territories already included.
Czech Republic	**Week 1 of 2005**	**Week 17 of 2023**		
Denmark	Week 1 of 2007	Week 23 of 2023		Relatively small and range of other Northern Europe territories already included.
England & Wales	**Week 1 of 2010**	**Week 22 of 2023**		
Estonia	Week 1 of 2000	Week 23 of 2023		Relatively small and range of other Northern Europe territories already included.
Finland	Week 1 of 1990	Week 18 of 2023		Two Nordic territories (Norway and Sweden) selected instead.
France	**Week 1 of 2000**	**Week 18 of 2023**		
Germany	**Week 1 of 2000**	**Week 22 of 2023**		
Greece	Week 1 of 2015	Week 17 of 2023	No	
Hungary	Week 1 of 2000	Week 17 of 2023		Range of other Eastern Europe territories already included.
Iceland	Week 1 of 2000	Week 17 of 2023		Relatively small.

[6] Our approach for defining regions can be found on this website: https://unstats.un.org/unsd/methodology/m49/

Territory	Start of data	End of data	Data from 2010	Otherwise excluded
Israel	**Week 1 of 2000**	**Week 20 of 2023**		
Italy	**Week 1 of 2011**	**Week 12 of 2023**	**No**	
Latvia	Week 1 of 2000	Week 21 of 2023		Relatively small and range of other Northern Europe territories already included.
Lithuania	**Week 1 of 2000**	**Week 17 of 2023**		
Luxembourg	Week 1 of 2000	Week 17 of 2023		Relatively small and range of other Western Europe territories already included.
Netherlands	**Week 1 of 1995**	**Week 22 of 2023**		
New Zealand	**Week 52 of 2010**	**Week 22 of 2023**	**No**	
Northern Ireland	Week 2 of 2015	Week 23 of 2023	No	
Norway	**Week 1 of 2000**	**Week 22 of 2023**		
Poland	**Week 1 of 2000**	**Week 21 of 2023**		
Portugal	Week 1 of 2000	Week 22 of 2023		Range of other Southern Europe territories already included.
Republic of Korea	**Week 1 of 2010**	**Week 30 of 2022**		
Russia	**Week 1 of 2000**	**Week 53 of 2020**		
Scotland	**Week 2 of 2000**	**Week 23 of 2023**		
Slovakia	**Week 1 of 2000**	**Week 17 of 2023**		
Slovenia	Week 1 of 2000	Week 20 of 2023		Range of other Southern Europe territories already included.
Spain	**Week 1 of 2000**	**Week 21 of 2023**		
Sweden	**Week 1 of 2000**	**Week 20 of 2023**		
Switzerland	**Week 1 of 2000**	**Week 22 of 2023**		
Taiwan	Week 1 of 2000	Week 52 of 2021		Relatively small and range of other world territories already included.
USA	**Week 2 of 2015**	**Week 18 of 2023**	**No**	

Appendix 2: Suitability of the European Standard Population

To explore the suitability of using the European Standard Population 2013 to calculate the weekly ASMRs (described in Section), we have analysed the population structure of each territory compared with that assumed under ESP.

Population structures of territories analysed

For each of the 24 territories included in this analysis we obtained population data, by calendar year and single year of age, from the HMD. In considering the populations for the territories in this analysis, we found that:

- Most territories had similar population structures by age to the ESP.
- Israel, Republic of Korea, New Zealand, Russia and Slovakia all had generally younger populations.
- No territory had a significantly older population than the ESP.

Of the territories analysed, Israel had a population structure that we considered to be most different to the ESP (measured by the sum of squares of differences in the proportions of the population in 5-year age bands between Israel and the ESP).

Sensitivity test of using ESP

As a sensitivity test to the appropriateness of using ESP for in the analysis in this paper, we have considered the results if the population of Israel (the country with the most different population structure to the ESP) was used as the standard population in the calculation of the ASMRs and the impact this has on cumulative excess mortality since week 10 of 2020.

Our analysis found that of the 24 territories analysed, using the population of Israel as the standard population resulted in differences in cumulative excess mortality to the end of 2022 (or earlier if data for the territory ends at an earlier point) of:

- Less than 1% for 11 territories
- Between 1% and 2% for 8 territories
- Between 2% and 3% for 3 territories
- Between 3% and 4% for 2 territories (USA and Poland, which had a cumulative excess mortality calculated with ASMRs standardised to the Israel population to the end of 2022 of 48% and 43% respectively)

Based on this analysis we believe that the ESP remains an appropriate standardising measure for the calculation of the ASMRs used in this analysis.

Appendix 3: Differences to CMI mortality monitors

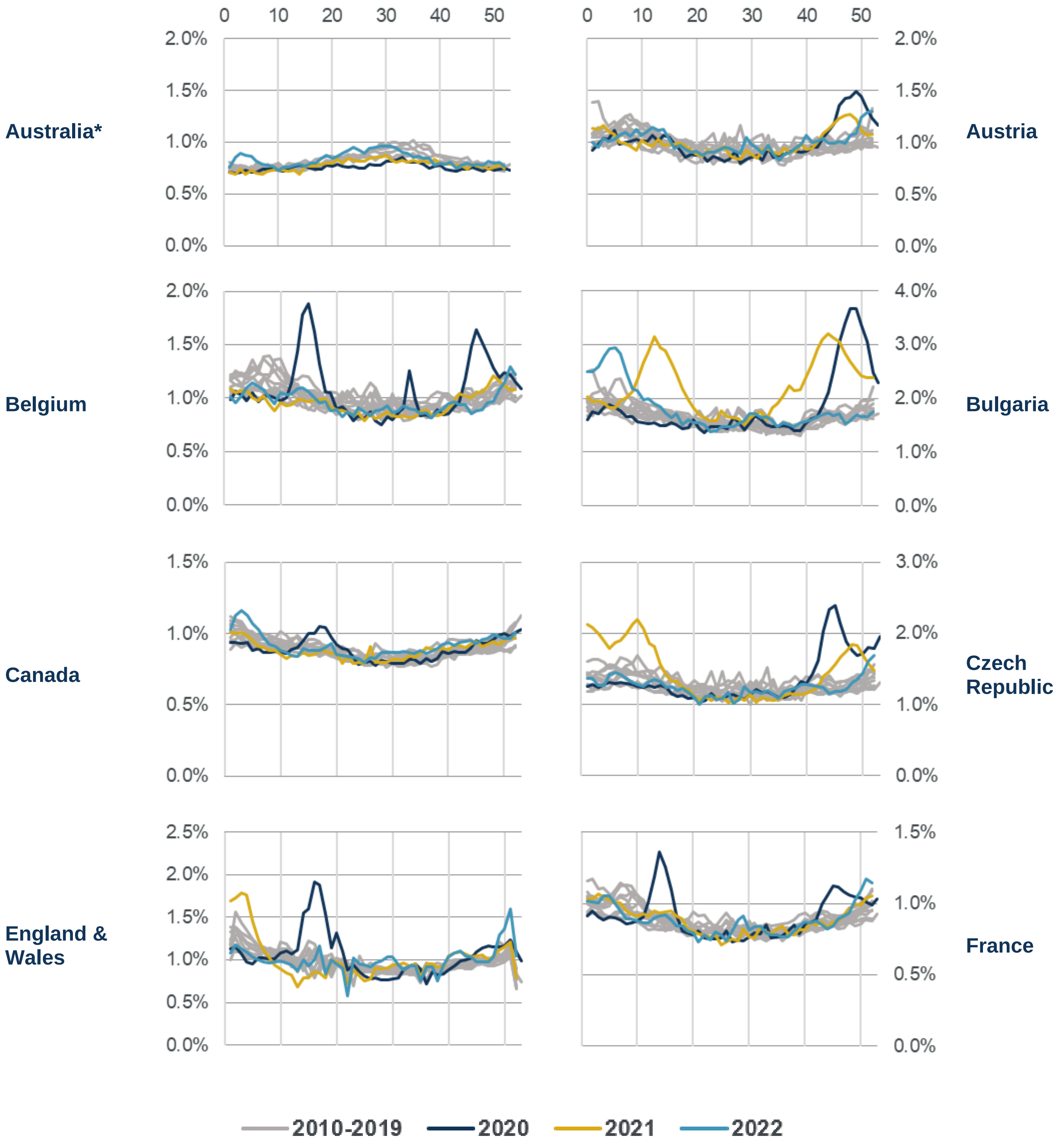
In this appendix, we describe the differences in methodology and assumptions used in the analysis in this paper compared to the CMI mortality monitors:

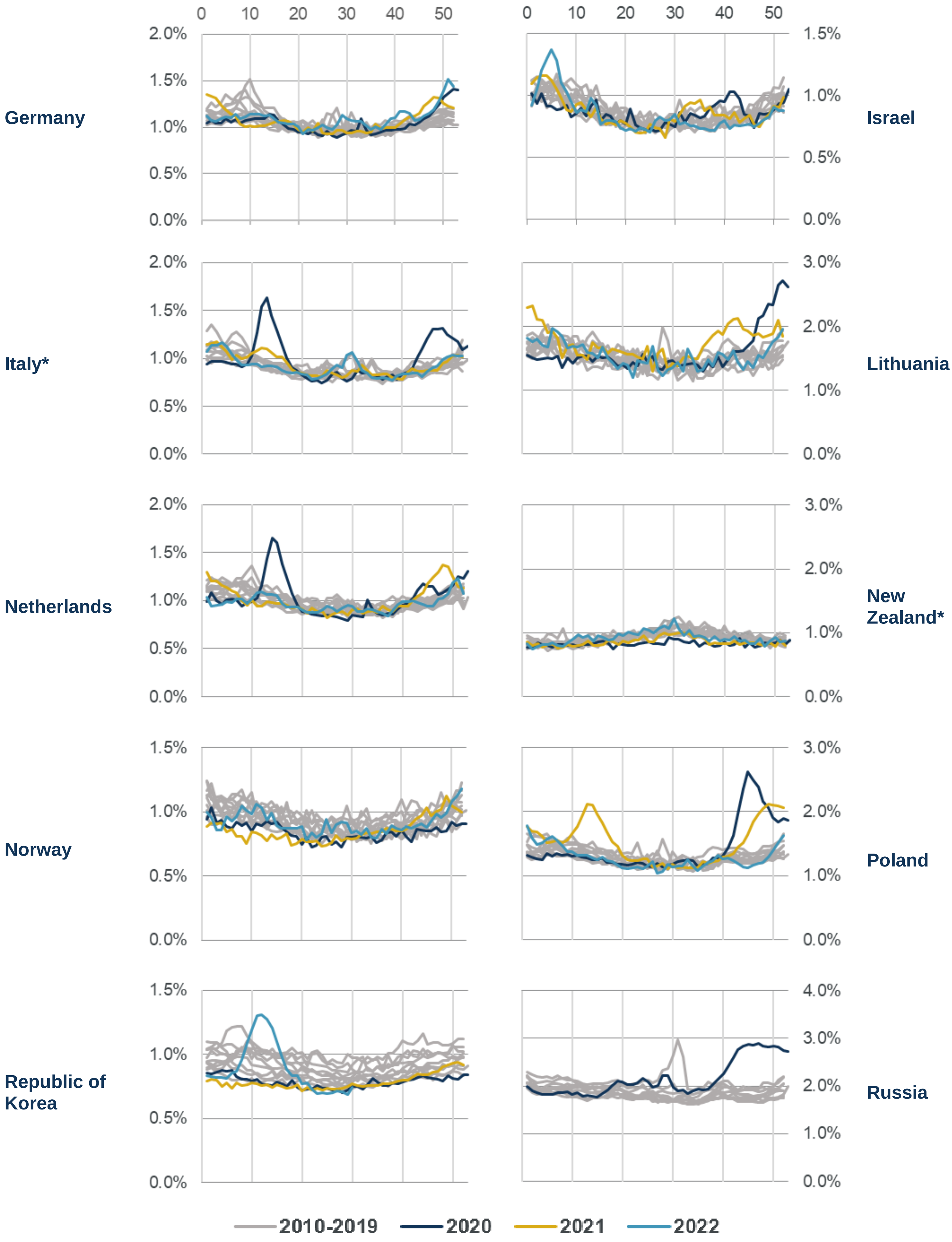
- The CMI mortality monitors source weekly deaths data directly from the Office of National Statistics (ONS). The HMD STMF data series analysed in this paper uses data sourced from the ONS for England & Wales, so the source data was consistent between the two at the time this paper was published. However, they may diverge in future if revisions are made by the ONS which are not incorporated into the HMD STMF.
- The ASMRs in the mortality monitor are for ages 20-100, to match the age range of the data used to calibrate the CMI Mortality Projections Model. The ASMRs in the analysis in this paper use all ages.
- As noted in Section 3, this paper calculates expected mortality using a log-linear projection of annual ASMRs to 2019 using annual ASMRs for 2010 (where available) to 2019, with a factor to allow for seasonality. When calculating excess mortality for weeks in 2020 to 2023 for England & Wales, the CMI mortality monitor uses the ASMR for the corresponding week in 2019 as its measure of expected mortality. We have opted to use the projected 2019 ASMR in this paper as it provides an objective measure for comparing excess mortality for the 24 international territories analysed, and a high level review of trends in annual ASMRs for 2010 to 2019 suggests this is a reasonable approach for the territories as mortality typically fell over the period. However, we still believe using ASMRs in 2019 as an expected measure for deaths for England & Wales for the mortality monitors is reasonable following the in-depth analysis undertaken in the week 53 of 2020, week 52 of 2021 and week 1 of 2022 mortality monitors.
- As noted in Section 2 and Section 3, the ASMRs for England & Wales in this paper are based on estimated death occurrences, whereas ASMRs in the CMI mortality monitor are on a registrations basis.

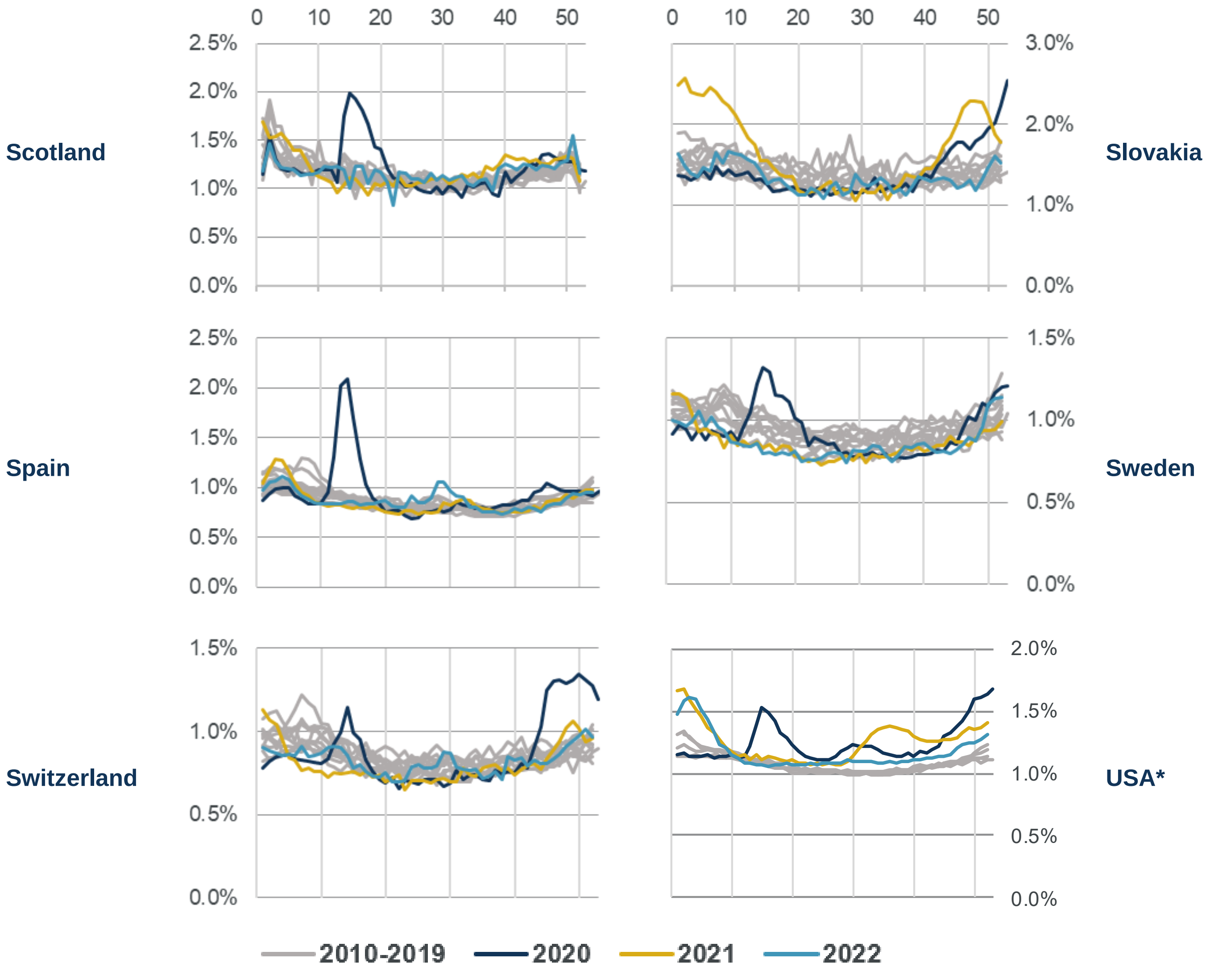
Appendix 4: Weekly ASMRs in 2010-2022

Chart A4A shows annualised weekly ASMRs in 2010-2022 for each territory. ASMRs in 2010-2019 are shown in grey, with those for 2020, 2021 and 2022 shown in dark blue, gold and light blue respectively. Note that the y-axis ranges of the charts differ by territory due to the wide range of mortality rates in the territories analysed.

Chart A4A: Annualised weekly ASMRs in 2010-2022*




Germany
Israel
Italy*
Lithuania
Netherlands
New Zealand*
Norway
Poland
Republic of Korea
Russia
2010-2019
2020
2021
2022



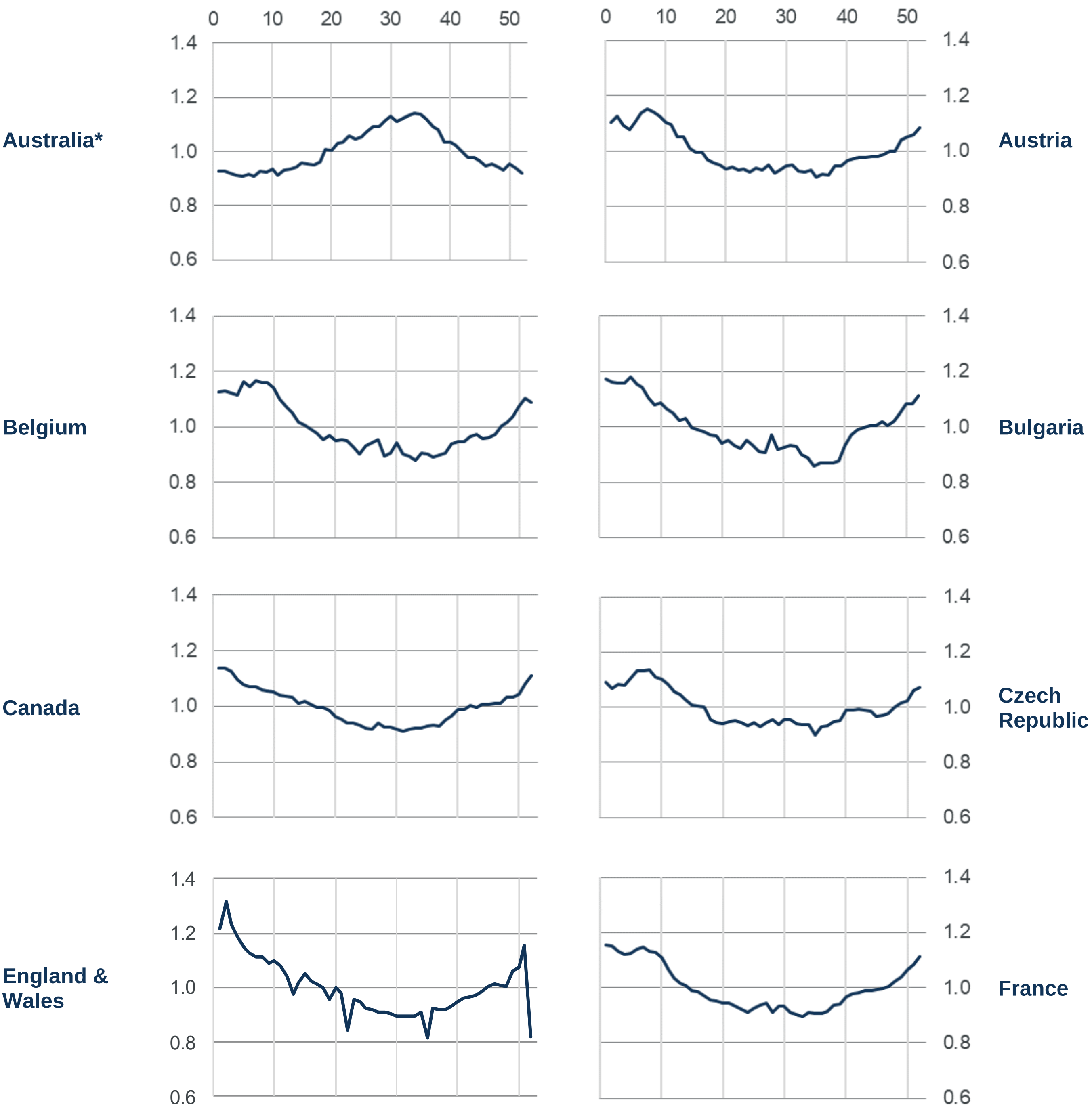
*Results for Australia, Italy, New Zealand and the USA show weekly ASMRs for fewer years than the other territories due to the availability of data (2011-2019 for Italy and New Zealand, 2015-2019 for Australia, and 2016-2019 for the USA).

Appendix 5: Seasonality factors

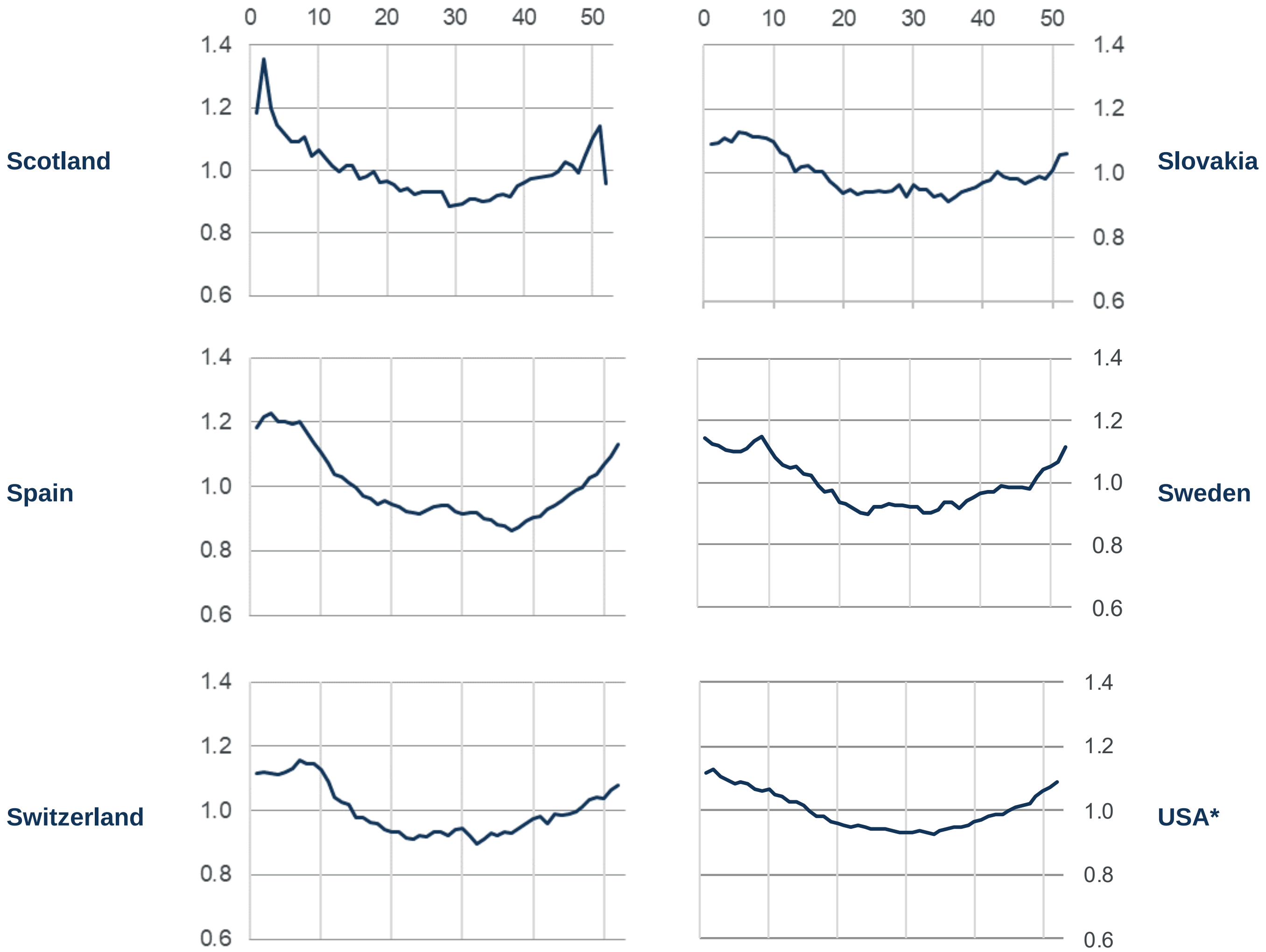
Chart A5A shows the weekly seasonality factors applied to the fitted 2019 ASMRs in order to calculate expected deaths, as described in Section 3.4, for each territory analysed in this paper.

Most northern hemisphere countries show a broadly similar pattern, with mortality being highest in the winter and lowest in the summer. The opposite pattern is seen for Australia and New Zealand. The seasonality for England & Wales and for Scotland shows spikes due to the use of registered deaths rather than occurrences.

Chart A5A: Seasonality factors for territories analysed




0 10 20 30 40 50
1.4 1.2 1.0 0.8 0.6
Germany
Israel
Italy*
Lithuania
Netherlands
New Zealand*
Norway
Poland
Republic of Korea
Russia



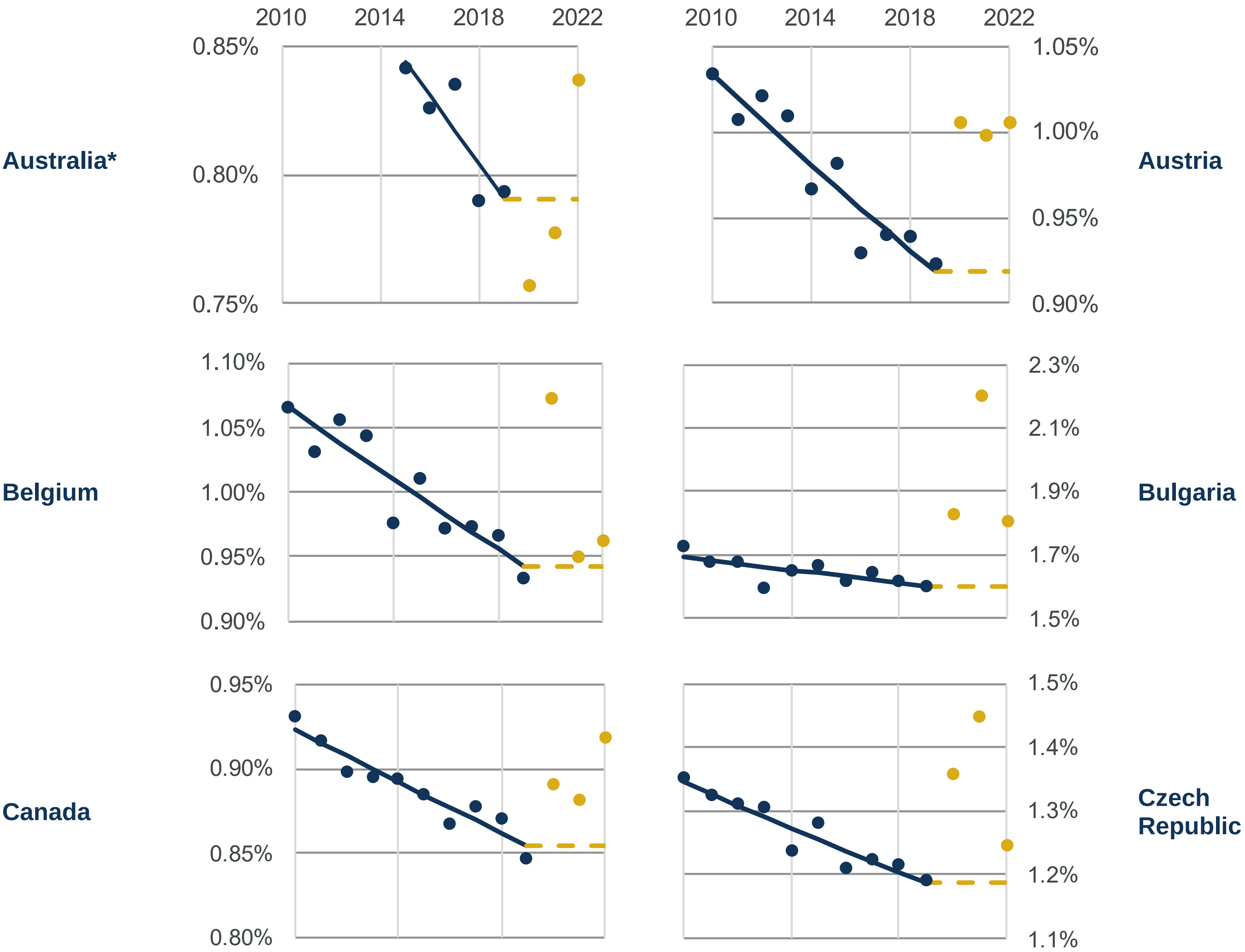
* Note that the seasonality factors for Australia, Italy, New Zealand and the USA are calculated using weekly and annual ASMRs for shorter periods than the other territories, as data is not available from 2010 for these territories (2011-2019 for Italy and New Zealand, 2015-2019 for Australia, and 2016-2019 for the USA).

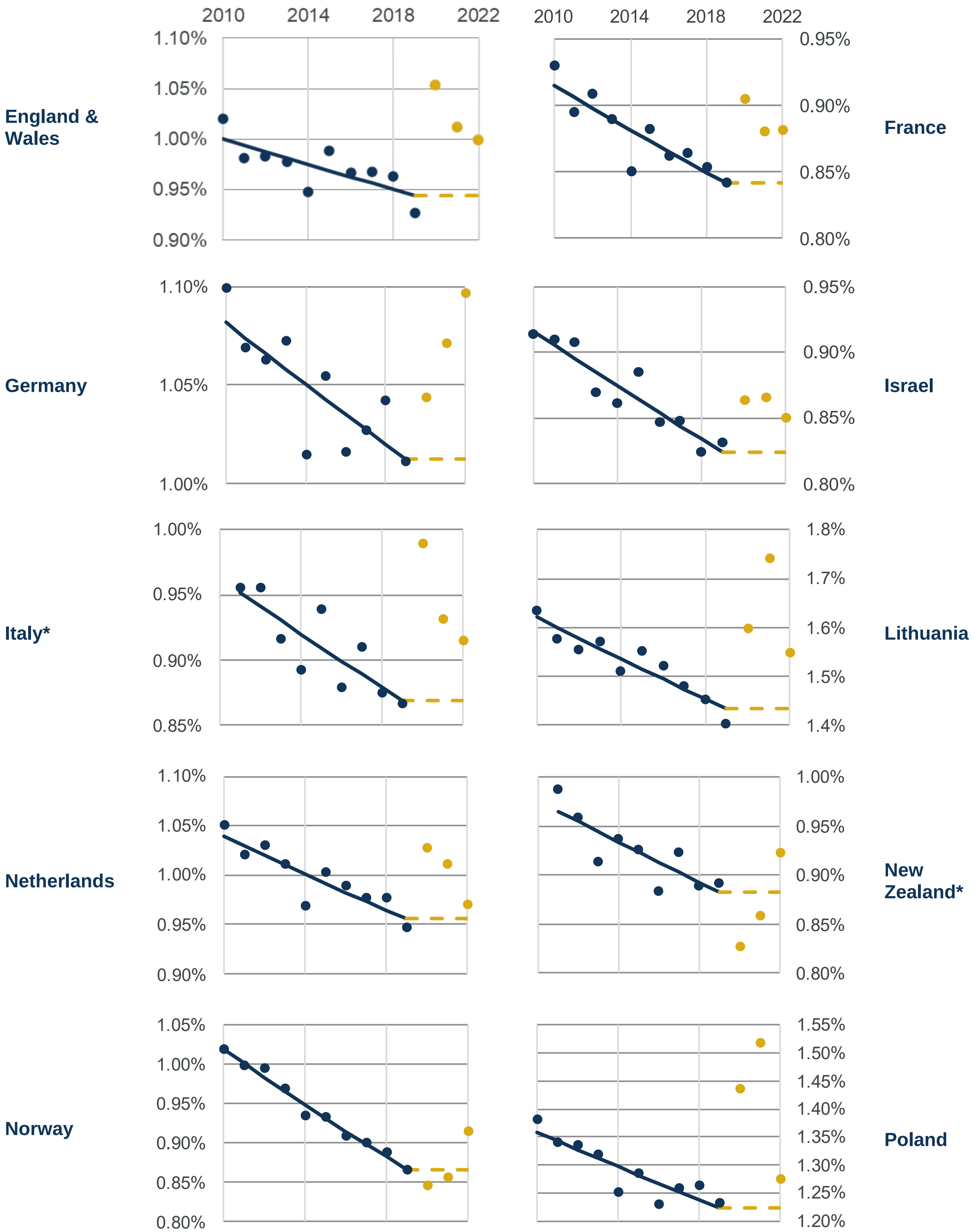
Appendix 6: Comparison of fitted mortality trend line to crude annual ASMRs

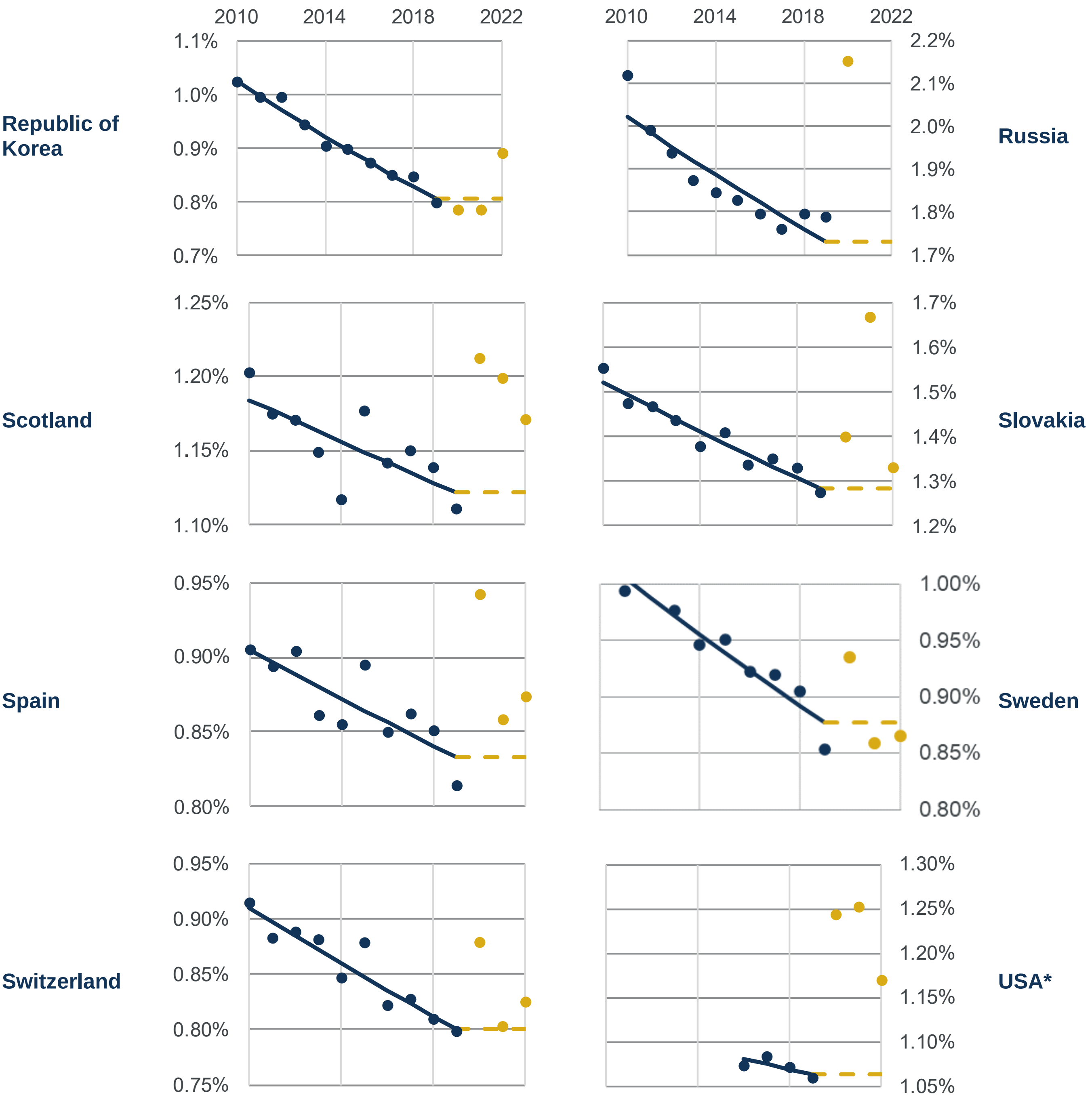
Chart A6A shows the calculated annual ASMRs for each territory, as described in Section 3.3, and the fitted trendline, as described in Section 3.4. Annual ASMRs for each calendar year to 2019 are presented as dark blue points, with the trendline shown as a dark blue solid line. The 2019 value of the fitted trend (i.e. the value used to calculate expected mortality in 2020, 2021 and 2022) is extended as a gold dashed line to enable readers to compare 2020, 2021 and 2022 mortality to the baseline. Crude annual ASMRs for 2020, 2021 and 2022 are shown as gold points.

Note that the y-axis ranges of the charts differ by territory due to the wide range of mortality rates. Using different ranges for different territories allows more detail to be seen for each territory, but means that caution is needed when comparing different territories.

Chart A6A: Annual ASMRs in 2010-2022* and fitted mortality trend based on 2010-2019*




2010
2014
2018
2022
2010
2014
2018
2022
England & Wales
1.10%
1.05%
1.00%
0.95%
0.90%
0.95%
0.90%
0.85%
0.80%
France
Germany
1.10%
1.05%
1.00%
0.95%
0.90%
0.85%
0.80%
Israel
Italy*
1.00%
0.95%
0.90%
0.85%
1.8%
1.7%
1.6%
1.5%
1.4%
Lithuania
Netherlands
1.10%
1.05%
1.00%
0.95%
0.90%
1.00%
0.95%
0.90%
0.85%
0.80%
New Zealand*
Norway
1.05%
1.00%
0.95%
0.90%
0.85%
0.80%
1.55%
1.50%
1.45%
1.40%
1.35%
1.30%
1.25%
1.20%
Poland



* Note that for Australia, Italy, New Zealand and the USA data is not available from 2010. For these territories we have shown the period used for calculating the expected baseline, which is the longest full year period available.

Appendix 7: Description of the accompanying Tableau Workbook

We have released a Tableau Workbook alongside this paper to allow users to interact with some of the results. The data underlying the Tableau Workbook is available in the accompanying “chart values” spreadsheet.
The Tableau Workbook allows the user to interact with the following charts:

- Chart 4A (weekly relative excess mortality during 2020-2022, for each of the 24 international territories analysed in this paper) on the “Weekly relative excess” dashboard. The dashboard includes the charts for four territories in grid of charts, with the position of the charts variable to allow comparison between different territories.
- Charts 4B-4E (cumulative relative excess mortality in 2020-2022) on the “Cumulative excess (week 10 of 2020)” and “Cumulative excess (week 26 of 2021)” dashboards. The dashboards show all territories on a single chart.
- Chart A4A (weekly ASMRs in 2010-2022, for each of the 24 international territories analysed in this paper) on the “Weekly ASMRs” dashboard.
- Chart A5A (seasonality factors) on the “Seasonality factors” dashboard.

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