UNESPA

Longevity Risk Investigation

21 January 2009

TOWERS PERRIN

PRIVATE AND CONFIDENTIAL

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Dear Mr.Ávalos,

We enclose our Final Report setting out the results of our study of the volatility of mortality improvement factors by various combinations of age range and risk cover duration, and their impact in the Solvency II standard proposed longevity shock. We also suggest applying different levels of shock for age range and risk cover duration which we believe to be a better methodology, and more suited to achieving the desired levels of minimum risk capital.

Should you have any comments or questions when you have had the opportunity to review the report, we will be pleased to discuss those with you.

Yours sincerely,

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1. EXECUTIVE SUMMARY

UNESPA has requested Towers Perrin to assess the Solvency II proposed longevity shock and to consider how the proposal might be improved. In particular, to calculate the possibility of performing a longevity shock across a combination of age bands and risk cover durations. Our study suggests one possible improvement to the Solvency II shock methodology.

1.1 Context

Unless insurance companies opt to develop and get approval for an internal model, the default position under Solvency II is that companies must calculate their SCR using a standard approach.

The default SCR standard approach generally seeks to balance having sufficient sophistication to achieve accurate results, with being sufficiently simple that implementation is not expensive for smaller insurers.

This study focuses exclusively on the standard approach calculation for the risk posed by greater than expected improvements in future mortality and does not consider other risks. The currently proposed SCR standard approach requires companies to allocate sufficient capital to provide for the impact of having greater than expected mortality improvements in their longevity products (basically annuities) portfolio. The proposed longevity shock is a fixed, one-off 25% immediate decrease in expected mortality.

1.2 General reasoning

We consider that the fixed one-off 25% immediate shock of expected mortality, which we understand to be a sudden and permanent decrease of mortality, results in:

- A calculation which does not reflect the real nature of the risk or the risk profile over time. This calculation will have very significant consequences for the annuities business underwritten in most of European countries; the final impact and potential distortion will depend on the insured age and the insurance outstanding duration for each company.

- A simplification, which may well require higher longevity risk capital than the generally intended 99.5% confidence level over one year.

Historical data shows that mortality has gradually improved over time, but has not shown sudden substantial permanent movements.

1.3 Foundations of the study

The objective of the analysis performed by Towers Perrin is the investigation of the longevity shock in the context of the EU countries.

We have worked with the total population data of each country. The Mortality data used in this study is sourced from the Human Mortality Database (www.mortality.org) supported by the University of California, Berkeley (U.S.A.) and the 'Max Planck' Institute for Demographic Research (Germany).

After assessing and processing all available information, we analyzed data from 22 European countries that represents 92.21% of the total European Union population. The balance represents countries where appropriate data was not available (Ireland, Romania, Greece, Malta and Cyprus).

1.4 Methodology

We have used a predictive mortality model based on historical data. Theoretically, these types of models are influenced by trends and uncertainty. In this manner:

- The trend observed in the historical data can be affected by events which are not predictable; e.g. medical improvements which reduce mortality.

- There is also projection uncertainty: past experience is not necessarily reliable for the future, due to changes in the people behaviour.

Further, we should highlight the existence of the parameter risk: insurance companies cannot be certain that their data truly reflects their underlying risk: the larger their portfolio is, and the more data they have, the better the expected mortality estimate should be.

Our investigation is based on historical data, so as it is usual in these types of approaches, it does not include uncertainty.

We have started our analysis in year 1956 in order to avoid distortions produced by the World Wars and the lack of data of some important countries, with a significant emphasis on the total European population.

On the basis of the mortality probability data of the analysed countries, we have derived, for each country, the annual mortality improvement factor according to age bands and by sex. In the historical data, we can observe a constant and progressive mortality reduction, as well as mortality improvement which decreases as age increases. We have also checked that the evolution of this mortality improvement reasonably follows a Normal distribution.

The European annual mortality improvement factors, by age bands and sex, have been determined by the aggregation of factors per country, according to each country's demographical weight.

The calculation of expected mortality improvement, by age and duration bands, has been carried out through a stochastic projection of a base population. We have incorporated a random variable in the mortality projection, taking into consideration the dispersion around the average, in a 5,000 scenarios projection. From the given scenario projections, we have estimated the mean and standard deviation of the accumulated mortality improvement in order to evaluate the deviation against the mean, with a 99.5% confidence level.

When evaluating the mortality improvement impact on the combinations of age and duration, we have calibrated an equivalent percentage "once-off" change at the starting point; similar to the current longevity shock structure.

1.5 Annual mortality improvement factor

The historical information demonstrates that the improvement mortality factor doesn't undergo steep changes; rather, it changes gradually throughout the years. Of the empirical data, it is also observed that the mortality improvement and its standard deviation decrease with the age.

Table 1.5.1

Annual mortality improvement factor (Total Europe since year 1956)

	Total	< 50	50-60	60-70	70-80	80-90	> 90
Average	1.26%	1.79%	1.04%	1.29%	1.30%	0.97%	0.20%
Standard deviation	2.26%	2.98%	1.40%	1.32%	1.18%	1.01%	0.79%

a) Calculated by 5-years ranges

The improvement trend shown in the table above consistent with that revealed by other mortality investigations, both for the general population and the insured population.

1.6 Conclusions

Following the above mentioned general reasoning, we consider it reasonable to conclude that mortality has always improved gradually based on a broad variety of factors; amongst these are medical improvements, more access to the National Health systems, better nutritive habits and reduction in smoking prevalence. In the future, we expect changes to continue in a similar fashion. It is difficult to envisage a sudden and permanent 25% mortality improvement.

In this Report, we have been looking for an alternative longevity shock approach, which fits with the circumstances outlined above, and takes into account three fundamental elements:

- The results of mortality factor analysis covering the bulk of European countries for the last 50 years.
- The fact that the mortality improvement has been gradual and not uniform across all ages and sexes.

- A stochastic analysis of mortality trends, calibrated to actual experience. This analysis provides us with reasonable evidence that the 25% sudden shock requires more capital than the intended Solvency II 99.5% "over 1 year" confidence level.

In consequence, we suggest an alternative structure to the longevity shock which depends on age and duration. We consider that this structure will be a better fit with the intended confidence level and should be relatively easy to apply in practice.

Alternative longevity shock

A single one-off shock, which varies by combination of age range and coverage duration, based on the available data and the methodology explained above, might be based on the factors shown in Table 1.6.1:

Table 1.6.1

Example of a possible longevity shock

(Mortality reduction at the date of calculation of required Solvency capital)

Coverage duration / Age band	5 years	10 years	15 years	20 years	Whole of life
30 – 39			19%	21%	27%
40 – 49	11%	16%	17%	18%	19%
50 – 59	7%	8%	9%	10%	13%
60 – 69	6%	7%	8%	9%	11%
70 – 79	5%	6%	7%		9%
80 – 89	4%				7%
90 – 99					5%

This indicative table allows the following findings:

- When the duration is longer, there is greater possibility of mortality improvement.
- All ages should not have the same shock, because the younger the person is the greater the possible mortality improvement.
- A whole of life annuity should not have the same treatment as a temporary annuity.

The table above it is not an alternative proposal of calibration, rather, it is an alternative longevity shock based on combinations of age and coverage duration. It is based on historical data; it includes the expected trend risk but risk does not include uncertainty risk or parametric risk.

To incorporate parametric risk within our proposal, we suggest the addition of a uniform percentage to the table values. This single factor should be determined by the insurance company itself, and be lower when the portfolio is large and therefore the volume of experience data greater.

1.7 Reliances and Limitations

- Our investigation has required a number of approximations. Our results should therefore be considered as illustrative, and with potential for further development. Nevertheless, we consider that they show clearly that the 25% uniform, sudden and permanent reduction shock is inappropriate and we suggest that the alternative approach is a better approach to the longevity shock.
- A detailed description of the reliances and limitations of our Report is provided in Section 6.

2. BACKGROUND AND OBJECTIVE

2.1 Background

The European insurance industry is developing a new Solvency framework which establishes, amongst other important matters, the capital requirements for European insurance companies based on assumed risks. Quantitative Impact Studies (QIS) are being used to quantify the impact of the measures proposed in different waves, and they are helping to define more precisely the final Solvency framework.

In this environment, UNESPA as the Spanish Insurers' Association considers it necessary to analyse the reasonableness of the longevity risk shock that has been set out in QIS4; namely, a one-off, permanent 25% reduction in mortality rates.

We think that the formula proposed for the longevity shock is too simplistic and that it fails to reflect the real nature of the risk. This calculation will have significant consequences for the annuity business underwritten in many European countries; the impact will depend on the insured age and the outstanding contract duration.

Historical data about mortality shows that mortality improves gradually, and that it does not make sudden, permanent improvement. We have not found any theoretical justification for future mortality development in the form of a sudden and permanent 25% reduction.

Longevity risk is very significant in the Spanish market where there are very substantial portfolios of annuities generated by early retirement and by the placement of pension liabilities with insurers.

Given the importance of Solvency II, UNESPA has requested Towers Perrin to perform a longevity risk investigation.

2.2 Scope

The main objective of our collaboration with UNESPA is to examine the possibility of modifying the longevity shock proposed in Solvency II framework. UNESPA considers it preferable that the "shock" stress test should take into account both the age of the insured and the outstanding duration of the contract.

In particular, this collaboration is focused in:

- Studying the mortality improvement factor and its volatility, for all or most of European Union countries.
- Calculating if this improvement factor could be grouped as a combination of the insured age and the outstanding duration.
- Demonstrating, if the data permits, that the longevity risk shock is sensitive to age band or coverage duration.
- Suggesting, based on our analysis, a possible modification which improves the longevity shock.

2.3 Considerations

Unless companies opt to develop and get approval for an internal model, the default position under Solvency II is that companies must calculate their SCR using the standard approach. This standard formula requires the calculation of a series of risk capital amounts using a 1 year value at risk approach for independent 99.5th percentile stresses, which are then combined using a correlation matrix approach in order to calculate the final solvency capital requirement.

The default SCR standard approach generally seeks to balance having sufficient sophistication to achieve accurate results, with being simple enough to not be excessively expensive for smaller insurers to implement.

We should highlight the existence of "ORSA" (Own Risk and Solvency Assessment) whereby the insurance companies need to analyse appropriateness of the standard factors, even where the company does not seek approval of an internal model.

This report is solely focused in the standard approach calculation for the solvency capital calculation for the longevity shock, and it does not consider other risks.

The SCR standard approach requires companies to allocate capital to allow for the impact of having greater than expected mortality improvements in their longevity products (basically annuities) portfolio; that is, a life expectation higher than initially expected. The longevity shock is proposed as a fixed one-off and permanent 25% immediate decrease in mortality rates. A sudden change in mortality seems more probable in the context of a worsening of mortality, although the likelihood of a permanent worsening seems very low.

We consider that we demonstrate in this report that the QIS4 proposed longevity shock is too simplistic, and that it could materially misstate the capital needed in respect of longevity risk. In particular, we think it fails to take into account the important factors of age and outstanding duration, and that it does not reflect the profile of gradually improving mortality over time. As a consequence, we think that the current longevity shock does not achieve the desired capital level targeted by Solvency II.

3. DATA USED TO PERFORM THE INVESTIGATION

The Mortality data used in this section was sourced from the Human Mortality Database (www.mortality.org) supported by the University of California, Berkeley (U.S.A.) and the 'Max Planck' Institute for Demographic Research (Germany).

All the data analyzed is based on the population figures, rather than data for insured populations.

We analyzed data from 22 European countries that represents 92.21% of the total European Union population. The balance represents Romania, Greece, Malta and Cyprus, where appropriate data was not available. The total data analyzed cover 232,650 observations.

For all analysed countries, observations are broken down by sex, calendar year (from 1956 to 2005) and age (up to 110 years old).

3.1 Insured population analysis

We did not carry out any analysis on the insured population because there is no consistent, regularly published information available which adequately covers the European insured population.

4. METHODOLOGY

4.1 General description

Having identified the public information available, we have assumed that it is homogeneous enough to utilize it for the purposes of our investigation.

We have used a predictive mortality predictive model based on the historical data.

First of all, we used the historical data to calculate the annual mortality improvement factor by country.

Then, we analysed the distribution function of the annual mortality improvement factor by age bands and calculated the global demographical weighted average, for all countries.

Although in Solvency II the Value at Risk ("VaR") calculation is based on a one-year time horizon, we believe that the mortality improvement assumed in the initial year is not intended to apply on for that first year, but for the whole life of the insured. So to assess longevity risk improvement we consider it necessary to carry out a mortality improvement projection.

To do so, we used a stochastic model. Once this projection has been carried out for different durations (term and whole of life), and assuming a Normal distribution, we have established a *projected longevity shock* (over time) based on a comparison of the mean and the 99.5% confidence level results.

Finally, we transformed the *projected mortality improvement shock* to an equivalent "once-off" shock of the form proposed by QIS4. Calibrating in this way, we have derived a unique, initial and permanent shock in the expected mortality for different combinations of age range and durations, and the results indicate a 99.5% confidence level which is considerably below a 25% shock in almost all cases.

4.2 Data and its treatment

The public available information of the death rates in each one of the 22 analyzed European countries has a different origin calendar year. We have analysed data since 1956 for several reasons.

First, we felt that the time horizon used should be consistent across all the countries, so as not to distort the global result.

Secondly, Germany, with a considerable weight in terms of population, does not have available and credible information before year 1956.

Third and lastly, we felt that beginning from 1956 would avoid the impact of the two World Wars on the volatility of the annual mortality improvement factor. (Appendix D)

4.3 Use of different age ranges for the analysis

Annual Mortality Improvement Factor

The annual mortality improvement factor is analyzed by age bands. We decided to do this as there are potentially different behaviour patterns by generation, i.e., tobacco habits, diet, development of the National Health systems and medical improvements, amongst others. The analysed age bands are as follows:

- Less than 50 years old.
- Between 51 and 60 years old.
- Between 61 y 70 years old.
- Between 71 y 80 years old.
- Between 81 y 90 years old.
- More than 90 years old.

We also made a global analysis, without a break-down by age bands.

Longevity Shock

The longevity shock theoretically would be specific for each combination of age and outstanding duration and would depend on the mortality rates for each age, the mortality improvement factors and the duration of the contract.

Conceptually, it would be possible to propose a longevity shock table which had a longevity shock for each combination of age and outstanding contract duration. However, to carry out the stochastic simulation in this Report, we have focused our investigation in the following combinations of age and duration which we consider to be significant for the insurance industry.

Table 4.3.1

Age & outstanding duration combinations for the longevity shock

Coverage duration / Age band	5 years	10 years	15 years	20 years	Whole of life
30 – 39			X	X	X
40 – 49	X*	X*	X	X	X
50 – 59	X	X	X	X	X
60 – 69	X*	X	X	X	X
70 – 79	X	X	X		X
80 – 89	X				X
90 – 99					X

For each age band, our calculations were performed using the central age of the interval. For the entries marked "*"[1], we have used the lowest age of the range.

For "Whole of life" annuities, we assumed a limiting age of 110 years in our projections.

4.4 Annual mortality improvement factor. Historical analysis

The study of the annual mortality improvement factor has been performed based on historical data and via comparisons of mortality rates separated by periods of 5 years.

We derive the 5 year mortality improvement factor as follows:

> *Mortality improvement factor 5 years = [death probability year (t+5) / death probability year (t)].*

[1] As we think they are representative in the Spanish insurance industry.

In order to annualize this we have taken the annual improvement factor to be the fifth root of the 5 year factor.

Thereby, we derived the annualized mortality improvement factor for each five year period.

For the analysed countries, we have carried out a goodness of fit test for a Normal distribution. We have measured the goodness-of-fit in the annual mortality improvement factors as between the theoretical sample distribution and the empirical distribution. In Appendix A, we describe the Kolmogorov-Smirnov Lilliefors goodness of fit test used.

Finally, we have calculated the mean and the standard deviation of all annualised mortality improvement factors, each five years, from 1956 to the most recent data date.

Global results for the analysed countries have been calculated taking into account the demographic weight of each country.

Table 4.4.1

Annual Mortality Improvement Factor (both sexes: Europe since 1956)

	Total	< 50	50-60	60-70	70-80	80-90	> 90
Average	1.26%	1.79%	1.04%	1.29%	1.30%	0.97%	0.20%
Standard Deviation	2.26%	2.98%	1.40%	1.32%	1.18%	1.01%	0.79%

We present this data without differentiating by sex, as the results by sex are very similar (Appendix E)

4.5 Projection of the expected mortality improvement. Stochastic process

Here, our objective is to determine, with a specific confidence level, the expected evolution of the population under investigation. We take the mathematical model for the time series of projected mortality rates to be a stochastic process.

To determine the projected mortality improvement, we aggregate annual mortality improvement factors from the age selected for the analysis to a predetermined duration, whether term or whole of life. When we have a whole of life projection, we have assumed 110 years old as the maximum age.

Considerations for the stochastic model

To aggregate annual mortality improvement factors, we have done the following:

- **Base Mortality:** Expected mortality without improvements. We have chosen GRM95. This base mortality is taken as an example – other base mortalities are possible, of course.

- **Annual mortality improvement factors:** As previously described per age ranges. These factors are used to adjust to mortality rates in the base population projection over time.

- **Projected mortality improvement:** The results of applying the annual mortality improvement factors to the base mortality.

- **Normal distribution of the projected mortality improvement:** Assuming that the annual mortality improvement factor follows a Normal distribution, the aggregation of annual factors will also have a Normal distribution, this being an attribute of the sum of Normal distributions.

  It should be noted that we cannot be certain that the mortality improvement factor follows a Normal distribution in the extreme tails, although we have made this assumption to facilitate the projection work, which requires a large number of scenarios; and estimation is simplified by taking the total distribution to be Bivariate Normal.

- **Randomness in the projected mortality improvement:** We assume that there is randomness around the sample mean annual mortality improvement factor.

- **Scenarios:** We consider that 5,000 scenarios are sufficient. Using more scenarios does not contribute more robustness to the results.

Stochastic Model

We have projected the evolution of the base population taking into account the number of people alive from one year to another, including a random variable within the annual mortality improvement factor. The formula used is as follows:

$$\mathbf{l'_{x+1} = l_x * [1 - q_x * (1 - \mu x + \sigma x * k_{aleatory})]}$$

Where:

Data from the base mortality table:

- $\mathbf{l_x}$: population alive in year 0, given an x age.
- $\mathbf{q_x}$: probability of death within a year under the standard table, given an age of x years old at the start of the year.

Calculated data:

- $\mathbf{l'_{x+1}}$**:** population alive in year x+1, given an age of x years old at the beginning.
- μ x: mean of the mortality improvement factor for the analysed age range.
- σ x*:* standard deviation of the mortality improvement factor for the analysed age range.
- $\mathbf{k_{aleatory}}$: the random value which generates the required variability in the annual mortality improvement factors. See Appendix B.

In a particular simulation, the population alive calculation at the end of the projection ("year n") would be:

$$\mathbf{l'_{x+n} = l'_{x+n-1} * [1 - q_{x+n-1} * \prod_{i=1}^{n} (1 - factor\_i)]}$$

Where "*factor-i",* in the particular simulation for the calculation of the population alive at the end of the projection, would be:

$$factor\_i = \mu x+i + \sigma x+i * k_{aleatory.}$$

This calculation has been repeated 5,000 times for each combination of age/duration.

4.6 Projection of appropriate mortality improvement shock

To calculate the *projected longevity shock,* we have compared the expected evolution of a base population against the projection of this base population taking into account the mortality improvement factors. We have compared the number of survivors at the end of the analysed period (term or whole of life) between the base population and the base population with improvement factors. For an "x" age, an "n" period and a specific simulation, we have proceeded as follows:

1. First, we calculate the base mortality in period "n": **$1 - l_{x+n}/l_x$**
2. Then, we calculate the expected mortality improvement in period "n" as: **$1 - l`_{x+n}/l_x$** .
3. Finally, we compare both mortalities, base and improved, and calculate the mortality improvement factor for an "x" age and an duration "n" which are being analysed.

We have carried out the projection of 5,000 scenarios for each age and duration. Assuming that each annual mortality improvement factor follows a Normal distribution, the aggregation of annual mortality improvement factors would also be Normal.

Thus, we have calculated the mean and the standard deviation of the projected mortality improvement factor for each age and outstanding duration and can derive the distribution of *the projected mortality improvement shock* and the confidence levels of 99.5% ($l´_{x+t\_95}$) and 50% ($l´_{x+t\_50}$).

The difference of *the projected mortality improvement shock* between confidence levels of 50% and 99.5% is the risk measure, called **fm_50-95t**.

4.7 Alternative to QIS4 longevity shock

To obtain comparable results of the *projected longevity shock*, similar to the QIS4 longevity shock, we have calculated a unique, initial and permanent shock for the expected mortality which is equivalent to the 99.5% result **"fm_50-95t"**.

It's important to highlight that the difference between the projected population used to derive the *projected longevity shock* (using the 5,000 scenarios) and the one used to calculate the longevity shock, lies in the mortality improvement factors used. In the first case we use different mortality improvement factors each year (**factor_i**), depending on the projection age, and in the second case the mortality improvement factor is common to all years, being comparable to the QIS4 longevity shock. We have not considered projection uncertainty risk or parametric risk.

5. CONCLUSIONS

5.1 Longevity shock by combination of age and duration bands

- As previously explained, we believe that our conclusions are reasonable taking into account that mortality has improved gradually in the past due to many factors, such as medical advances, more access to the National Health systems, improvement in the diet, reduction in tobacco consumption, etc. In the future, it is expected that gradual improvement will continue, but it is difficult to believe that there will be a sudden and permanent mortality improvement of 25%.

- We consider that if the aim is purely one of simplicity, the application of a shock based on a sudden, immediate and permanent reduction of 25% over mortality rates for all ages does achieve a simple calculation. However, such a methodology does not appropriately reflect the nature of longevity risk.

- In this Report, we suggest an alternative approach of the longevity shock, which takes into account three fundamental elements:

  — The analysis of the mortality factors in the last 50 years for most of European countries.

  — That mortality factor improvement has occurred gradually and is not uniform for all ages and sexes.

  — The projection of mortality with a stochastic analysis calibrated to actual past experience.

- In this report we demonstrate empirically that the mortality improvement factor has a significantly different pattern in all age and duration bands, and historic data shows that the mortality improvement factor tends to decrease with age. This is a very important point, as the majority of the insurance products that cover the risk of longevity related to policyholders from 50 years old. In addition to the age aspect, we have to take into consideration the outstanding duration of the risk, as the impact is not the same in a whole of life annuity than in a term annuity.

- We suggest an alternative structure to the longevity shock depending on age and duration; we understand that this structure would be within the required confidence level and would be relatively easy to apply.

Table 5.1.1

Example of a possible longevity shock

(Mortality improvement for the calculation on the Solvency Capital required)

Coverage duration / Age band	5 years	10 years	15 years	20 years	Whole of Life
30 – 39			18.32%	20.68%	26.80%
40 – 49	11.05%	15.54%	16.78%	17.29%	18.56%
50 – 59	6.76%	7.67%	8.79%	9.97%	12.89%
60 – 69	5.46%	7.07%	8.02%	8.76%	10.88%
70 – 79	4.21%	5.45%	6.44%		8.62%
80 – 89	4.06%				6.97%
90 – 99					4.95%

- The longevity shocks in the above table are a suggestion based on historical data. We should highlight that neither the projection uncertainty risk nor the parametric risk are included in this calculation.

- To include the parametric risk within our suggestion, we suggest the addition of uniform percentage to the above table. This unique factor could be selected by companies, and be lower where companies have greater volumes of data.

- In the above table it is clear that the longevity shock decreases as the age increases and increases with duration. This is logical because as the age increases there is less time to benefit from life expectancy improvements, and when the outstanding duration is lower there is less time for life expectancy improvement.

6. DATA USED AND LIMITATIONS

6.1 Data used

Towers Perrin has performed this investigation based on public information.

The mortality probabilities used in this study were sourced from the Human Mortality Database (www.mortality.org) supported by the University of California, Berkeley (U.S.A.) and the 'Max Planck' Institute for Demographic Research (Germany).

The table with all the critical values of the Kolgomorov-Smirnov Lilliefors test was sourced from "Table of percentage points of Kolgomorov Statistics", J. Amer.Statist. Assoc., 51:111-121 (1956).

The methodology to calculate the death probabilities in the HMD are homogeneous and uniform among all the European analyzed countries.

6.2 Reliances and Limitations

This report is for internal and external use of the Directors and Management of Unión Española de Aseguradoras (UNESPA). Distribution of this report to any other party is allowed without Towers Perrin's prior written consent, as described in our proposal of consulting services in relation to Solvency II framework development.

- Our investigation is based on historical data, so as it is usual in these types of approaches, it does not include uncertainty.
- Our analysis does not include the valuation of the parametric risk related to the estimation of the expected mortality. This risk could be considered by adding a uniform percentage for all ages/durations, such as we describe in our Conclusions.
- Except where we say the contrary, Towers Perrin has carried out this analysis over the total population, so the results and conclusions are related to total population from 1956 for the 22 countries analysed.
- Towers Perrin no has not attempted to determine the existing probabilities of death in the 'Human Mortality Database' (www.mortality.org), supported by the University of

California, Berkeley (USA) and the 'Institute of Demographical Investigation Max Planck' (Germany). We have assumed that all information is homogenous.

- Towers Perrin has analysed 22 European countries which represent 92.21% of the total EU population. The balance represents countries such as Ireland, Malta, Greece, Romania or Cyprus, where appropriate data was not available or was incomplete.
- The aggregation of the 22 countries' population in this Report has been carried out by a population weighing. Other type of weighing or a future evolution resulting in a different weighing could modify some of the conclusions of this Report.
- The weighing of the demographical weight of each country implicitly assumes that all countries are in a homogenous mortality pattern development situation.
- We have assumed that there is a Normal distribution in the annual mortality improvement factor extreme tails. We understand that this assumption is used in this type of investigations.
- We have, of necessity, made a range of approximations in performing this investigation. Thus the results should be seen as indicative and capable of further development. Nonetheless, we believe that the work provides a clear demonstration of the inappropriateness of a 25% sudden, uniform and permanent reduction, and we consider that the alternative approach suggested within this Report is a better approach to the longevity shock.

It shall also be understood that:

- Towers Perrin has performed the work assigned and has prepared this report in conformity with its intended utilisation by a person technically competent in the areas addressed and for the stated purposes only. Judgements as to the data contained in the report should be made only after studying the report in its entirety, as the conclusions reached by review of a section or sections on an isolated basis may be incorrect.
- Further, members of Towers Perrin staff are available to explain or expand on any matters presented herein, and it is assumed that the user of this report will seek such explanation or amplification as to any matter in question.

APPENDIX A: NORMAL DISTRIBUTION - KOLMOGOROV-SMIRNOV LILLIEFORS GOODNESS OF FIT

A goodness of fit test had been performed to confirm that the annual mortality improvement factors follow a Normal distribution. We want to measure the degree of fit between the theoretical and the empirical distribution of the annual mortality improvement factors.

We decided to use the Kolmogorov-Smirnov Lilliefors (S-K) test, to measure the degree of fit of the annual mortality improvement factor to a Normal distribution. The test works with a distribution function (cumulative frequency distribution).

A brief description of this test follows.

$F_0(x)$ is the theoretical distribution function for the variable X (the annual mortality improvement factor), and represents the probability that variable X has an equal or lower value than x (it can be also understood as the expected proportion of observations that have an equal or lower value than x), i.e.:

$$F_0(x) = P(X < x) = \int_{-\infty}^{x} f_0(x)dx$$

$F_n(x)$ is the empirical distribution function, calculated on the observed values of the n observations of the sample. $F_n(x)$ represents the value proportion that is equal or lower than x, and it's defined as:

$F_n(x) = P\ (X \leq x$/ given the sample results) = acum/n

Where 'acum' is the values observed that are equal or lower than x.

In the S-K test, we're interested in the highest difference between the theoretical and the empirical distribution, i.e. between $F_0(x)$ and $Fn(x)$, for all the value range of x. The null hypothesis states that these deviations should be low and fall in the random errors limits. Therefore, the S-K test calculates the highest difference between $Fn(x)$ and $F_0(x)$, i.e. $Dn(x)$ and its expression is as follows:

$Dn(x) = Max \mid Fn(x) - F_0(x) \mid$

The Dn(x) distribution is known and depends on the 'n' number of observations. We accept the null hypothesis that there is no significant differences between the theoretical and the empirical distributions if the value of Dn(x) is equal or lower than the critical value Dn(α,n). That means that the statistical test is performed by calculating the statistic Dn, and we reject the Normal hypothesis when Dn is significantly high, i.e. when it's bigger than the value given by the tables at the significant level chosen, in our case the 5%.

We have proceeded to calculate the value of the statistic for the analyzed European countries, from year 1956 and ages older or equal than 50 years. The result of the S-K test depends on the following factors:

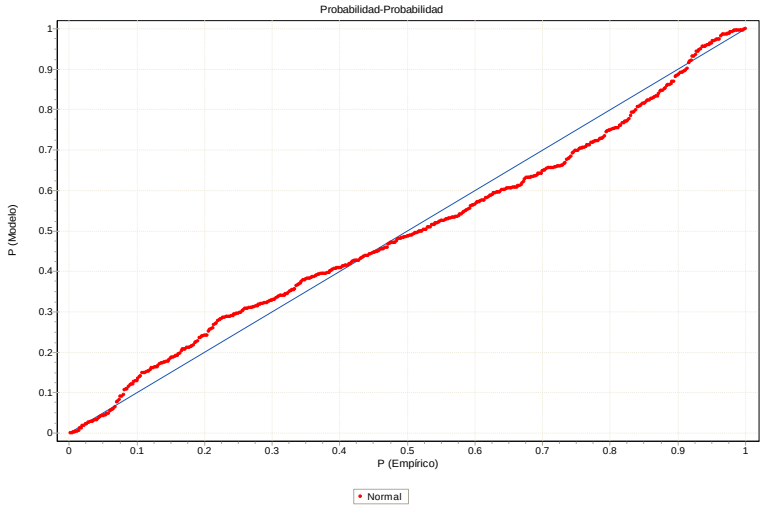
- K-S statistic: this is the value of the statistic of Kolmogorov-Smirnov Lilliefors, $Dn(x) = Sup|Fn(x)–F_0(x)|$
- Significance level and confidence level: α is the significance level and is the probability of having an error in our estimation. Thus our confidence level is equal to 1-α and represents the probability that the true value of the estimated parameter of the sample falls in the desire range.
- Critical value: it is usually represented by Z, and it is the value of the abscissa in a determined distribution that leaves to its right side an area equal to α or $\alpha/2$, given that α is the significance level.
- P-value based in Kolmogorov - Smirnov: Probability that on the right of the calculated statistic of the reference distribution. It's also known as the lowest level of significance level for which the null hypothesis, (the annual mortality improvement factor follow a Normal distribution), is rejected. A p-value close to zero shows that your null hypothesis is false. 5% is the limit generally accepted to value the appropriateness of a null hypothesis.

In the K-S goodness-of- fit of the annual mortality improvement factors to the Normal distribution, we applied this test to those countries with more than 15 million of population. In each country we repeated the test, for the population older or equal to 50 years, by age ranges of 5 or 10 years. We arrived at the following conclusions:

- There exists sufficient evidence not to reject the Normal hypothesis and to accept it at a significant level of $\alpha = 5\%$.
- The majority of the age ranges of 5 years have a p-value higher than 0.05, therefore we can accept the null hypothesis that the annual mortality improvement factor follows a Normal distribution, with a confidence level of 95%.
- The age ranges from 60 to 69, 80 to 89 and 90 to 99 are those which fit best a Normal distribution. The rest of the age ranges, i.e., 50 to 59 and 70 to 79 accept the null hypothesis at a significance level between 1% and 5%.

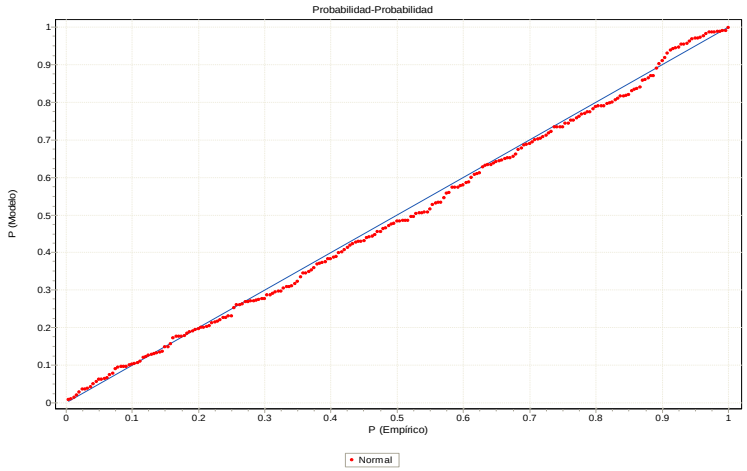
Below we show three probability-probability plots ("P-P plots"), for a specific country and age range as an example. This graph it is used to determine how well a specific distribution fits to the observed data. This plot will be approximately linear if the specified theoretical distribution is the correct model.

GRAPH A.1 SPANISH GOODNESS OF FIT TO A NORMAL DISTRIBUTION FOR AGE RANGES FROM 70 TO 79 YEARS.



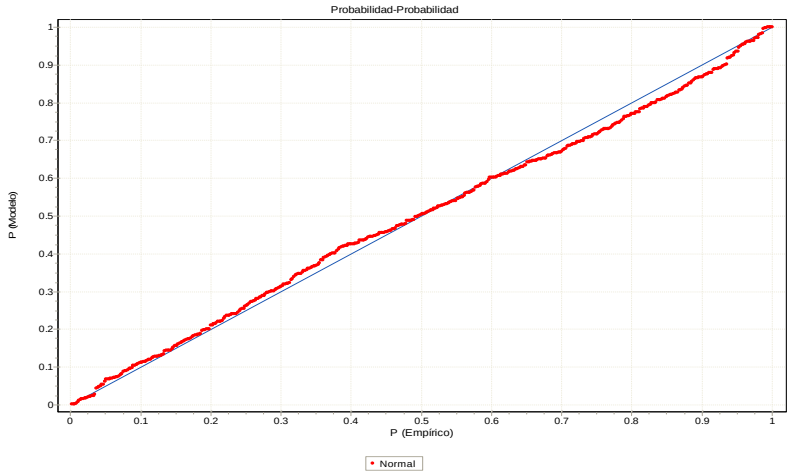
Another P-P plot used to determine how well a specific distribution fits to the observed data is Poland for ages from 50 to 54 years.

GRAPH A.2 POLISH GOODNESS OF FIT TO A NORMAL DISTRIBUTION FOR AGE RANGES FROM 70 TO 79 YEARS.



The third P-P plot used to determine how well a specific distribution fits to the observed data is UK for ages from 80 to 89 years.

GRÁPH A.3 BRITISH GOODNESS OF FIT TO A NORMAL DISTRIBUTION FOR AGE RANGES FROM 80 TO 89 YEARS.



The critical values table for the Kolmogorov-Smirnov Lilliefors Test is the following:

N	α =0.2	α =0.15	α =0.1	α =0.05	α =0.01
1	0.9	0.925	0.95	0.975	0.995
2	0.684	0.726	0.776	0.842	0.929
3	0.565	0.597	0.642	0.708	0.828
4	0.494	0.525	0.564	0.624	0.733
5	0.446	0.474	0.51	0.565	0.669
6	0.41	0.436	0.47	0.521	0.618
7	0.381	0.405	0.438	0.486	0.577
8	0.358	0.381	0.411	0.457	0.543
9	0.339	0.36	0.388	0.432	0.514
10	0.322	0.342	0.368	0.41	0.49
11	0.307	0.326	0.352	0.391	0.468
12	0.295	0.313	0.338	0.375	0.45
13	0.284	0.302	0.325	0.361	0.433
14	0.274	0.292	0.314	0.349	0.418
15	0.266	0.283	0.304	0.338	0.404
16	0.258	0.274	0.295	0.328	0.392
17	0.25	0.266	0.286	0.318	0.381
18	0.244	0.259	0.278	0.309	0.371
19	0.237	0.252	0.272	0.301	0.363
20	0.231	0.246	0.264	0.294	0.356
25	0.21	0.22	0.24	0.27	0.32
30	0.19	0.2	0.22	0.24	0.29
35	0.18	0.19	0.21	0.23	0.27
>35	$1.073/\sqrt{n}$	$1.14/\sqrt{n}$	$1.224/\sqrt{n}$	$1.358/\sqrt{n}$	$1.627/\sqrt{n}$

Where "n" is the sample's size.

The table of Kolgomorov-Smirnov test critical values has been obtained from "Table of percentage points of Kolgomorov Statistics", J. Amer.Statist. Assoc., 51:111-121 (1956).

APPENDIX B: "RANDOM K"

Assuming that the annual improvement factor follows a Normal distribution, we wish to introduce a random factor in the mortality projection in order to determine, with a specific confidence level, the behaviour of a population sample evaluation.

Being:

μ : This is the sample average of the annual improvement mortality factors. We considered this statistic as the best estimate.

σ : This is the standard deviation of the annual improvement mortality factors.

K: The random value. To calculate this value, the improvement factors should be normalized in order to find its value in the Normal (0, 1) distribution tables. This is where we assume randomness. We consider that the deviation of mortality is around the mean and that it is distributed uniformly between one and zero; i.e. α can have any value between zero and one.

A key step in this simulation is having routines that generate random variables which follow a Normal distribution. This simulation is carried out in two phases:

- *Generation of a random numbers sequence distributed uniformly between 0 and 1.*

  We have used a function which generates successive random numbers, which are independent between them and are distributed uniformly between 0 and 1. This is done for the 5,000 scenarios and all the projection years.

- *Transformation of the random numbers sequence to obtain the random values of the Normal distribution.*

  Once we have generated the uniform random numbers sequence for a time period and for the 5,000 scenarios, and given that we know they are independent between them and are distributed between 0 and 1, we can calculate the corresponding values in the inverse accumulation function of the Normal distribution.

The last figures are the $\mathbf{k_{aleatory}}$ values, which are used in the final calculations of the mortality improvement factors for the given age ranges and durations (temporary and whole of life).

In a specific simulation, the population alive calculation for the whole projection would be as follows:

1st year: $\mathbf{l'_{x+1} = l_x * [1 - q_x * (1\text{-}factor\_1)],}$

Where $(1\text{-}factor\_1) = (1 - \mu x + \sigma x * k_{aleatory})$

2nd year: $\mathbf{l'_{x+2} = l'_{x+1} * [1 - q_{x+1} * (1\text{-}factor\_1) * (1\text{-}factor\_2)],}$

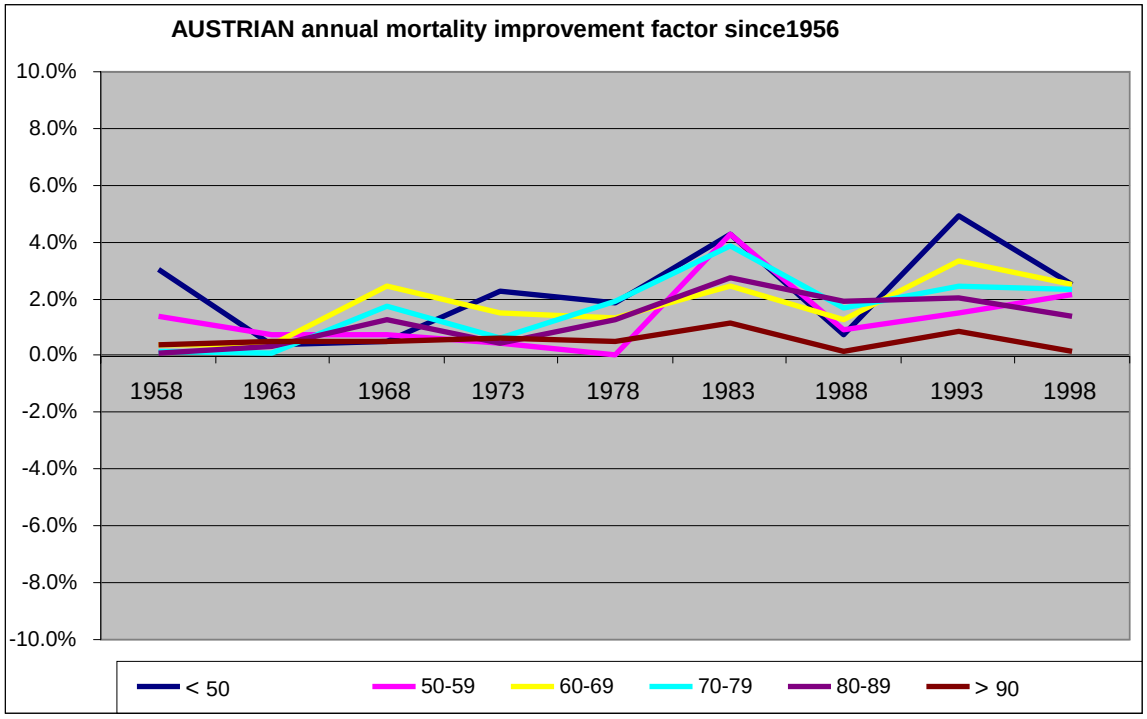
Where: $(1\text{-}factor\_2) = (1 - \mu x+1 + \sigma x+1 * k_{aleatory})\ i$

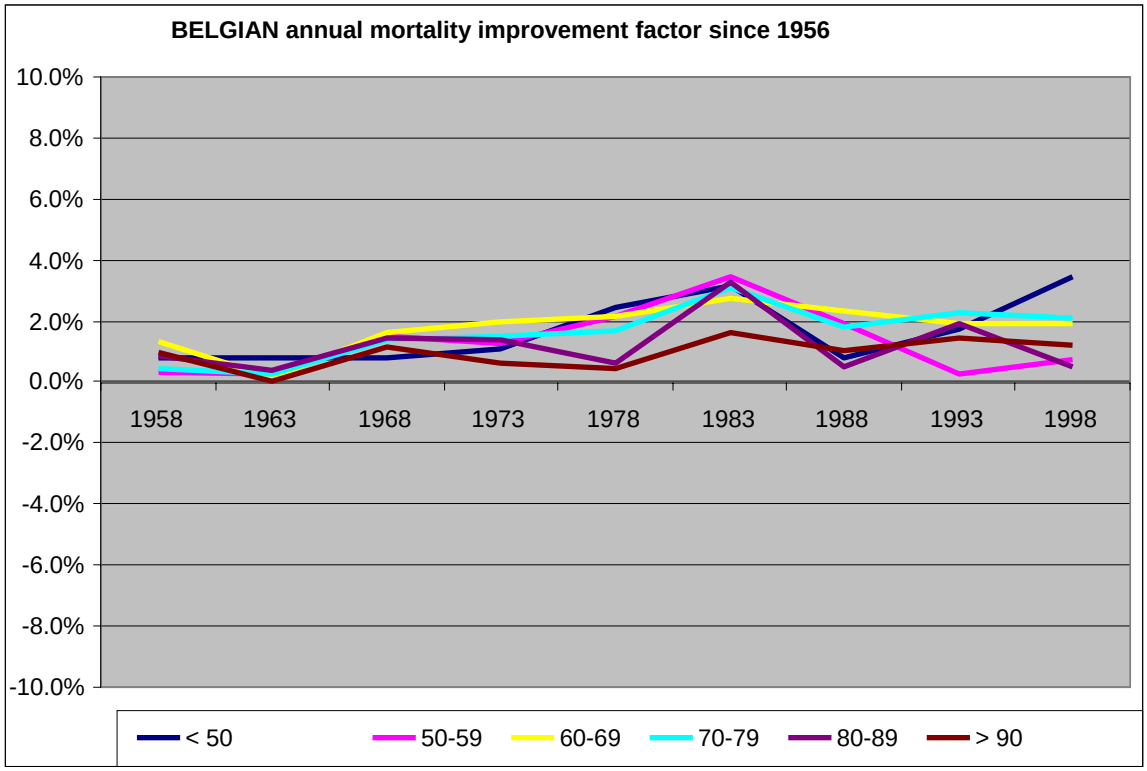
We should highlight that the factor is the same along the projection for each simulation; i.e. $factor\_1$ is the same in each projection year for a specific scenario.

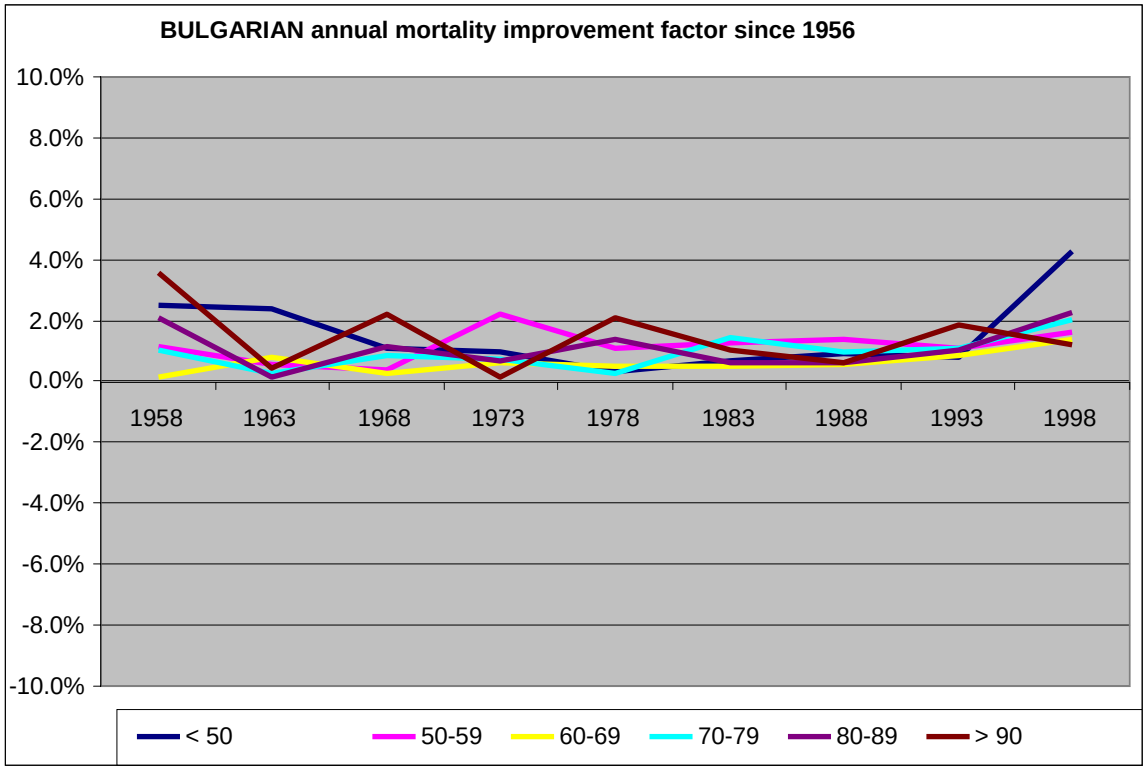
Year n: $\mathbf{l'_{x+n} = l'_{x+n-1} * [1 - q_{x+n-1} * \prod_{i=1}^{n}(1 - factor\_i)\ ]}$

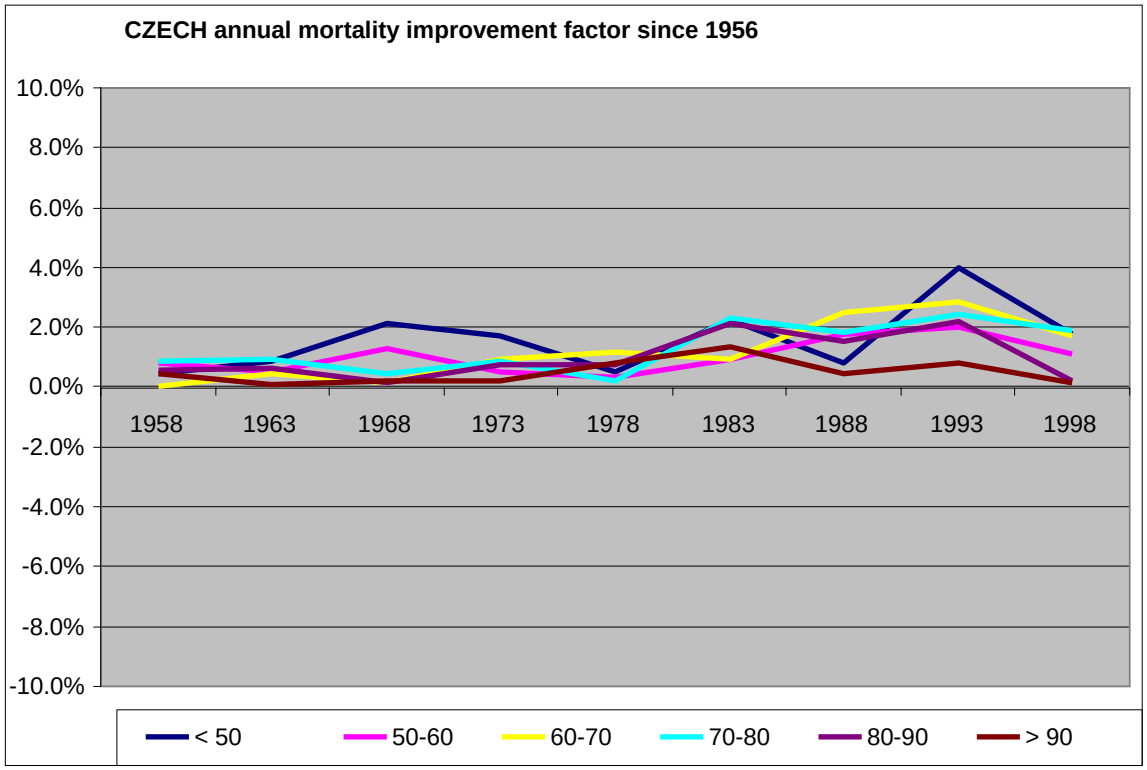
APPENDIX C: GRAPHS OF THE HISTORIC MORTALITY ANNUAL IMPROVEMENT FACTOR BY COUNTRY & PERFORMANCE OF THE ANNUAL MORTALITY IMPROVEMENT FACTOR BY AGE.

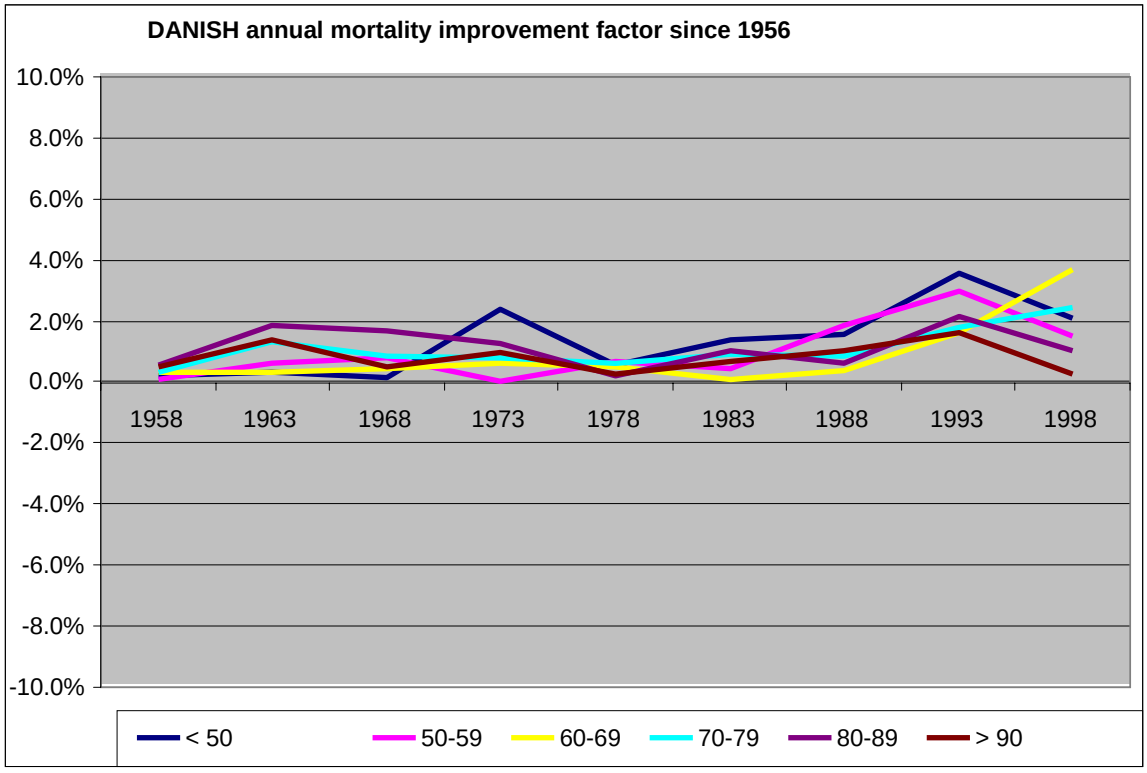
Positive values represent favourable annual mortality improvements factors.

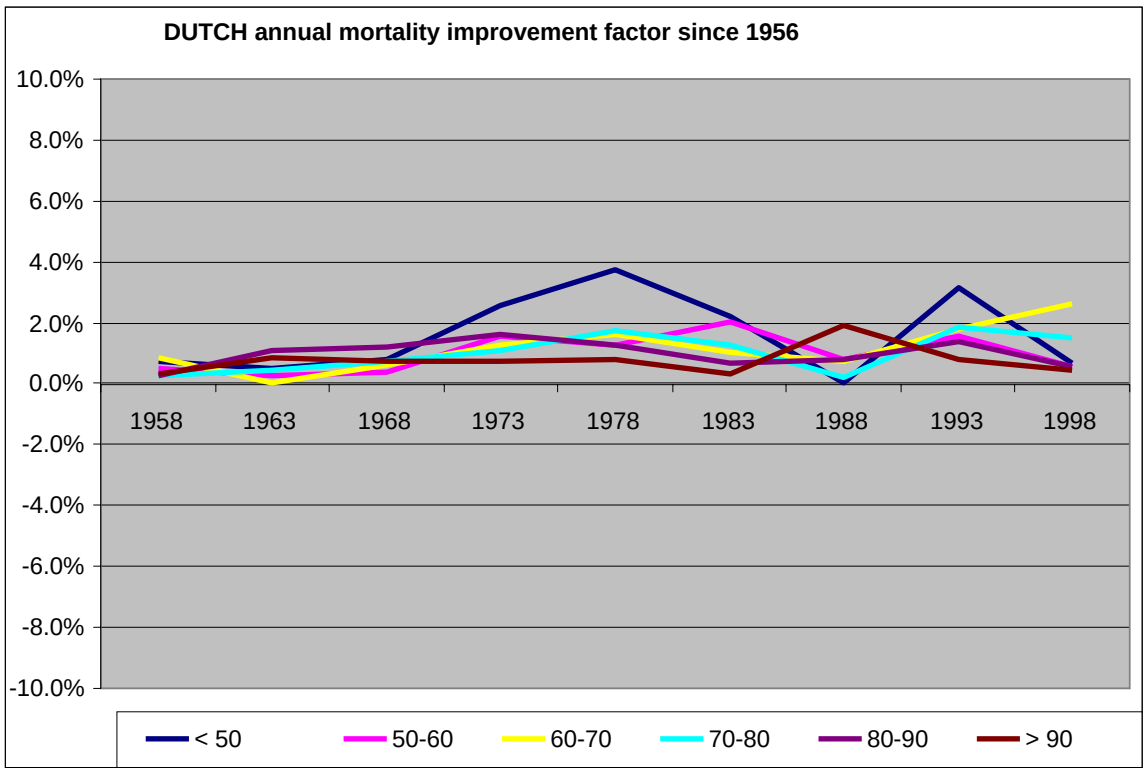


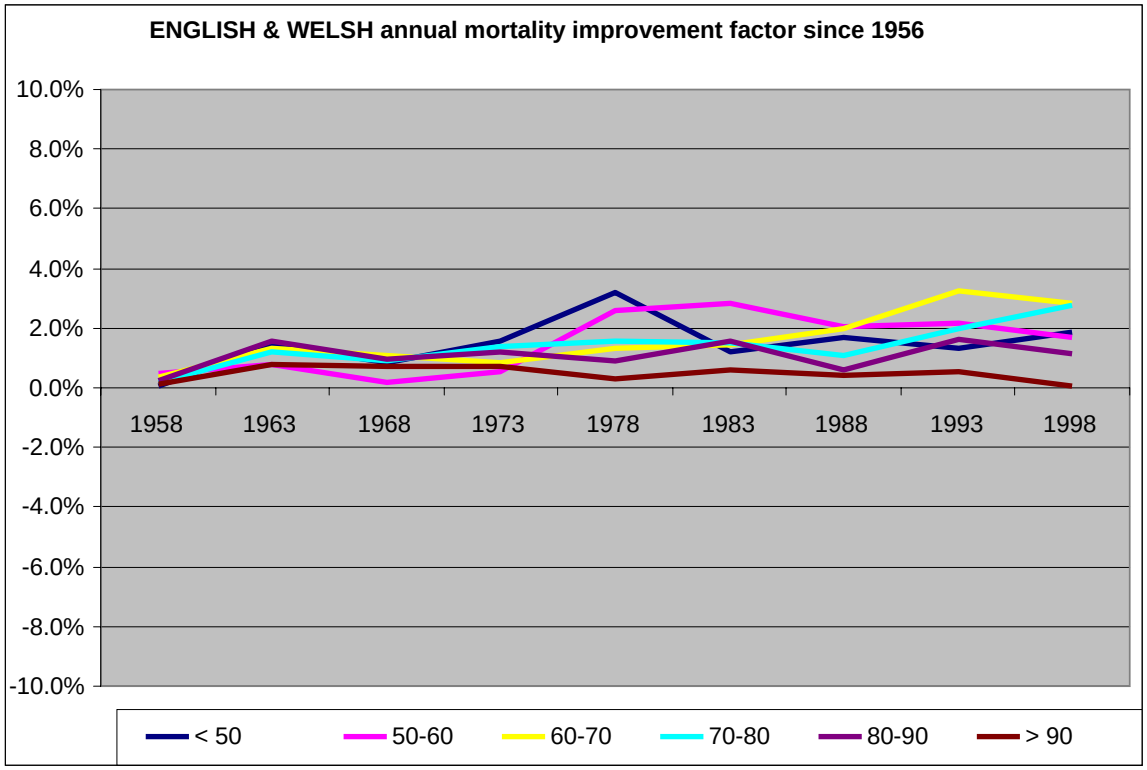


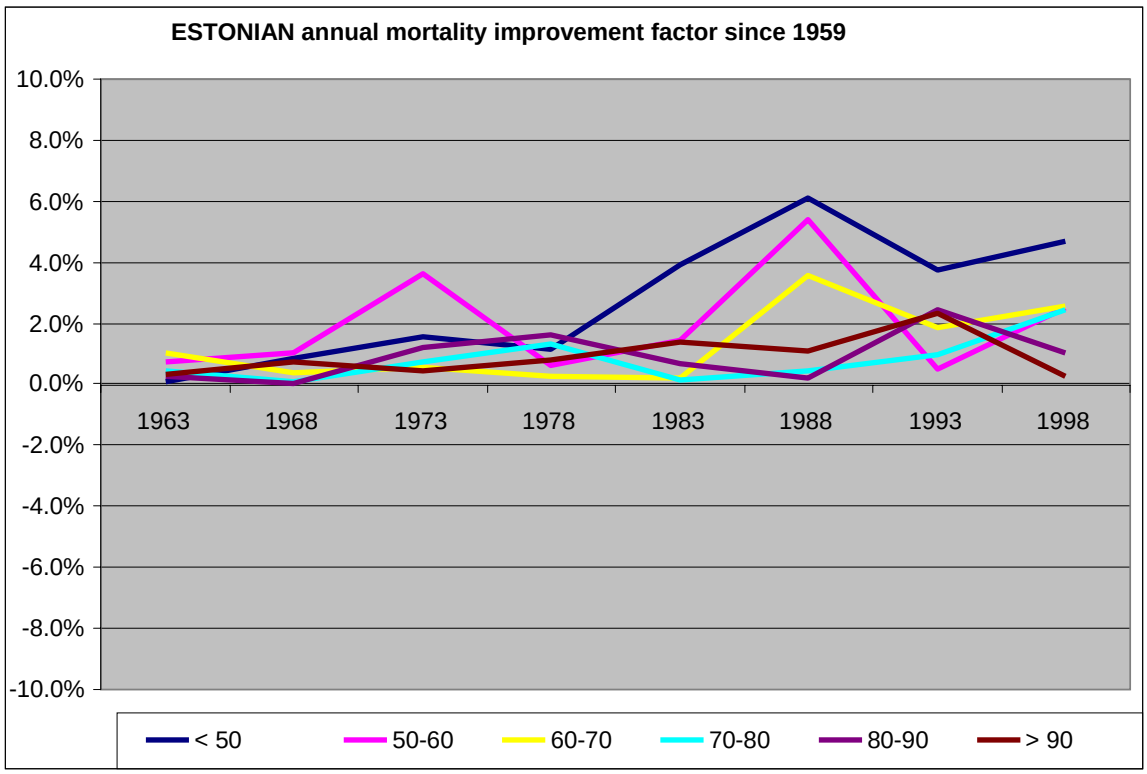


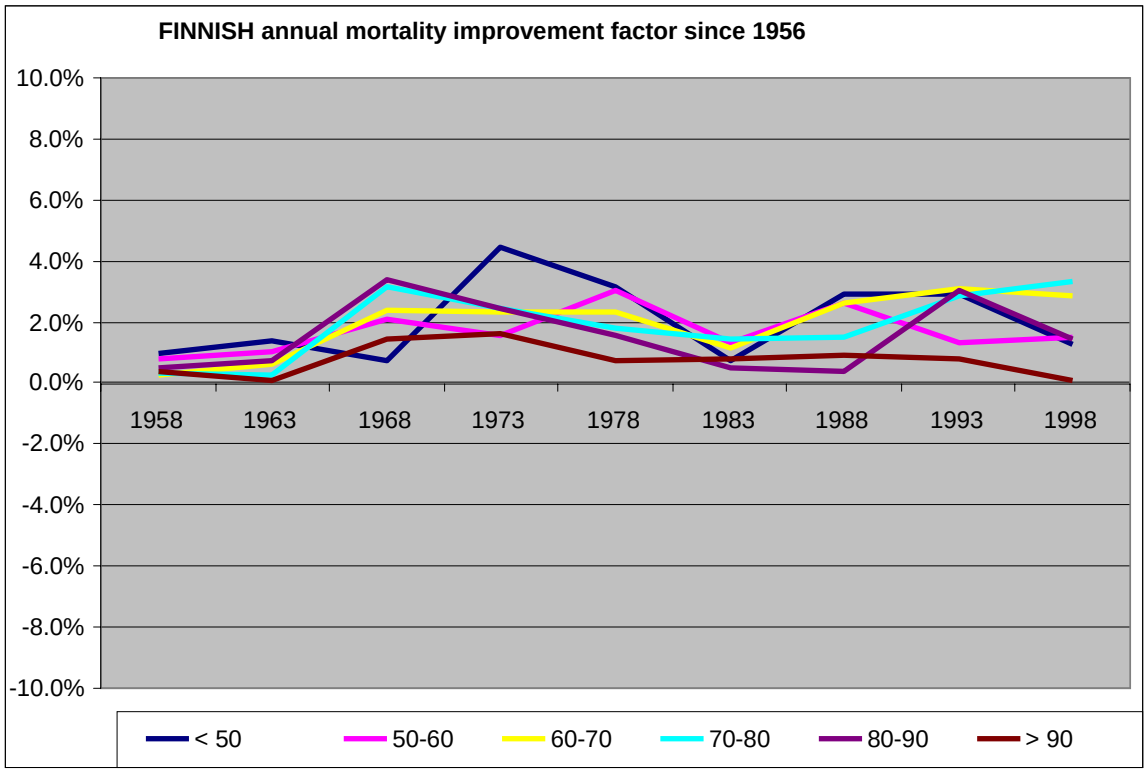


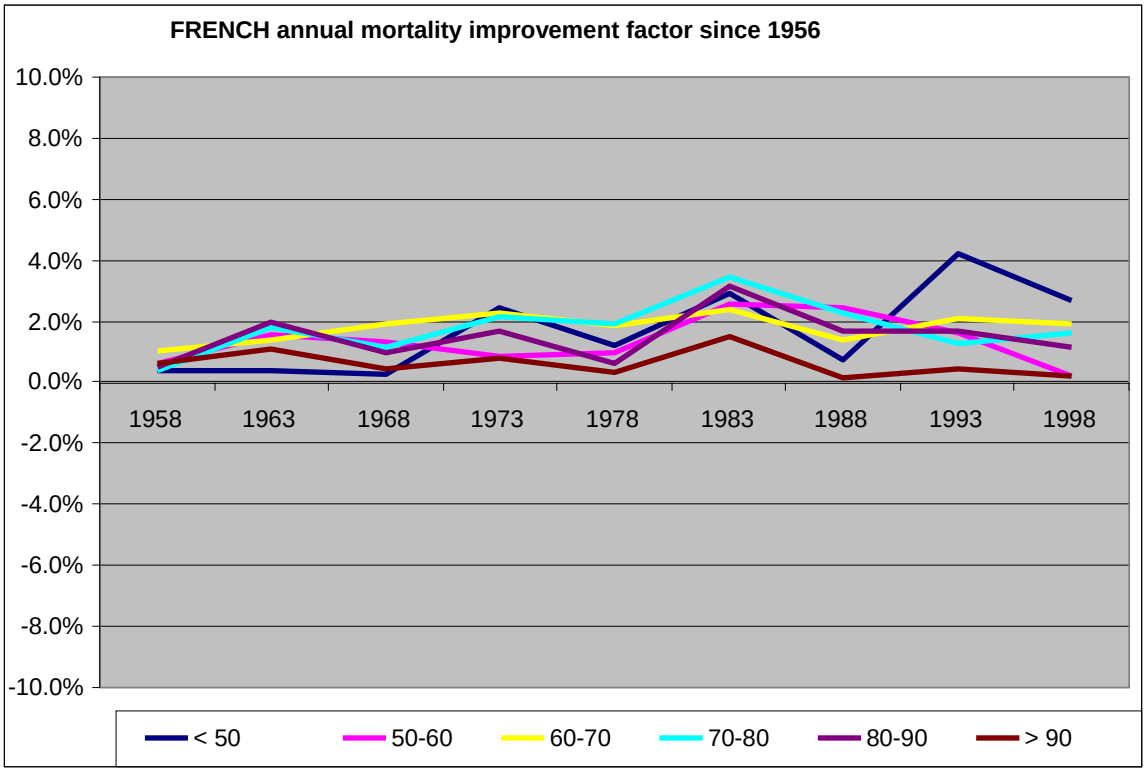


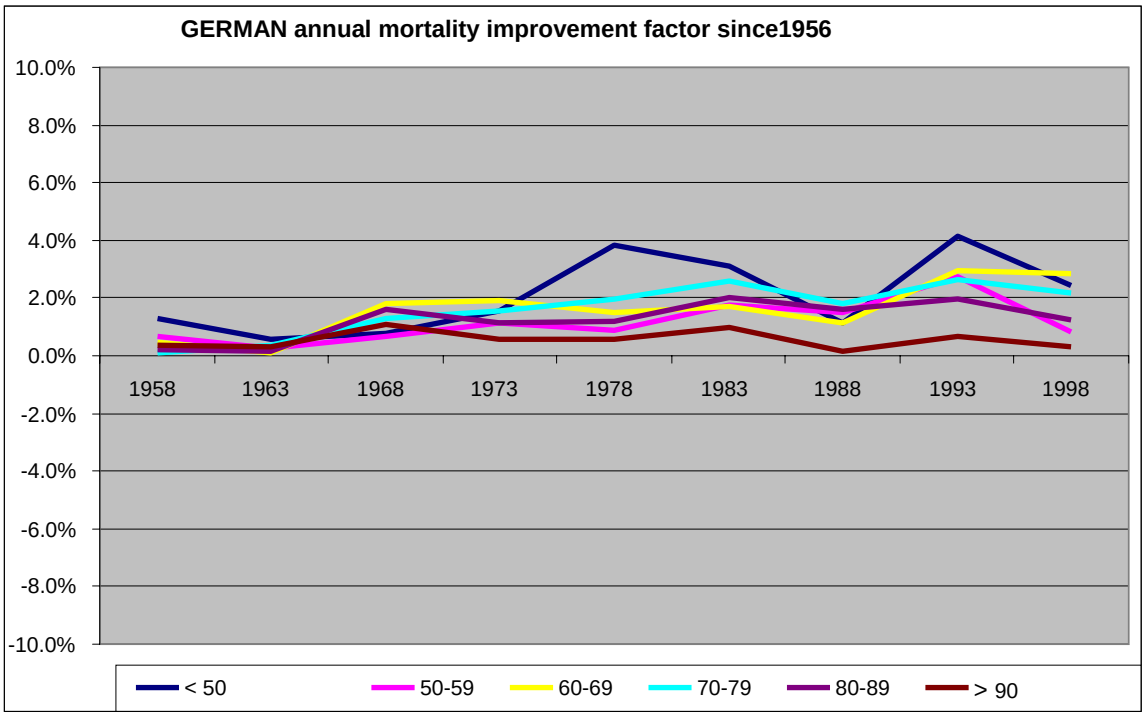


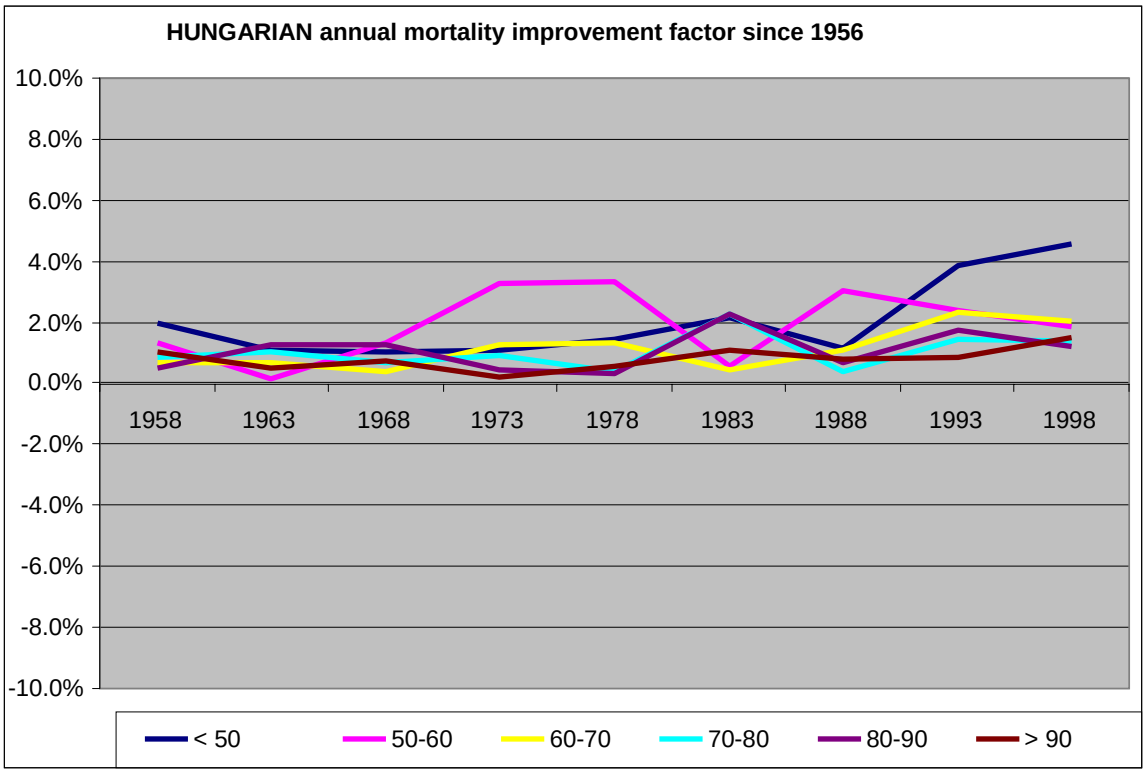


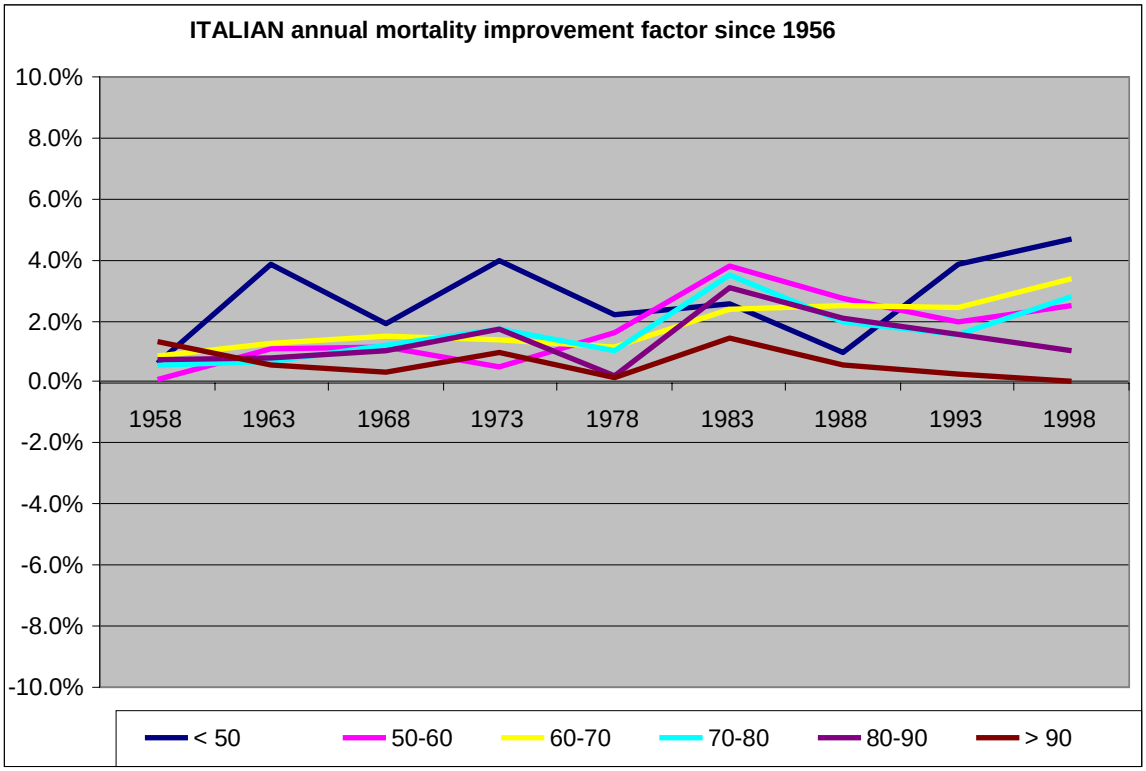


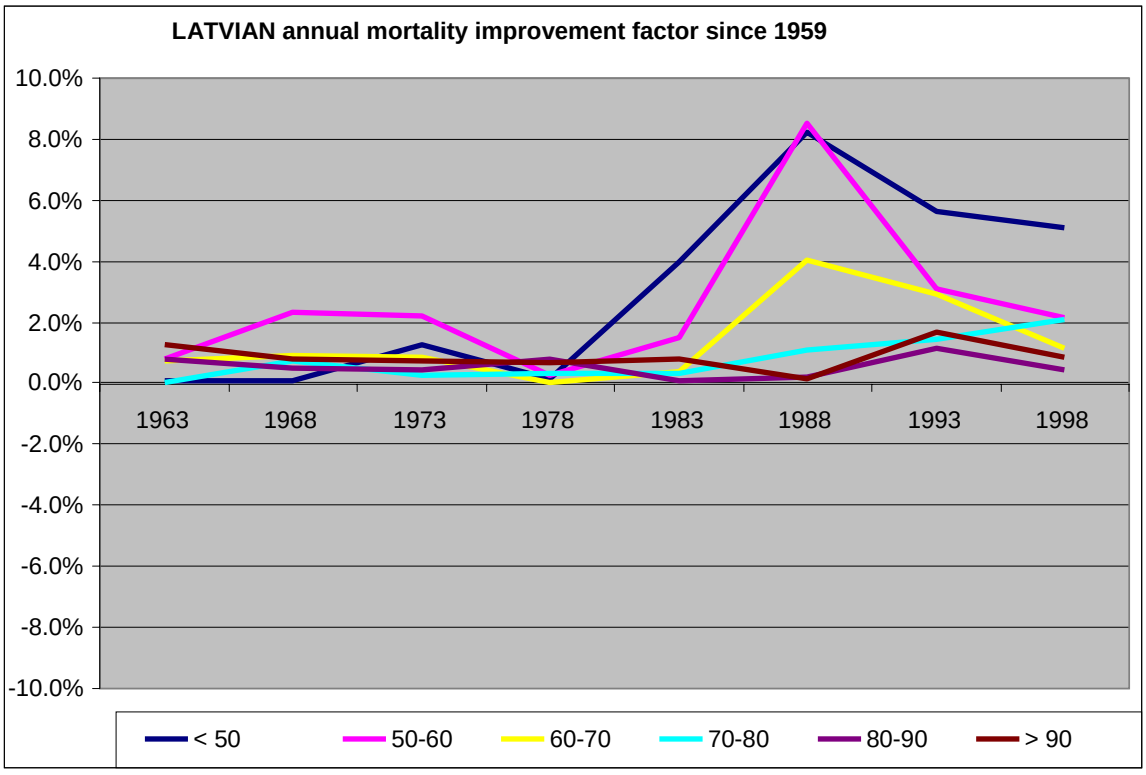


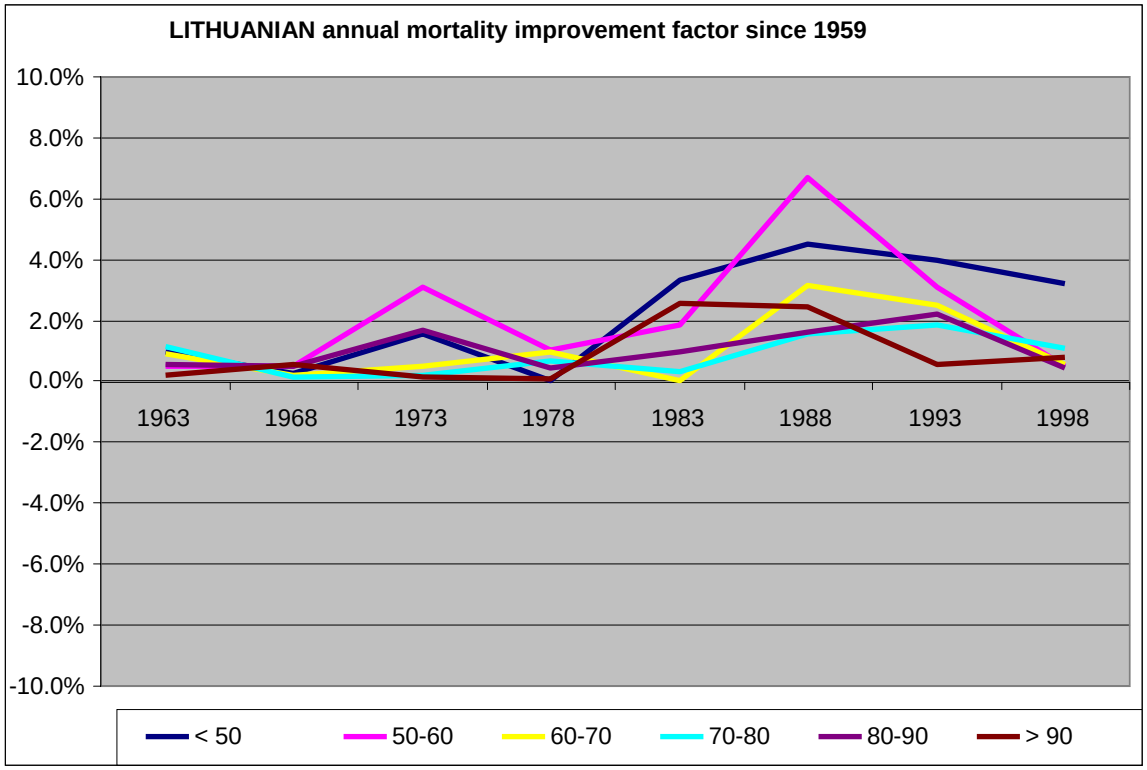


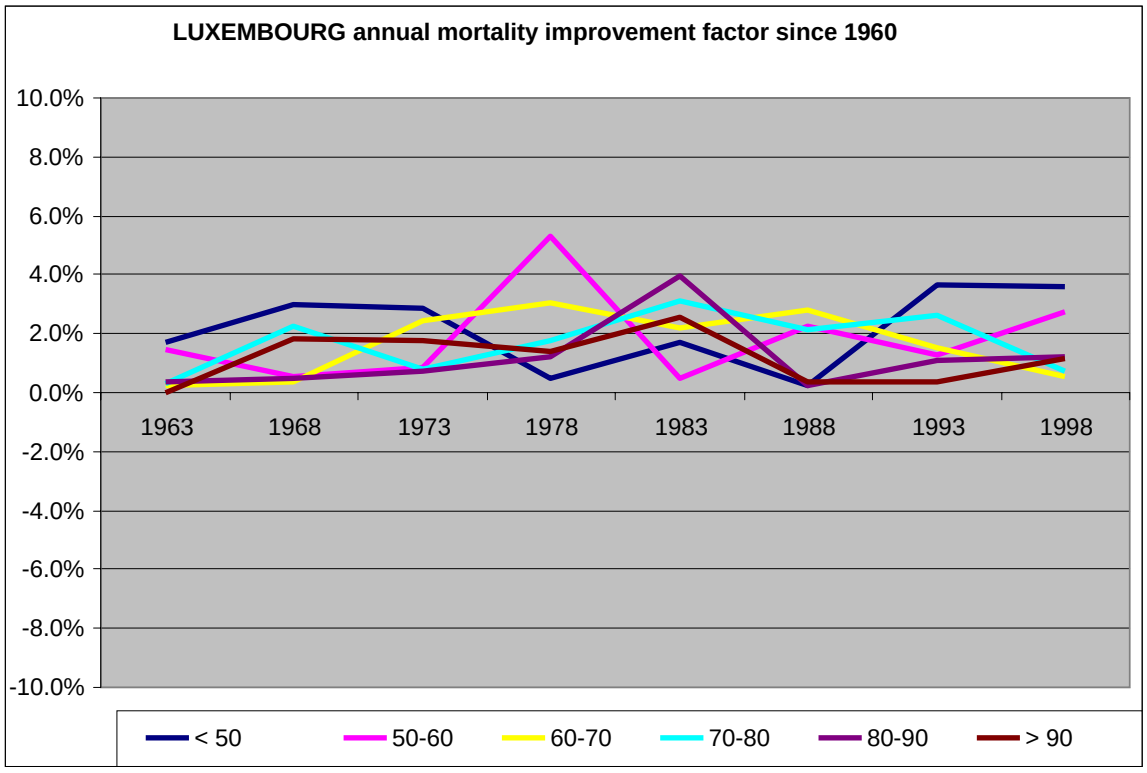


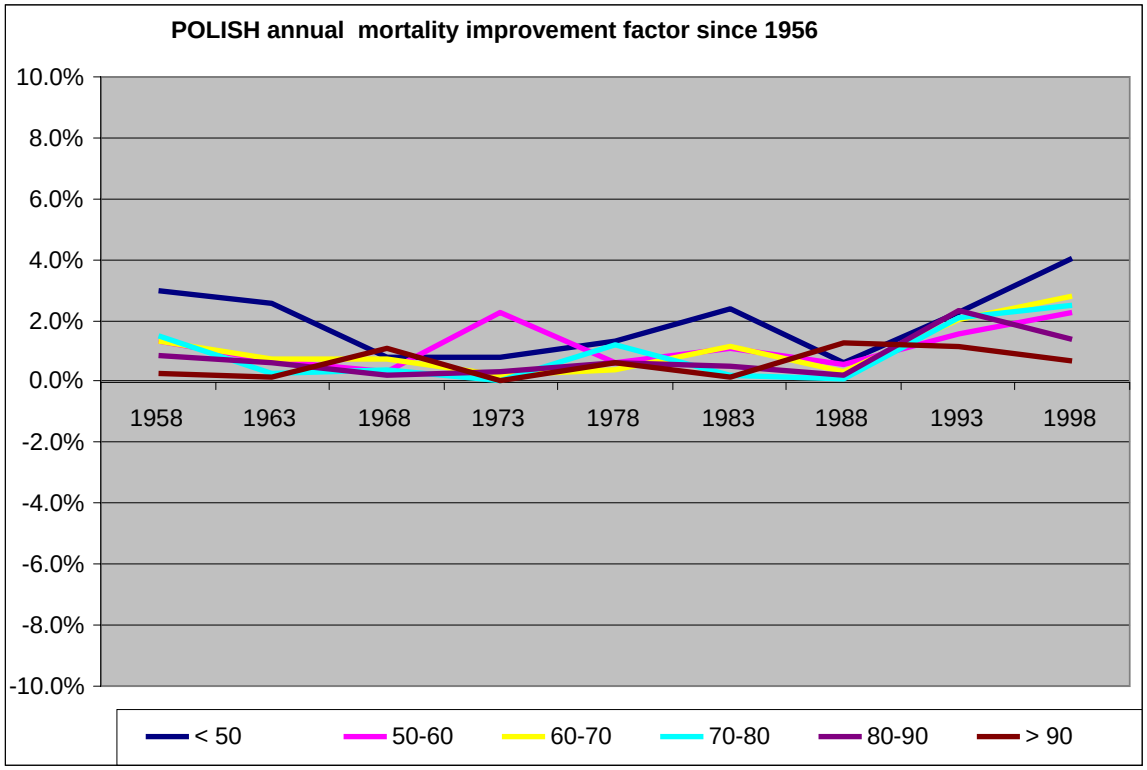


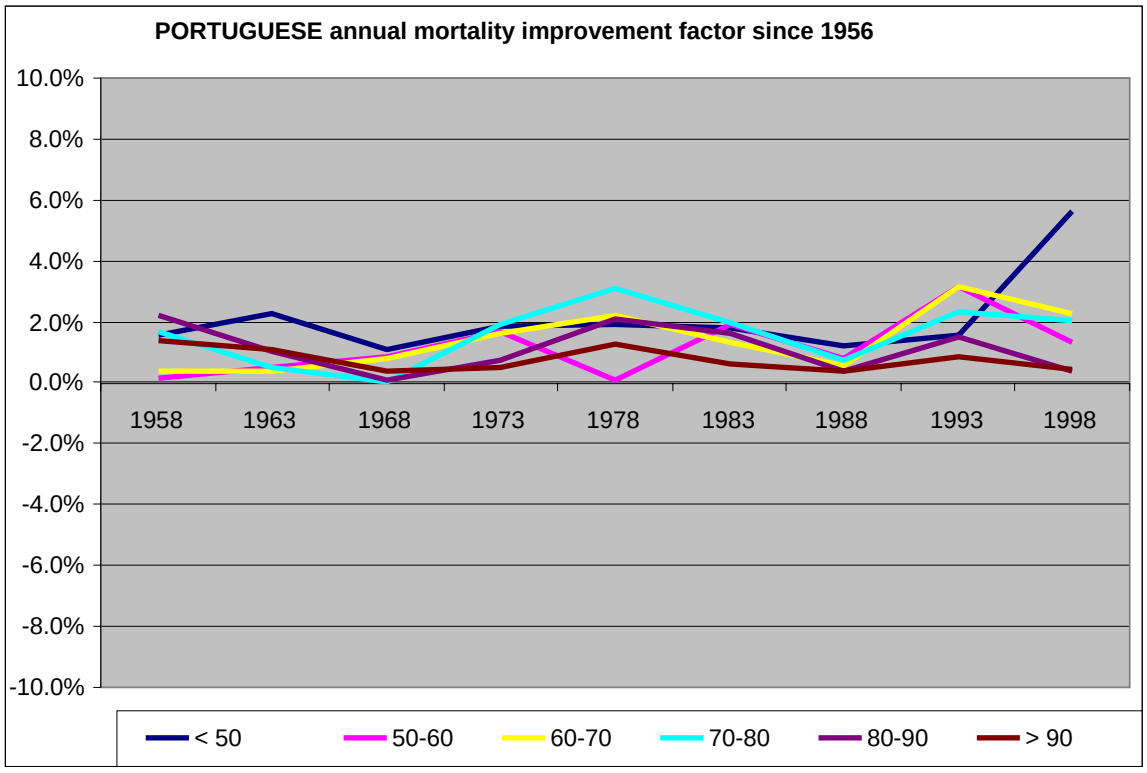


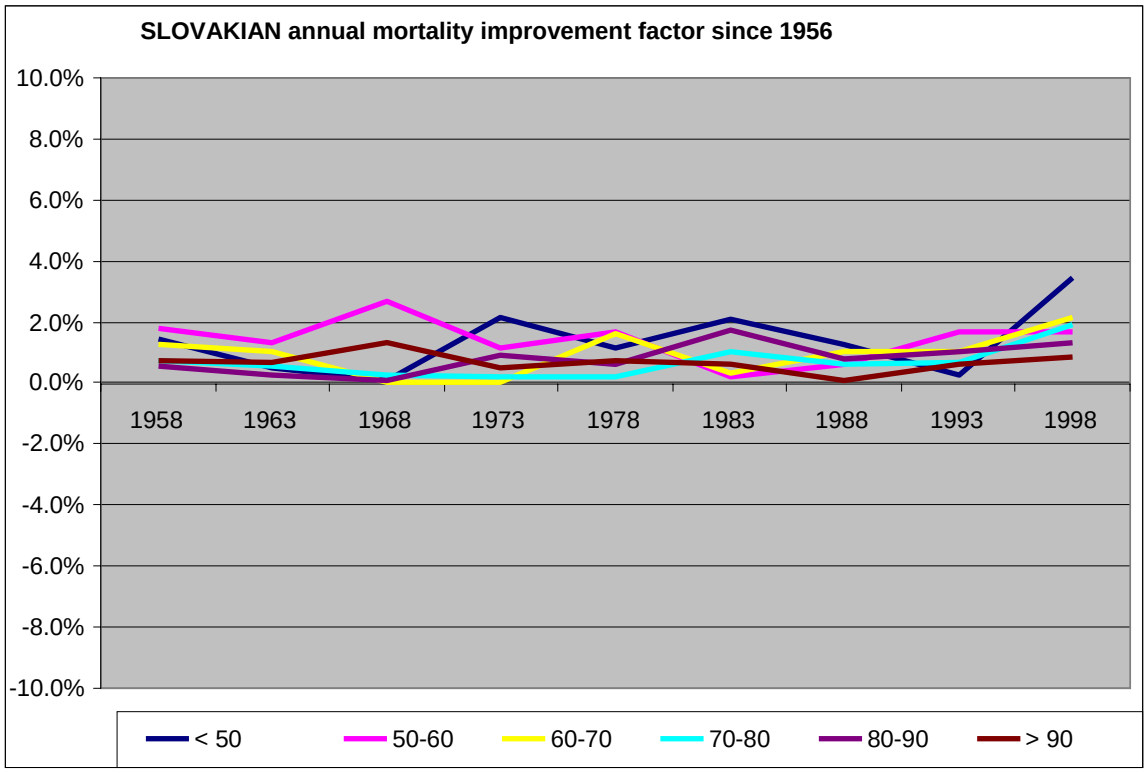


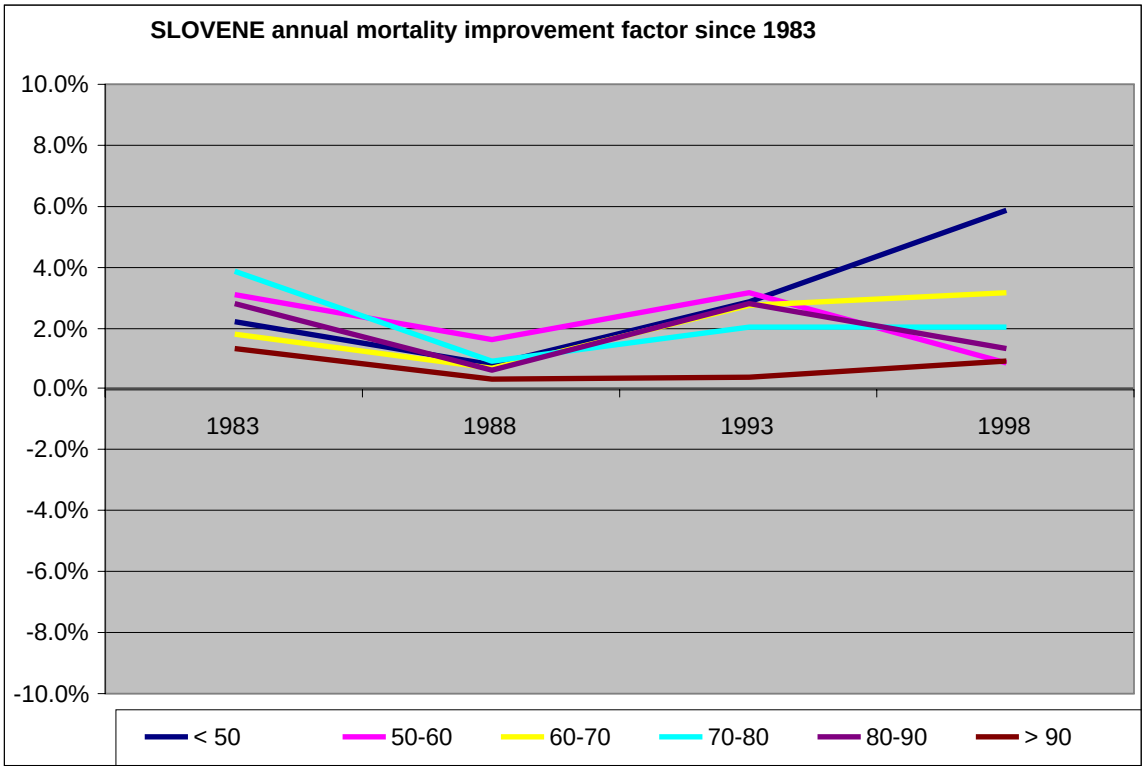


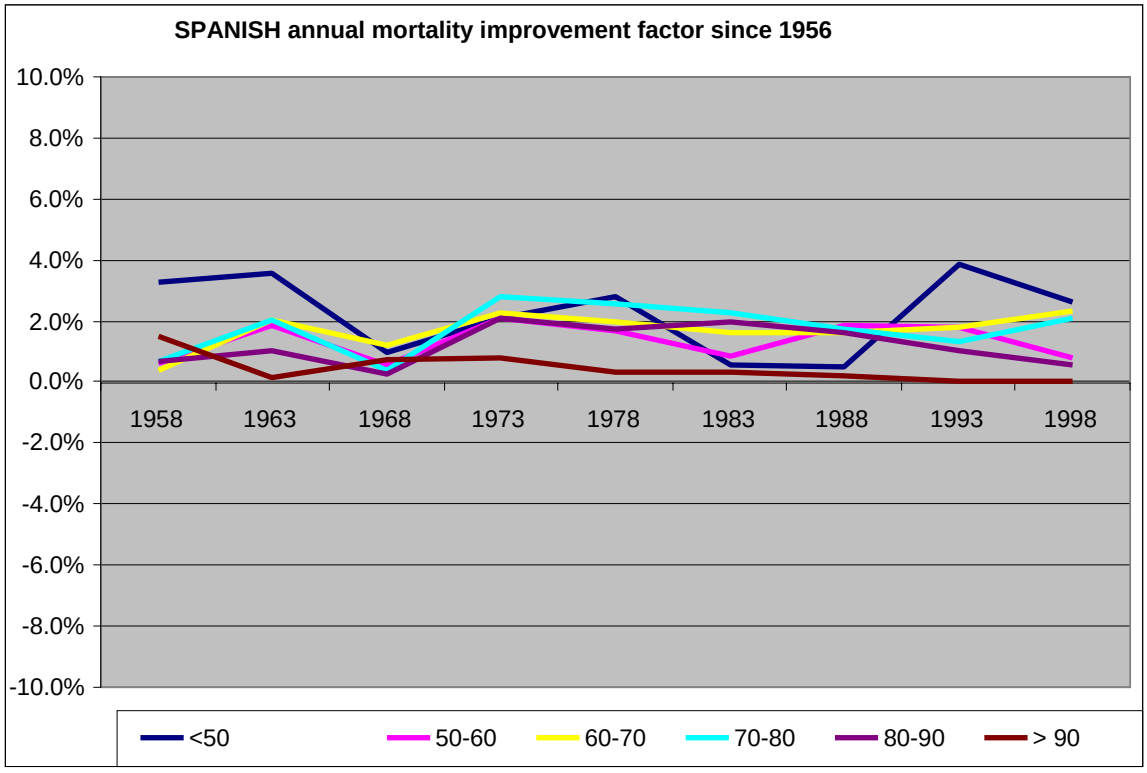


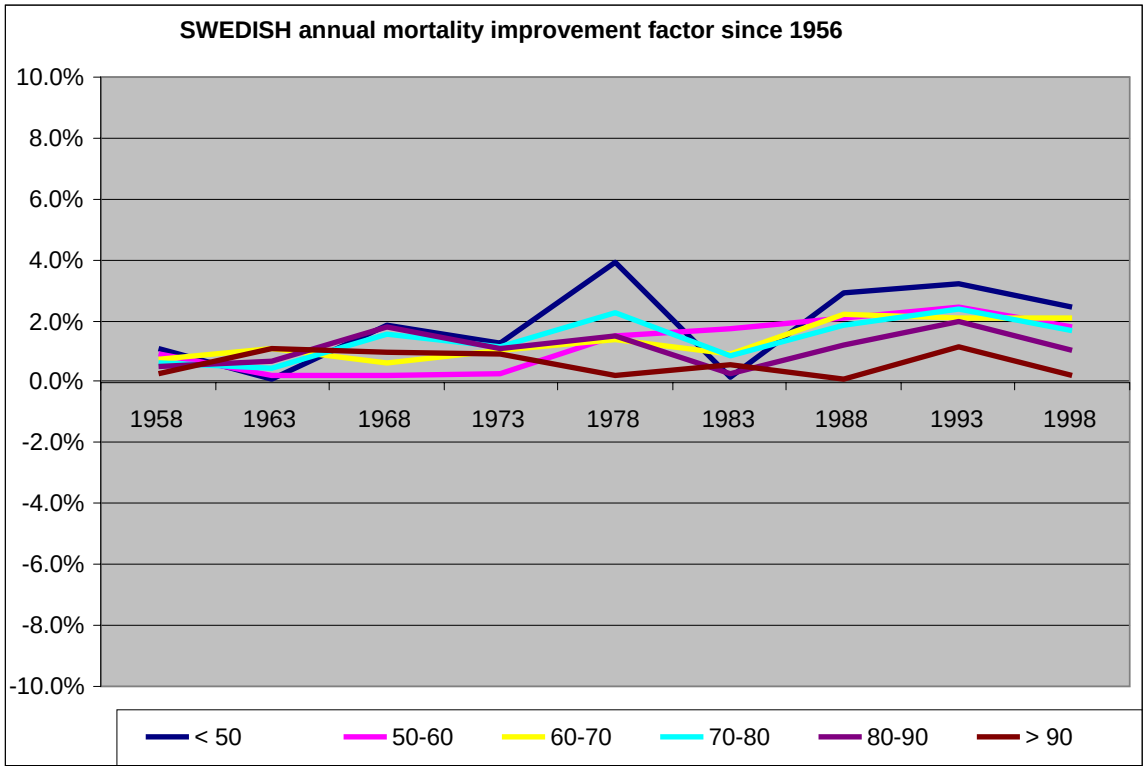












APPENDIX D: FRENCH ANNUAL MORTALITY IMPROVEMENT FACTOR FROM 1908 TO 2005. EXPLANATION OF WHY THE INVESTIGATION WAS PERFORMED FROM 1956.

For all the analyzed countries, the data is broken down by sex, calendar year (from 1956 to 2005) and age (up to 110 years).

As mentioned in Section 4.2 of this Report, the investigation was performed from 1956. One of the reasons for this is to avoid the volatility introduced by the World Wars in the mortality improvement factor. This volatility is shown in the following tables for the case of France:

Table D.1.1

French annual mortality improvement factor calculation (Total from year 1908)

FRANCE	Total	< 50	50-60	60-70	70-80	80-90	> 90
'Best estimate' from 1908	1.41%	2.06%	1.23%	1.32%	1.30%	0.97%	0.26%
Standard deviation	6.80%	9.91%	2.17%	1.58%	1.73%	1.81%	1.40%

Table D.1.2

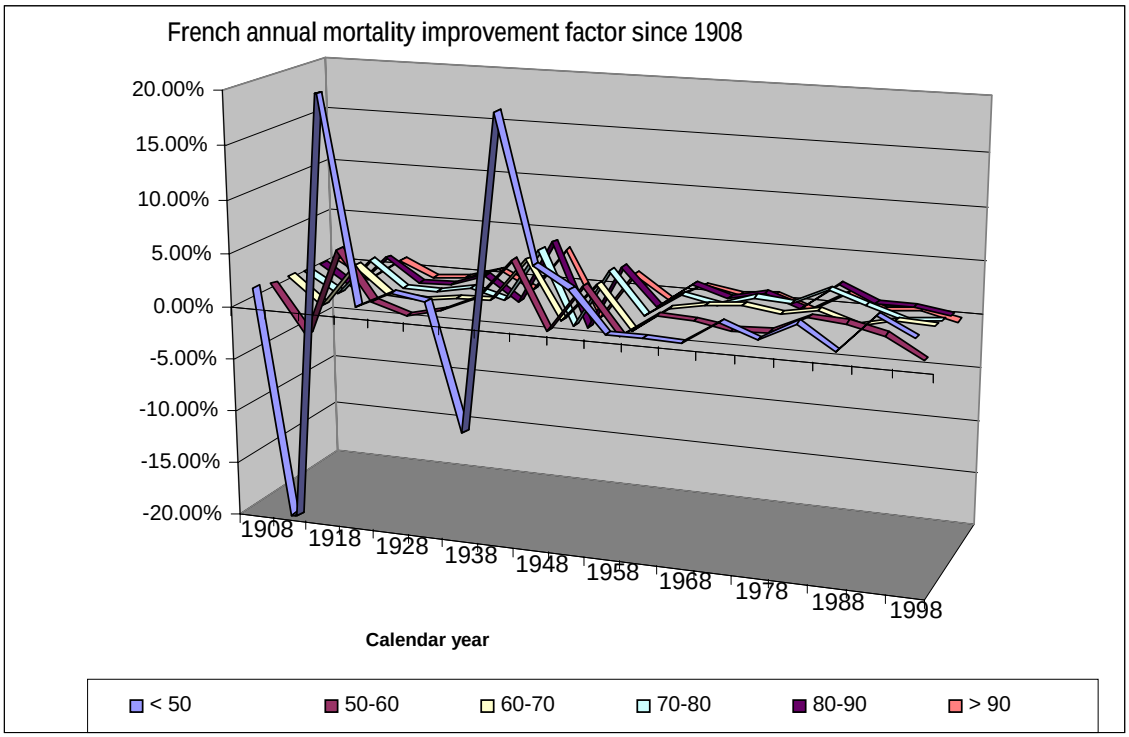
French annual mortality improvement factor calculation (Total from year 1956)

FRANCE	Total	< 50	50-60	60-70	70-80	80-90	> 90
'Best estimate' from 1956	1.36%	1.70%	1.18%	1.56%	1.70%	1.38%	0.37%
Standard deviation	1.96%	2.58%	1.28%	1.20%	1.14%	1.09%	0.77%

Comparing both tables we can highlight that the volatility since 1908 is focused mainly in people younger than 50 years. The two World Wars had a great effect on the population able to fight, especially on men.

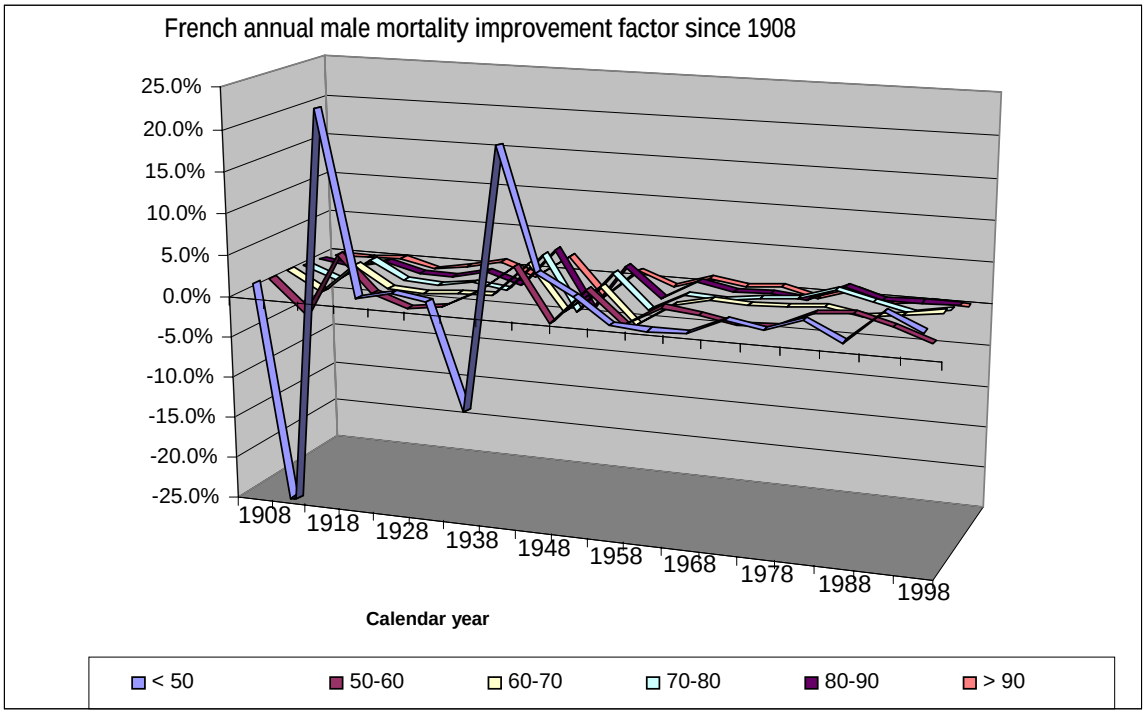
The following graph shows the performance of the French annual mortality improvement factor since 1908. It's interesting how the annual mortality improvement factor decreased during the two World Wars and how they automatically increased after them, especially in the youngest people.

GRAPH D.1.1

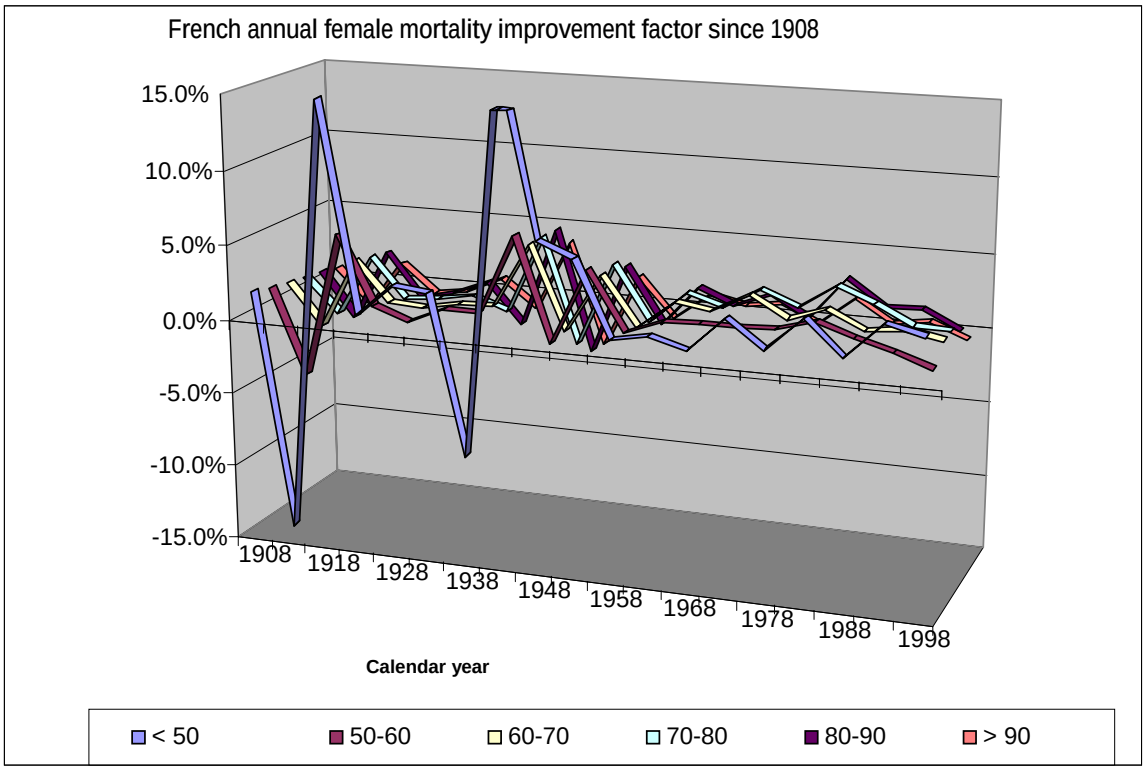


The comparison between the 1908 and 1956 analysis has been repeated by sex in graphs D.1.2 and D.1.3.

GRAPH D.1.2



GRAPH D.1.3



APPENDIX E: ANNUAL MORTALITY IMPROVEMENT FACTOR

E.1 Annual mortality improvement factor by age range

The investigation of our suggested longevity shock was carried out both for men and women combined because the mean of the best estimate is similar to that of individual sexes. In fact, there is a slight difference between the global calculation and the calculation by sex as is shown in the following tables:

Table E.1.1.

Annual mortality improvement factor (Total Europe since year 1956)

	Total	< 50	50-60	60-70	70-80	80-90	> 90
Average	1.26%	1.79%	1.04%	1.29%	1.30%	0.97%	0.20%
Standard deviation	2.26%	2.98%	1.40%	1.32%	1.18%	1.01%	0.79%

Table E.1.2

Annual female mortality improvement factor calculation since year 1956.

Women	Total	< 50	50-60	60-70	70-80	80-90	> 90
'Best estimate'	1.47%	2.10%	1.24%	1.57%	1.60%	1.08%	0.19%
Standard deviation	2.84%	3.84%	1.48%	1.33%	1.21%	1.09%	0.84%

Table E.1.3

Annual male mortality improvement factor calculation since year 1956.

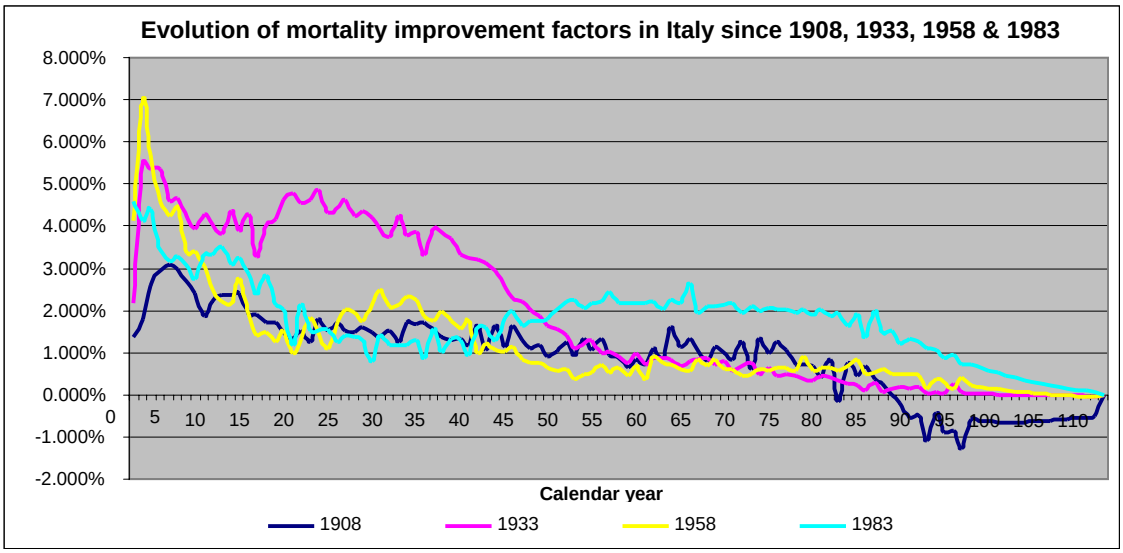
Men	Total	< 50	50-60	60-70	70-80	80-90	> 90
'Best estimate'	1.14%	1.67%	0.98%	1.11%	0.98%	0.76%	0.23%
Standard deviation	2.59%	3.45%	1.66%	1.59%	1.39%	1.13%	0.90%

E.2 Slow down of the annual mortality improvement factor as the age increases

There is a global trend, in all the analysed countries, of lower annual mortality improvement factors as the age increases, as is shown in Appendix C graphs. In some countries, this trend is not evident for the highest age ranges.

As an example, the following graph shows how this trend exists for Italy regardless of the starting year of the investigation. However, when data is closer to 2009, mortality improvement factors for advanced age are higher.

GRAPH E.2.1



Our empirical observation can be also seen in the 'Continuous Mortality Investigation' (CMI), a British study coordinated by the Institute of Actuaries and the Faculty of Actuaries in Great Britain. CMI creates standard mortality tables to be used by actuaries working on Life insurance companies. New standard tables are usually created every 10 years. Mortality reduction factors for series "92" assume that mortality rates exponentially decrease to asymptotic values; thus, as we have observed in this Report, mortality improvement factors are much higher in early ages than in advanced ages. This does not seen to imply that in the future, mortality improvement factors for advances ages will significantly increase.