The Cost of Living Longer: Projections of the Effects of Prospective Mortality Improvement on Economic Support Ratios for Fourteen More Advanced Economies

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Abstract

The aims of this paper are threefold; (1) to forecast mortality for a wide range of more developed countries from 2010-2050; (2) to project the effects of the forecast mortality patterns on economic support ratios assuming continuation of current fertility, migration and labour force participation; and 3) to calculate changes to labour force participation which would offset these effects. The mortality forecasts are prepared for fourteen countries using the Poisson Common Factor Model proposed by Li (2013). The mortality forecasts show that the projected gains in life expectancy are greatest in Japan, Australia and East-Central Europe, and are least in Netherlands, North America and Sweden, and correlate negatively with fertility and migration levels. The support ratios are projected to fall most over the period to 2050 in Japan, East-Central and Southern Europe, and least in Sweden and Australia. However, except for Poland, some recovery in support ratios is projected for the East-Central and Southern European countries post 2050. Using the valuation method of Parr and Guest (2014), the largest percentage increases in labour force participation needed to counterbalance the projected effects of mortality improvement are for Japan, Poland and the Czech Republic, and the smallest increases for the USA, Canada, Netherlands and Sweden. The dependency of the estimated effects of mortality improvement on support ratios and the initial age structure and the assumed levels of fertility, migration and labour force participation is discussed.

Introduction

The economic implications of ongoing increases in life expectancies and of population ageing have become important concerns for almost all the governments of More Developed Countries (Lee and Tuljapurkar 2000; European Commission 2006; Kupiszewski et al. 2006; Australian Government 2010; Bloom, Canning and Fink, 2010 Australian Productivity Commission 2013; OECD 2013; Saczuk, 2013; Tickle and Booth 2014; UNPD 2013). The implications include those for public expenditure on pensions, social security, health and aged care and on the proportionate size of the economically active population. Increases in the official normal ages for eligibility for state pensions have been planned in most OECD countries, and rationalised on the basis of forecast longevity gains (Australian Treasury 2013, 2014; OECD 2013; UK Department of Work and Pensions 2013; Scherbov, Sanderson and Mamolo 2014). This paper considers the prospects for future mortality change across an extensive range of more developed countries and. their implications for economic support ratios and related policy.

The pattern of mortality improvement over recent decades has varied significantly between countries. In 2010 Japan has the highest overall life expectancy at birth, after impressive increases for males (averaging 0.24 years per year) and especially for females (0.28 years per year) over the preceding 40 years (Wang et al., 2012, Table 1). Of the countries considered in this paper, Portugal had the fastest improvement in life expectancy at birth for both sexes between 1970 and 2010, with much of the improvement being due to rapid reductions in infant mortality (Leon 2011). Australia, Italy, Switzerland, Spain, and the UK also had relatively large life expectancy gains. After stagnation or even – for males – declines over 1970 to 1990, life expectancy at birth increased dramatically from 1990 in the East-Central European countries Czech Republic, Hungary and Poland (0.27-0.33 per year for males and 0.23-0.26 for females since 1990). Indeed of the countries we consider for both sexes the Czech Republic experienced the largest post-1990 gains in life expectancy. Bijak (2013) outlines some of the health policy and other factors contributing to these changes. The increases in life expectancy at birth for Netherlands, Sweden, the USA and Canada were relatively slow throughout the 1970 to 2010 period. For most countries, previously divergent trends for female and male life expectancy have been succeeded by convergent patterns with male improvements outstripping female improvements. Japan is a notable outlier in which onset of the convergence of male and female life expectancy has been relatively recent (post 2004) and the magnitude of convergence very small (Liu et al. 2013). Forecasts of future mortality improvement which are based on extrapolative methods therefore will vary between countries,

This paper focuses on the between-country differences in the implications of forecast mortality changes for population age structure and the direct effects of such population age structure changes on economic support ratios. Such variability is to be expected both because of the between-country variability in projected mortality change and because of the international variability in base populations, future fertility, future migration and future labour force participation rates, all of which interact with the effects of mortality change. Mortality change, related changes to health, and population ageing more broadly can also affect population and labour force size, growth rates and productivity, consumption and saving, government expenditure and taxation revenue all of which which, in turn, may affect labour force participation rates (Auerbach and Kotlikoff 1992; McDonald and Kippen 2000; Lee et al. 2000, 2001; Kelley and Schmidt 2005; Skirbekk 2008; Lee and Mason 2010; Williamson 2013; Parr and Guest 2014; Prskawetz and Sambt 2014; Scherbov, Sanderson and Mamolo 2014). Consideration of such effects is deliberately avoided here, in view of their extensive data and modelling requirements. In view of the expressed intentions of various governments to proactively implement pension and other policy changes ostensibly to counterbalance the effects of forecast mortality gains, we present examples of changes to age and sex specific labour force participation patterns which could compensate for the direct effects of mortality improvement on support ratios.

Future mortality changes over a specified period of time will affect population age structure and hence support ratios beyond the end of that period (Parr and Guest 2014). This paper is distinctive in considering the very long run prospects for population age structure and the very long run implications of mortality changes to mortality over the coming 40 years through consideration of the stable populations to which there would be convergence under the (purely hypothetical) maintenance of constant end-of-period values for all data inputs, and model-based estimates of the paths of convergence (Parr and Guest 2014).

Data and Method

Data

The patterns for the following fourteen countries are considered; Australia, Canada, Czech Republic, Hungary, Italy, Japan, Netherlands, Poland, Portugal, Spain, Sweden, Switzerland, United Kingdom, and United States of America. The choice of countries was restricted to more developed countries for which all the requisite data inputs could be identified. We endeavoured to select a range of countries which were diverse in terms of their geographical regions and in their recent mortality trends, giving preference for inclusion to countries with larger populations over those from the same region with smaller populations.

The mortality forecasts were based on data from the Human Mortality Database (HMD 2013). The population, fertility, migration, and labour force data were sourced from the websites of a range of international agencies (United Nations, OECD, Eurostat) and official national data sources.

Methods

Mortality Forecasts

The forecasts of mortality were developed using the Poisson Common Factor Model of Li (2013). This is a coherent forecasting method, and was applied here to ensure coherence between sexes, with each individual country forecasted independently. Appendix A describes the technical formulation of this model. Following Booth et al. (2002) the length of the time period on which the forecast for a particular country was based was selected according to the pattern of goodness-of-fit for that country, and these "fitting periods" varied between countries. For some countries the overall mortality trend has changed quite considerably in the recent past, most notably post-1990 rates of mortality improvement for the former communist countries of East-Central Europe, the Czech Republic, Hungary, and Poland, have been considerably more rapid than before 1990. For these countries fitting periods commencing in 1990 have been used. In all other cases, a fitting period starting in either 1970 or 1980 was used depending on patterns in the mortality trend.

Projections of the Effects of Mortality Change on Support Ratios

For each country we consider projections of the economic support ratio (L_t / N_t), as measured by the ratio of hours worked per week to total population for future time points t. Projections of population are prepared using the standard cohort component method (e.g. Pollard et al. 1990), and projections of hours worked by applying assumed future age and sex specific labour force participation rates, employment rates, and mean hours worked per employed person to the projected numbers in the population by age and sex (Appendix B presents the algebraic specification). The effect of projected mortality change is calculated by comparing the values of L_t / N_t for a projection using our best estimates of forecast future mortality to those produced by a projection with the same assumptions for fertility, migration and labour force participation but instead assuming mortality rates remain constant at the levels for the base year of the projection (i.e. 2010).

For all countries we consider, firstly, projections over the period 2010-2050 and comparison of projected trends under the forecast mortality change with those projected with mortality constant at the 2010 level and, secondly, the stable populations to which the populations would converge if the values of the fertility, mortality, migration and labour force participation were to remain constant at the 2050 levels used, and the contrasts with those generated holding mortality constant at 2010 levels (Pollard 1973, Cerone 1987, Espenshade et al. 1982). The latter were considered because the forecast mortality change between 2010 and 2050, in addition to contributing to population change between 2010 and 2050, will have implications for population change post-2050.

Calculations of Changes to Labour Force Participation With Equivalent Effects on Support Ratios To the Forecast Mortality Change

In theory multiple combinations of changes to labour force participation could have effects on support ratios of equivalent value to those of a forecast pattern of mortality change. Such combinations differ according to the breadth of the range of age and sex groups across which labour force participation changes, the relativities between changes in different age and sex groups, and the gradients of change over time in the participation rates of the various age and sex groups.

We consider two alternative patterns of change for labour force participation. Firstly we calculate the percentage change in labour force participation which would be needed to counterbalance the effects of the forecast mortality improvement assuming the same percentage change applied to every age and sex group. Secondly we calculate the percentage change in labour force participation rates for the 60 to 64 and 65 and above age groups which would be needed to if labour force participation remained unchanged for all ages below 60. The latter scenario is motivated by public pronouncements by politicians which have linked the need to increase labour force participation in the later working ages to forecast mortality improvements, whilst the former indicates how more broadly-based solution involving changes to labour force participation. Since the aim is merely to indicate relative degrees of change needed in different national contexts, the percentage changes are calculated assuming the change in participation occurs immediately.

The equivilisation of value of changes in labour force participation to the forecast changes in mortality uses a method proposed by Parr and Guest (2014), and involves evaluations over the entire long run path towards the stable population (see Appendix B for technical details of the Parr-Guest method).

Assumptions

Base Population

The proportionate age distributions of the base (2010) populations differ significantly (Table 2). The United States, Australia, the UK, the Netherlands, Sweden and Canada have the highest percentages aged under 20 years, whilst Japan, the Southern European countries (Italy, Spain and Portugal), and the East-Central European countries (Czech Republic, Hungary and Poland) have the low percentages in this age range. In contrast, for the percentage of its population aged 65 or over Japan has the highest value, followed at a distance by Italy. The United States, Australia and Poland have the lowest initial percentages aged over 65. The range of variation for the percentage of population in the main working age range (20-64) is fairly small. The percentages in this age range are highest for the East-Central European countries and for Spain, and lowest for Sweden, and Japan.

Fertility

The fertility assumption for all countries is that all age-specific fertility rates remain constant at the 2010 level. The assumed Total Fertility Rates are highest for Sweden, and for three of the mostly English-speaking countries (Australia, UK and USA) (Table 2). Japan, the East-Central and Southern European countries have the lowest fertility levels.

Net Migration

For all countries annual net migration in total and by age and sex is assumed constant at the average level for the 2006-2010[1] period. Where total net migration was positive the absolute numbers of migrants by age and sex are used, whilst for the two countries with negative net migration, Japan and Poland, constant age-specific net migration rates are applied. The choice of the average migration over this period as opposed to the level of the most recent year was made in view of quite significant year-to-year volatility in net migration. In terms of the absolute numbers the assumed net migration to the United States far exceeds that for all other countries considered. Spain and Italy, Australia, Canada and the UK all had net immigration over 200,000. When viewed as a rate per 1000 population net migration was highest for Spain, Switzerland and Australia, followed by Canada, Italy, and Sweden.

Labour Force Participation

The labour force projections used the average values over the period 2006-10 for age and sex specific labour force participation, employment, and hours worked per employed. Following the Global Financial Crisis (GFC) in 2008 there were significant increases in unemployment rates in some countries, most notably those in Southern Europe. Thus the values of labour force participation measures we use represent averages of pre and post-GFC values. Table 3 presents age-standardised summary measures of labour force participation. The key values in Table 3 are the standardised mean hours per person aged 15 and over and the standardised mean ages for

[1] Following US Census Bureau (2013) in the apparent absence of suitable data for the United States an assumed level of 725,000 per annum was applied to the proportionate age and sex distribution of net international migration for Canada

workforce participation. For males Japan has by far the highest average number of hours per person. This reflects its high participation rate, low unemployment and unusually high average hours worked per employed male (across some age groups the averages exceed 48 per week). The English-speaking countries, Switzerland and the Czech Republic also have high hours worked per person. Except for the Czech Republic, these countries have above average male labour force participation rates, and above average hours worked per male employed, and in the case of Switzerland and Australia low unemployment rates are also a factor. Hungary, Italy, Poland, and Spain have the lowest hours worked per male. This is the product of their lower male participation rates, higher unemployment rates and lower mean hours per employed.

Swedish females have the highest mean hours worked per person, a pattern driven by their much higher participation rate (Table 3). The USA, Canada and Portugal also have high average hours per female. For USA and Portugal females it is due to a relatively high participation rate and a relatively high hours average worked per employed female. For females in Canada it is driven by relatively high participation rate and a slightly higher than average employment rate. Italy has the lowest hours worked per female, primarily due to a much lower labour force participation rate. Despite a high female participation rate and a low unemployment rate, the Netherlands has one of the lowest hours worked per female. This is driven by an unusually low average hours per employed, a pattern linked to widespread part-time work. Spain also has a low average hours per female, due to its low participation rate and high unemployment rate.

There are some considerable between-country differences in the pattern of variability of hours worked per person by age (not shown). For both males and females in the 15-19 age group Switzerland has the highest average hours per person, followed by Australia, Canada and the UK. Switzerland, Japan, Portugal, Australia, the UK and the USA have the highest hours worked for males and females aged 20-24. For males aged between aged 25 and 59 the hours worked by Japanese men far exceed those for the other countries. For females Portugal has the highest hours worked over the main reproductive ages (i.e. 25-39), whilst for those between the ages of 40 and 59 the Czech Republic and Sweden have the highest rates. For males in the 60-64 age range Japan, Switzerland and Sweden have the highest values, whilst for females in this age range Sweden, and the USA have the highest values, followed by Japan. For both sexes Japan and the USA have the highest hours worked for males aged over 65. The standardised mean age of labour force (based on hours worked) for males is highest for Japan and lowest for Poland (Table 3). Sweden has the highest mean age for females in the labour force and Netherlands and Switzerland the lowest mean ages.

Other Assumptions

The Parr-Guest method additionally requires the formulation of assumptions for a social discount rate, ρ, which allow an equivilisation of the social value of consumption at different time points, the very long run rate of productivity growth, g, and a returns to scale parameter α (Samuelson 1958, Parr and Guest 2014, Appendix B). Values of 2.0 per cent per annum for *ρ* and 1.5 per cent per annum for g were adopted for all countries. Since our aim was to isolate the effect of mortality change on support ratios we adopted a constant returns-to-scale (α = 1) scenario for all countries.

Results

Mortality Forecasts

For both sexes the greatest increases in life expectancy at birth are forecast to occur in Japan, followed by three East-Central European countries (Table 4, Figures 1 and 2). The forecast gains in life expectancy in Australia and the UK are also relatively large. For both sexes the Netherlands is forecast to have the smallest increase in life expectancy at birth. The forecast gains in life expectancy at birth are also relatively small for the North American countries and Sweden for both sexes, and for Spanish females. In all the countries considered between 2010 and 2050 the increase in male life expectancy at birth is expected to be greater than that for females (Table 4). Except for males in the USA, the forecast increases in life expectancy are greater between 2010 and 2030 than between 2030 and 2050.

Figures 1 and 2 show the progressive widening of the gaps between the forecast life expectancies at birth for Japan and those for the other countries over time both for males and for females. For females the forecast life expectancy at birth in 2050 for Japan is a huge 5.3 years greater than for the next highest country (Australia). For both sexes by 2050 Australia is forecast to have a significantly higher life expectancy at birth than all the European countries considered. The gaps between the life expectancies of the East-Central European countries and the Western

European countries are forecast to be significantly smaller in 2050 than in 2010. The forecast rate of improvement in life expectancy for the Czech Republic is second only to that for Japan and by 2050 the forecast life expectancy at birth for both sexes for the Czech Republic exceed those for the USA, the Netherlands, and Portugal. For females life expectancy at birth for Poland is also forecast to have surpassed that for the United States by 2050.

In Figure1 and Figure 2 the countries have been separated into those with very low fertility (TFR below 1.5) and low fertility countries (TFR above 1.5). Comparison of the graphs for the two groups of countries shows that both for males and for females the forecast increases in male and female life expectancy tend to be greater in countries in countries with very low fertility rates (also Figure 3, Tables 2 and 4).The forecast increases in life expectancy also have a negative correlation with the net migration rate. The correlations between the forecast gains in life expectancy and the standardised mean ages for labour force participation are positive but very weak (R^2 = 0.07 for males and 0.08 for females).

For Japan relatively steep decreases in central death rates are forecast for all age groups and both genders. For most ages increases in male to female age-specific mortality ratios are forecast, with the exceptions being at the two extremes of the age range (under 10 and over 90). For the East-Central European countries mortality declines are forecast for all age and sex groups. However the reductions in the $\log(m_x)$ are expected to be considerably more rapid in the younger ages than in the older ages. Male to female ratios for mortality rates remain more or less constant for all age groups. The patterns of mortality improvement for Australia and the UK exhibit similarities with the fastest decreases in $\log(m_x)$ occurring below age 20 and in the 40-79 age range (more so for 40-59 year olds in Australia), with little change for 20-39 year olds. For the USA and Canada deteriorating mortality is predicted for the over 90 age range. For the Netherlands for both sexes future reductions in $\log(m_x)$ are greater in the younger ages than in the older ages, and male to female ratios in age-specific mortality are forecasted to increase slightly. For both sexes life expectancy at age 65 is forecasted to increase most in Japan. Of all the countries we consider the USA has the smallest future increase in life expectancy at age 65 for males, and for females only the Netherlands has a smaller gain than the USA.

Projected Changes in Age Distributions

Over the period between 2010 and 2050 population ageing is projected to occur in all the countries we consider. The rate of ageing is generally more rapid in those countries which currently have and are assumed in the future to continue to have very low fertility. The rapidity of ageing is compounded in most of these countries by the effects of relatively rapid increases in life expectancy. The most rapid ageing of all is projected to occur in Japan and Poland, the two countries which net outmigration is assumed to continue, in addition to very low fertility and rapid increases in life expectancy. The other East-Central European countries and the Southern European countries, all of which have very low fertility and most of which also have large forecast gains in life expectancy also are projected to experience relatively rapid growth of the percentage aged 65 or above.

The projected increase in the percentage of population aged 65 or above over the period 2010 to 2050 is least in Sweden, followed by the mostly English-speaking countries, Switzerland and Netherlands. Except for Switzerland, where a high rate of net immigration serves to slow the ageing of the population, these countries have relatively high fertility rates and, except for Australia and the UK are forecast to experience relatively small increases in life expectancy.

The percentage of population aged under 20 is projected to reduce in all the countries considered between 2010 and 2050, with the largest decrease being for Poland and the smallest for Sweden. The changes in the percentages in this “young dependent” age range are smaller than those projected to occur in the percentage in the “older dependent” over 65 age range.

Projected Changes in Support Ratios 2010 to 2050

In all the countries considered the support ratio is projected to decrease significantly between 2010 and 2050 (Table 5). The projected decreases are relative to unusually favourable initial (2010) support ratios which have been elevated by a combination of a proportionately smaller pre-workforce entry populations, produced by the general lowering of birth rates over the preceding decades, and a diminution of the post-retirement age groups by relatively low birth rates during the 1930s and early 1940s, whilst higher post World War Two fertility and its echo effects have increased the main working age groups. The projected decreases in support ratios are driven by the projected ageing of these populations over this period, with growth in the older more dependent age groups, driven by the retirement of post-World War Two baby boom cohorts and their children, outweighing the effects of diminishing proportions of population in the younger more dependent age groups.

Over the period from 2010 to 2050 the decreases in the support ratios are projected to be more rapid in the countries which currently have (and are assumed in the future to have) very low fertility rates, with Poland, Spain and Japan are projected to experience the greatest decreases both in absolute and in percentage terms (Tables 2 and 5). In 2010 the very low post-1990 levels of fertility would have been beneficial to the support ratios, by reducing the proportionate size of the child and young adult age groups. By 2050 the effect of the post-1990 and (assumed) continuing very low fertility has spread across the working ages, and any beneficial effects on the support ratio accordingly are much reduced, whilst the growth of the older ages is fuelled by the legacy of earlier higher fertility. However the effect of the very low fertility in these countries is supplemented and compounded by the effects of relatively rapid mortality improvement in the older ages which they are forecast to experience. Moreover in most of the very low fertility countries considered (Switzerland, Spain and Italy are the most notable exceptions) low rates of net migration are slow to stem the diminution of annual numbers of births by the very low fertility, and hence the lagged effects of falling births on workforce size (and in the case of Japan and Poland net outmigration adds to this effect). In most of the very low fertility countries relatively low labour force participation rates in the later working ages further compound the negative effect of the projected rapid population ageing on the support ratio. Japan, which has the highest labour force participation for both sexes over the age of 65 and the high rates of participation for both sexes for the 60-64 years age group, is a notable exception. So too is Portugal. For most of the very low fertility countries the reduction in the support ratio is greater between 2030 and 2050 than between 2010 and 2030.

Of all the countries considered Sweden has the smallest projected decrease in the support ratio between 2010 and 2050. The USA, Australia, the UK and the Netherlands are also projected to have relatively small decreases (Table 5). These countries share a pattern of relatively high fertility and a history of significant net immigration, both of which contribute to a slower projected rates of population ageing. For Sweden and the USA a relatively old profiles for labour force participation also contribute to the maintenance of the support ratio (Prskawetz and Sambt 2014). For most countries the projected reduction in the support ratio is greater between 2010 and 2030 than between 2030 and 2050.

In 2010 the three countries with the highest support ratios are Japan, Switzerland, and the Czech Republic (Table 5). These high support ratios reflect the relatively age-specific high hours worked per person in these countries (Table 3). For the Czech Republic, the age structure in 2010 is even more favourable than it is in other countries, whilst in Japan the high 2010 support ratios are despite its having a proportionately very large over 65 years age group (Table 2). According to the projections, in 2050 Switzerland, USA, and Sweden are projected to have the highest support ratios (Table 5).

Of the five countries with the lowest support ratios, both in 2010 and in 2050 (Italy, Hungary, Netherlands, Spain and Poland), four have very low fertility (Netherlands is the exception). For these very low fertility countries the gap in support ratios with the other countries is considerably greater in 2050 than in 2010.

Support Ratios for Terminal Stable Populations

Since the forecast mortality declines not only will affect support ratios during the 2010 to 2050 period but also will affect those beyond 2050, Table 5 also presents the support ratios for the terminal stable populations produced by the assumed levels of fertility, migration and labour force participation and with mortality at the forecast level for 2050. For nine of the fourteen populations we consider the terminal stable population support ratios are below those for 2050. The exceptions, for which the ratios for the terminal stable population are higher than for 2050, namely the Czech Republic, Hungary and Italy and Portugal, all are countries with very low fertility and positive net migration. For these countries the decline in annual births, resulting from very low fertility, is projected to become progressively shallower over time, as (eventually constant) births to immigrants progressively account for an increasing share of total births. The lagged effect of this trend for births is that the rate of decline in the numbers in the main working ages, and hence the labour force, becomes slower than the rate of decline in the post-retirement older ages, and so the support ratio increases. The recoveries in the support ratios are larger for the East-Central European countries for which the effects of migration on fertility in the terminal stable population are reduced by the migration being male dominated and the ages of childbearing relatively young, as well as by the low fertility levels than in Italy and Spain, where the migration is female dominated and the ages of childbearing relatively old.

The reductions in support ratios over the entirety of the transition between 2010 and the terminal stable population are largest, both in absolute and in percentage terms, for the two countries with assumed very low fertility, net outmigration, and also forecast rapid mortality improvements, namely Poland and Japan. In Poland the percentage decrease in the support ratio is particularly large. However, due to the projected post 2050 recoveries in support ratios, the differences between the support ratios of the initial and terminal are lowest for two other countries with very low fertility, Portugal and Hungary.

As a result of the post 2050 recovery, the Czech Republic has the highest support ratios for its terminal stable population, followed by Portugal, USA and Switzerland. Japan ranks only fifth. Italy still has the lowest values for both forms of the support ratio. Due to the large projected reduction, Poland has the second lowest support ratio for its terminal stable population.

The Effects of Mortality Improvement on Support Ratios

Table 6 shows that in all the countries we consider projected mortality change, according to the forecast best estimates, contributes to the projected reduction in the support ratio over the period from 2010 to 2050. There is considerable variation between countries. This would reflect not only the variation between countries in the forecast life expectancy gains but also the correlations between the forecast mortality improvements and other demographic patterns. Most notably the countries in which greater improvements in mortality are forecast tends also to have very low fertility. This very low fertility accelerates the aging of these populations and thus magnifies the detrimental effects of forecast older age mortality improvement on the support ratio. Low or even outwards net migration also generally serves to magnify the effects of the forecast mortality improvements.

The projected effects of mortality improvement are greatest for the Czech Republic and Japan. This is unsurprising since these are also the two countries in which the forecast increases in life expectancy are greatest, and in both countries very low fertility is assumed to continue (Table 4). In Japan the projected improvements in mortality at older ages are especially large relative to those for other countries. Since labour force participation by Japanese females is much lower than for males, the particularly large forecast improvements in female mortality are also a factor in the reduction of the support ratio. Moreover the effect of this mortality improvement is magnified by a population age structure which even in 2010 is the oldest in the World and which ages very rapidly. The effects of forecast mortality improvement are also relatively large for Poland and Hungary, both also countries in which the forecast improvements in life expectancy are large and which are projected to age rapidly.

The projected “mortality effects” are smallest for Sweden, USA, Canada, the Netherlands and Australia. Except for Australia, the forecast improvements in life expectancy in these countries are relatively small. All these countries have somewhat younger populations and slower rates of ageing which are linked to their having relatively high fertility and net immigration by young adults, as well as in most cases relatively slow mortality improvement. Their relative youthfulness reduces the importance of the forecast mortality improvement in the post-retirement ages.

For all fourteen countries considered, less than half of the projected change in the support ratio between 2010 and 2050 is attributable to the forecast mortality improvement. The percentage contributions of the forecast mortality improvements to the reductions in the support ratios between 2010 and 2050 are greatest for the Czech Republic and for the UK and Hungary. The contributions of mortality are smallest for Spain, Sweden, Canada, Portugal and Poland.

For all countries and both forms of the support ratios the projected effects of mortality change are negative both for the 2010 and for the 2030 to 2050 period, except for Sweden between 2030 and 2050. Except for Sweden, the support ratio lowering effects of mortality change are greater between 2030 and 2050 than between 2010 and 2030. These increases would be linked to the effects of mortality change becoming increasingly concentrated on the post retirement ages and the increasing weight placed on the post-retirement age groups due to population ageing.

The very long run implications of the forecast changes in mortality on support ratios are shown comparing the support ratio for the stable population with mortality at the level forecast for 2050 to that for the stable population generated by mortality at the current level. Unsurprisingly the magnitudes of the differences in the support ratios with and without the forecast mortality gains have strong negative correlations strongly with the forecast life expectancy gains for males and females. However the relationship between the difference in support ratios and the total fertility rate is relatively weak. Japan, Czech Republic and Poland, all countries for which large gains in life expectancy are forecast, have the largest mortality effects, and Netherlands, USA and the three Southern European countries the smallest mortality effects.

Parr-Guest Valuations of the Effects of Mortality

Using the method of Parr and Guest (2014) we evaluate the effect of the forecast mortality changes between 2010 and 2050 conditional on fertility, migration and labour force participation remaining at the assumed levels throughout future time, on there being no further mortality improvement post 2050 and assuming a net social discount rate of 1.5% per annum.

The values in the "Total Social Value" column of Table 7 represent the effect of the projected mortality change over the entire transition towards the terminal stable population as a multiple of the consumption value of one hour worked per week per capita (i.e. ignoring differences between countries in labour productivity). By this measure the effect of the projected size of the effect of mortality change is greatest for Japan, followed by the three East-Central European countries. The projected effect of mortality change is smallest for the United States, the Netherlands, Canada and Sweden.

The values in the fourth column of Table 7 which show the "mortality effects" expressed as percentages of the value of the constant mortality series, indicate the (immediate and sustained) percentage increases (relative to the 2006-2010 average level) in labour force participation which would compensate for the effect of the forecast change in mortality, if the percentage increases were uniformly spread across all age and sex groups. The greatest value is 7.8 per cent for Poland. This indicates that in Poland an increase of labour force participation of 7.8 per cent would be needed to compensate for the forecast mortality improvement. Japan has the second largest (relative to its higher participation rate) value in percentage terms, followed by the two other East-Central European countries. The North American countries have the smallest percentage changes in labour force participation required to offset forecast mortality improvement, followed by the Netherlands and Sweden.

The final column of Table 7 effectively shows the "mortality effects" as a percentage of the 2010 GDP, and serves to indicate the very large magnitudes of these effects if sustained over the very long run.

Conclusions

The forecasts show the considerable variation between countries in the extent of the life expectancy gains which are to be expected, with the largest forecast increases, for both sexes (for Japan), being more than double the smallest forecast gains (for the Netherlands). The life expectancy gap between Japan and the other countries is forecast to increase. Life expectancies at birth for Australia are forecast to increasingly exceed those for European countries. Within Europe our forecasts show a narrowing of the life expectancy gaps between Western European countries and East-Central European countries, with life expectancies for the Czech Republic exceeding those of two West European countries by 2050. The forecast increases in USA life expectancy are relatively slow and our best estimates indicate that by 2050 they may even fall below those for the Czech Republic for both sexes and for females also for Poland. The forecast patterns of improvement by age are similarly diverse. These forecasts are based on extrapolations of recently observed trends, and therefore reflect the diversity of recent patterns of mortality change.

The projections show that, in the absence of changes in participation rates, fertility or migration, over the period between 2010 and 2050 economic support ratios will decrease in all the countries we consider. The projected reductions in support ratios are relative to abnormally favourable 2010 values, which have been raised by both a diminution of young age dependency by recent low fertility rates and a diminution of old age dependency as a legacy of low fertility rates during the 1930s and World War II.

The extent of the projected decrease in the support ratio varies widely between countries, with the largest projected reduction (for Poland) being more than three times the smallest reduction (Sweden). The unevenness in the projected deterioration of the support ratios between countries is magnified by the correlation of lower fertility, larger prospective gains in life expectancy and low migration, shown by this paper. This study is distinctive in its attempt to isolate the effects of forecast improvement in mortality on support ratios. The projections show, unsurprisingly, that the effects of the forecast improvements in mortality are generally to decrease support ratios. For all the countries we consider the effect of forecast mortality improvement contributes less than half the projected reduction in the support ratio between 2010 and 2050. However, the effects of mortality will increase in importance over time as the population ages. The unevenness between countries in the projected effect of mortality improvement on the support ratio is magnified by the aforementioned correlation between larger gains in life expectancy and the other factors which accelerate population ageing, namely lower fertility (and lower net migration).

Whilst between 2010 and 2050 the reductions in support ratios are generally greater in very low fertility countries, for those very low fertility countries for which net immigration is assumed to continue, recoveries in the support ratios are projected post 2050. This occurs because of an immigration-created floor for annual births, and thus the differences in population numbers between ages become progressively smaller over time and increasingly become the product of immigration and mortality. Thus the projections indicate the potential long-run benefit of positive immigration for the age structures of countries with persistently very low fertility. They also show the potential for analyses which only consider the more immediate future (eg 40 years) to create a misleading impression of prospective support ratio trends for very low fertility countries.

Another distinctive feature of our paper is its application of a method, recently developed by Parr and Guest (2014), which can provide a basis for to provide a single-figure index of the cumulative effect over time of mortality change on the support ratio. The results illustrate the large size of the effects of mortality improvement effects when cumulated over the very long run and some of the combinations of changes in labour force participation which could compensate for these effects. The changes can be calculated conditional on the distribution of participation rate changes between age groups and the gradient of the changes over time. A number of more developed countries, including Australia and the UK, have recently sought to increase retirement ages and labour force participation more broadly in response to prospective increases in longevity and population ageing more generally (Australia 2010). The method used can evaluate the magnitude of increases which are needed.

Policies which aimed at increasing labour force participation rates, including increases to official pension ages, are being planned by almost all more developed countries. A common rationalisation for such policies is to counterbalance the adverse economic effects of increasing longevity. A further distinctive feature of this paper is its estimation of examples of changes to labour force participation rates which over the very long run would have an equivalent effect on living standards to that of the forecast mortality change. Due to the unevenness of the projected effects of mortality between countries, the extent to which labour force participation would need to be changed also is uneven, with the greater required increases being for Japan and for the East-Central European countries. Despite its forecast gains in life expectancy being larger than in most of the other countries, the equivalent proportionate increases to labour force participation rates are smaller than average, because of the younger population structure it is projected to maintain.

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Technical Appendix A: The Poisson Common Factor Method for Forecasting Mortality Coherently

The mortality projections were prepared using the Poisson Common Factor Model (PCFM) of Li (2013). This appendix summarises the specification of this model.

The specification of the PCFM is:

$$D_{x,t,i} \sim \text{Poisson}\left(e_{x,t,i}\ m_{x,t,i}\right), \tag{1A}$$

$$\ln m_{x,t,i} = a_{x,i} + B_x\ K_t + \sum_{j=1}^{n} b_{x,i,j}\ k_{t,i,j}\ , \tag{2A}$$

where $D_{x,t,i}$, $e_{x,t,i}$, and $m_{x,t,i}$ are the number of deaths, central exposed-to-risk, and central death rate at age *x* in year *t* for sex *i*), $a_{x,i}$ depicts the overall mortality schedule across age for sex *i*, K_t is the time-specific mortality index of the common factor with B_x as the age-specific sensitivity measure, and $k_{t,i,j}$ is the time component of the j^{th} additional factor with $b_{x,i,j}$ as the age-specific sensitivity measure. $B_x\ K_t$, the common factor, represents the main long-term trend in mortality change for both sexes, and $b_{x,i,j}\ k_{t,i,j}$, the j^{th} additional sex-specific factor, represents the short-term discrepancy from the main trend for that sex.

The parameters are estimated by (conditional) maximum likelihood via an iterative updating scheme, under the constraints $\sum_x B_x = 1$, $\sum_t K_t = 0$, $\sum_x b_{x,i,j} = 1$, and $\sum_t k_{t,i,j} = 0$. The number of additional factors, *n*, is determined based on the Bayesian Information Criterion (BIC) values, the residual plots, the trends of the additional parameters, and the amount of data being studied.

The mortality index K_t is modelled by a random walk with drift as usual:

$$K_t = \mu + K_{t-1} + \varepsilon_t\ , \tag{3A}$$

where μ is the drift term and the error term $\varepsilon_t \sim \text{N}\left(0\,,\sigma^2\right)$. The time component of an additional factor is modelled by an autoregressive (AR) model of order *p*:

$$k_{t,i,j} = \alpha_{0,i,j} + \alpha_{1,i,j}\ k_{t-1,i,j} + \alpha_{2,i,j}\ k_{t-2,i,j} + ... + \alpha_{p,i,j}\ k_{t-p,i,j} + \omega_{t,i,j}\ , \tag{4A}$$

where $\alpha_{0,i,j}$, $\alpha_{1,i,j}$, … , $\alpha_{p,i,j}$ are model parameters and the error term $\omega_{t,i,j} \sim \text{N}\left(0\,,\nu_{i,j}^2\right)$. Future death rates (in year $t > T$) are then projected as:

$$\hat{m}_{x,t,i} = m_{x,T,i} \exp\left(B_x\left(\hat{K}_t - K_T \right) + \sum_{j=1}^{n} b_{x,i,j}\left(\hat{k}_{t,i,j} - k_{T,i,j} \right) \right), \tag{5A}$$

in which the projection starts with the latest set of data in year T. The resulting male-to-female ratio of death rates (in year $t > T$) converges to a constant if the projected time components $\hat{k}_{t,1,j}$ and $\hat{k}_{t,2,j}$ also converge.

Technical Appendix B: The Parr-Guest Method for Socially Evaluating Very Long Run Demographic Paths

Parr and Guest (2014) propose a method which may be used to evaluate very long run effects of contrasts in demographic processes and their effects on population age structure and of labour force participation on living standards, defined as national consumption per capita. The framework it uses is as follows (Mason and Lee 2007):

$$\frac{C_t}{N_t} = \frac{C_t}{Y_t}\frac{Y_t}{L_t}\sum_x H_{x,t}\ \frac{E_{x,t}}{N_{x,t}}\ \frac{N_{x,t}}{N_t} \qquad \text{(1B)}$$

where C_t is consumption of goods and services at time t, N_t is the effective number of consumers (either total population or a needs-weighted population (eg as defined by Cutler et al. 1990 or according to age profiles of consumption for the relevant population see National Transfer Accounts Project (2014)), Y_t is output of goods and services (gross domestic product, GDP), and L_t is employment (for example, total hours worked). The ratio C_t/N_t is consumption per effective consumer, C_t/Y_t is the consumption share of GDP, Y_t/L_t is average labour productivity, and L_t/N_t is the employment to population ratio or support ratio, which is equal to one minus the total dependency ratio. $H_{x,t}$ denotes hours worked per employed person in age and sex group x at time t and hence $L_{x,t} = \sum_x H_{x,t} E_{x,t}$ where $E_{x,t}$ is the number of employed persons in age and sex group x, and $N_{x,t}$ is population in age and sex group x. In (2) the population age-structure affects living standards through the age-specific variation in $H_{x,t}$ and $E_{x,t}/N_{x,t}$. In order to isolate the role of L_t/N_t,, C_t/Y_t is assumed to be invariant to population age structure[2] and Y_t/L_t grows at a constant

[2] Prskawetz and Sambt (2014) found the effects on C/Y of actual and projected population age structure changes between 1970 and 2050 to be negligible for most of the European countries they considered.

rate, g, which is determined independently from the age composition. Hence the living standard at t is:

$$\frac{C_t}{N_t} = \frac{C_0}{L_0}(1+g)^t \frac{L_t}{N_t} \qquad (2B)$$

The value of a projected population over the entire path of future values of t is:

$$V = \left(\frac{C_0}{L_0}\right)\left[\sum_{t=0}^{\infty}\left(\frac{1+g}{1+\rho}\right)^t \left(\frac{L_t}{N_t}\right)\right] \qquad (3B)$$

ρ is a social discount rate which equivalises living standards for future time points t to values at the start point for the projection, 0, and depends on judgements about the social value of the consumption of present relative to future generations (Samuelson 1958).

Each value of C_t/N_t can be decomposed as follows:

$$\left(\frac{C_t}{N_t}\right) = \left(\frac{C_{s,t}}{N_{s,t}}\right) + \left[\left(\frac{C_t}{N_t}\right) - \left(\frac{C_{s,t}}{N_{s,t}}\right)\right] \qquad (4B)$$

where $(C_{s,t}/N_{s,t})$ is a constant which equals the living standard for the "terminal" stable age distribution of the projection series. Accordingly the value of the series is expressed as two components: a "stable population component" and a "transition path component". Substituting from (4B) into (3B):

$$V = \left(\frac{C_0}{L_0}\right)\left[\sum_{t=0}^{\infty}\left(\frac{1+g}{1+\rho}\right)^t \left(\frac{L_{s,t}}{N_{s,t}}\right) + \sum_{t=0}^{\infty}\left(\frac{1+g}{1+\rho}\right)^t \left[\left(\frac{L_t}{N_t}\right) - \left(\frac{L_{s,t}}{N_{s,t}}\right)\right]\right] \qquad (5B)$$

And the difference in social values of any two demographic projections, A and B, can be expressed as the sum of a "difference in stable population components" plus a "difference in the transition path components".

$$V(A) - V(B) =$$

$$\left(\frac{C_0}{L_0}\right)\left[\sum_{t=0}^{\infty}\left(\frac{1+g}{1+\rho}\right)^t\left(\left(\frac{L_{s,t,A}}{N_{s,t,A}}\right)-\left(\frac{L_{s,t,B}}{N_{s,t,B}}\right)\right)+\sum_{t=0}^{\infty}\left(\frac{1+g}{1+\rho}\right)^t\left(\left[\left(\frac{L_{t,A}}{N_{t,A}}\right)-\left(\frac{L_{s,t,A}}{N_{s,t,A}}\right)\right]-\left[\left(\frac{L_{t,B}}{N_{t,B}}\right)-\left(\frac{L_{s,t,B}}{N_{s,t,B}}\right)\right]\right)\right] \quad (6B)$$

Here A refers to the projection in which mortality changes according to the forecast and B the projection with mortality constant at the initial (2010) values. Thus V(A) – V(B) evaluates the very long run effect of the forecast mortality change. $V(A) - V(B)$ is finite when $\rho > g$ in which case the value of the "stable population component" in (6B) is simply calculated as the sum of a geometric series. The elements of the "transition path component" can be calculated for values of t up to and including the last calculated value T. The residual element of the "transition path component" of the value can be estimated through model-based imputation. Polynomials involving only negative powers of t were fitted to the elements of the valuation between 0 and T and the residual element estimated from the integral of these functions between T and ∞. Solution analyses calculating changes to future labour force participation (or migration or fertility or labour productivity) which would produce changes in value equal to the estimated effect of mortality on social value can then be performed.

References

Australian Government (2002). Intergenerational report 2002-2003. Canberra: Commonwealth of Australia. http://www.budget.gov.au/2002-03/bp5/html/ index.html.

Australian Government (2007). Intergenerational report 2007. Canberra: Commonwealth of Australia. http://www.treasury.gov.au.

Australian Government (2010). Australia to 2050: Future challenges. Canberra: Commonwealth of Australia. http://www.treasury.gov.au/igr/igr2010/report/pdf/ IGR_2010.pdf.

Australian Productivity Commission (2013) An Ageing Australia: Preparing for the Future. *Productivity Commission Research Paper.* Canberra: Commonwealth of Australia. Available at: http://www.pc.gov.au/__data/assets/pdf_file/0005/129749/ageing-australia.pdf. Cited 23 May 2014.

Australian Treasury (2013) Secure and sustainable pension reform: age pension age. Canberra: Commonwealth of Australia. Available at: http://ministers.treasury.gov.au. Cited 22 May 2014.

Australian Treasury (2014) Budget Speech 2014-15. Canberra: Commonwealth of Australia. Available at: http://www.budget.gov.au/2014-15/content/speech/html/speech.htm. Cited 22 May 2014.

Auerbach, A.J. and Kotlikoff, L.J. (1992) The impact of the demographic transition on capital formation. *The Scandinavian Journal of Economics.* 94 (2), 281-295.

Bijak, J. (2013). “Mortality scenarios for 27 European Countries, 2002-2052”, In M. Kupiszewski (Ed.), *International Migration and the Future of Populations and Labour in Europe*, Springer, 109-123.

Bloom, D., Canning, D. & Fink, G. (2010). ‘Population Aging and Economic Growth’, in M. Spence & D. Leipziger (Eds.), *Globalization and Growth: Implications for a Post-Crisis World,* The World Bank: Washington, D.C., 297-328.

Booth, H., Maindonald, J., & Smith, L. (2002). Applying Lee-Carter under conditions of variable mortality decline. *Population Studies, 56*, 325-336.

Booth, H. & Tickle, L. (2008). Mortality modelling and forecasting: A review of methods. *Annals of Actuarial Science,* 3 (I/II), 3-43.

Cerone, P. (1987). On stable population theory with immigration. *Demography,* 24 (3), 431-438.

Cutler, D., Poterba, J., Sheiner, L., and Summers, L. (1990). An aging society: opportunity or challenge? *Brookings Papers on Economic Activity*, 1-56.

Espenshade, T. J., Bouvier, L. F., and Arthur, W. B. (1982). Immigration and the Stable Population Model. *Demography* 19 (1), 125-133.

Human Mortality Database (HMD). (2013). University of California, Berkeley (USA) and Max Planck Institute for Demographic Research (Germany). www.mortality.org.

Kelley, A.C., and Smith, R.M. (2005) Evolution of recent economic--demographic modeling: a synthesis. *Journal of Population Economics* 18 (2), 275–300.

Kupiszewski, Marek, Bijak, Jakub, and Nowok, Beata (2006) Impact of future demographic changes in Europe. *Central European Forum for Migration Research Working Paper* 6/2016.

Lee, R.D., and Tuljapurkar, S. (2000) Population forecasting for fiscal planning: issues and innovations. In Auerbach, A. and Lee, R. (eds.) *Demography and Fiscal Policy*. Cambridge: Cambridge University Press.

Lee,R.,Mason,A. (2010). Fertility, human capital, and economic growth over the demographic transition. *European Journal of Population/Revue européenne de Démographie*, 26 (2),159-182.

Lee, R., Mason, A., and Miller, T. (2000) Life--cycle saving and the demographic transition in Eastern and Southeastern Asia. *Population and Development Review,* 26 (Supp,). 194–219.

Lee, R., Mason, A., and Miller, T. (2001) Saving, wealth, and the demographic transition in East Asia. In Andrew Mason, ed., *Population change and economic development in East Asia: challenges met, opportunities seized*. Stanford University Press: Stanford.

Leon, David A. (2011) Trends in life expectancy: a salutary view. *International Journal of Epidemiology*. 40: 271-277.

Li, J. (2013). A Poisson common factor model for projecting mortality and life expectancy jointly for females and males. *Population Studies* 67(1): 111-126.

Liu, Yan, Arai, Asuna, Obayashi, Yoshihide, Kanda Koji, Boostrom, E., Lee, Romeo B., and Tamashoro, H. (2013) Trends of gender gaps in life expectancy in Japan, 1947-2010: Associations with gender mortality ratio and a social development index. *Geriatrics Gerontology International.* 13: 792-797.

McDonald, P. and Kippen, R. (2000) Labour supply prospects in 16 developed countries 2000-2050.*Population and Development Review*. 27(1): 1-32

National Transfer Accounts project (2014) (http://www.ntaccounts.org).

OECD (2013), *Pensions at a Glance 2013: OECD and G20 Indicators*, OECD Publishing. Available at:
http://dx.doi.org/10.1787/pension_glance-2013-en Accessed May 24 2014.

Parr, Nick and Guest, Ross (2014) A Method for Socially Evaluating the Effects of Long Run Demographic Paths on Living Standards. *Demographic Research.* 31: 275-318.

Pollard, A.H., Farhat Yusuf, and Pollard, G.N. (1990) *Demographic Techniques.* Pergamon: Oxford.

Pollard, J. H. (1973). *Mathematical models for the growth of human populations*. London: Cambridge University Press.

Prskawetz, A. and Sambt, J. (2014). Economic support ratios and the demographic dividend in Europe. *Demographic Research* 30(34): 963–1010.

Saczuk, K. (2013). "Labour Force Participation Scenarios for 27 European Countries 2002-2052", In M. Kupiszewski (Ed.), *International Migration and the Future of Populations and Labour in Europe*, Springer, 173-189.

Samuelson, P. A. (1958) An exact consumption--loan model of interest with or without the social contrivance of money. *Journal of Political Economy* 66 (6), 467-482.

Scherbov, S., Sanderson, W.C. and Mamolo, M. (2014) Quantifying policy trade-offs to support aging populations. *Demographic Research*, 30(20), 579-608.

Skirbekk, V. (2008). Age and productivity potential: a new approach based on ability levels and industry-wide task demand. *Population and Development Review*, 34, 191-207.

Tickle, L. and Booth, H. (2014) The Longevity Prospects of Australian Seniors: An Evaluation of Forecast Method and Outcome. *Asia-Pacific Journal of Risk and Insurance*, DOI: 10.1515/apjri-2013-0004

United Kingdom Department for Work and Pensions (2013) Reviewing the state pension age. Available at: https://www.gov.uk/government/policies/reviewing-the-state-pension-age. Cited 22 May 2014

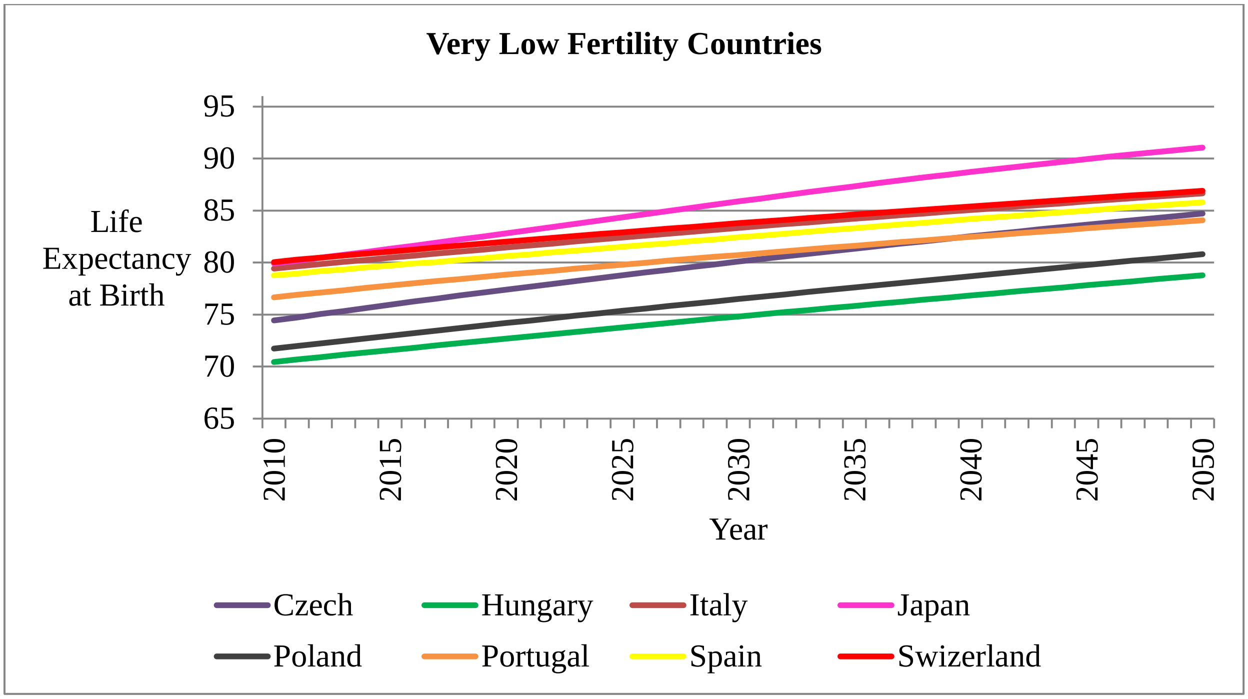
United Nations Population Division (UNPD) (2013). *World Population Policies 2013*. New York: United Nations.

United States Census Bureau (2013) *Methodology and Assumptions for the 2012 National Projections.* Washington DC: US Census Bureau. Date accessed 19 September 2013
http://www.census.gov/population/projections/files/methodology/methodstatement12.pdf

Williamson, J. G. (2013) Demographic dividends revisited. *Asian Development Review*, 30 (2): 1-25.

Tables and Figures

Figure 1 Forecast Change in Male Life Expectancy at Birth: Selected Very Low Fertility Countries and Low Fertility Countries 2010-2050



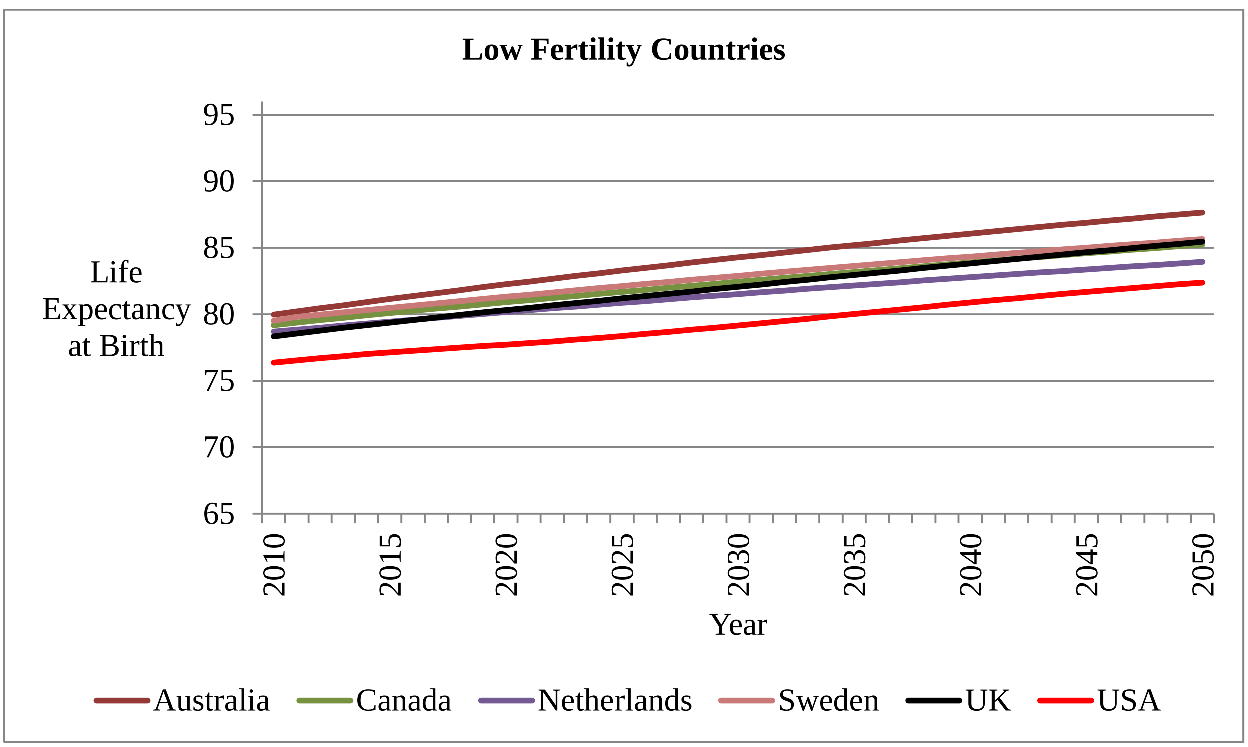
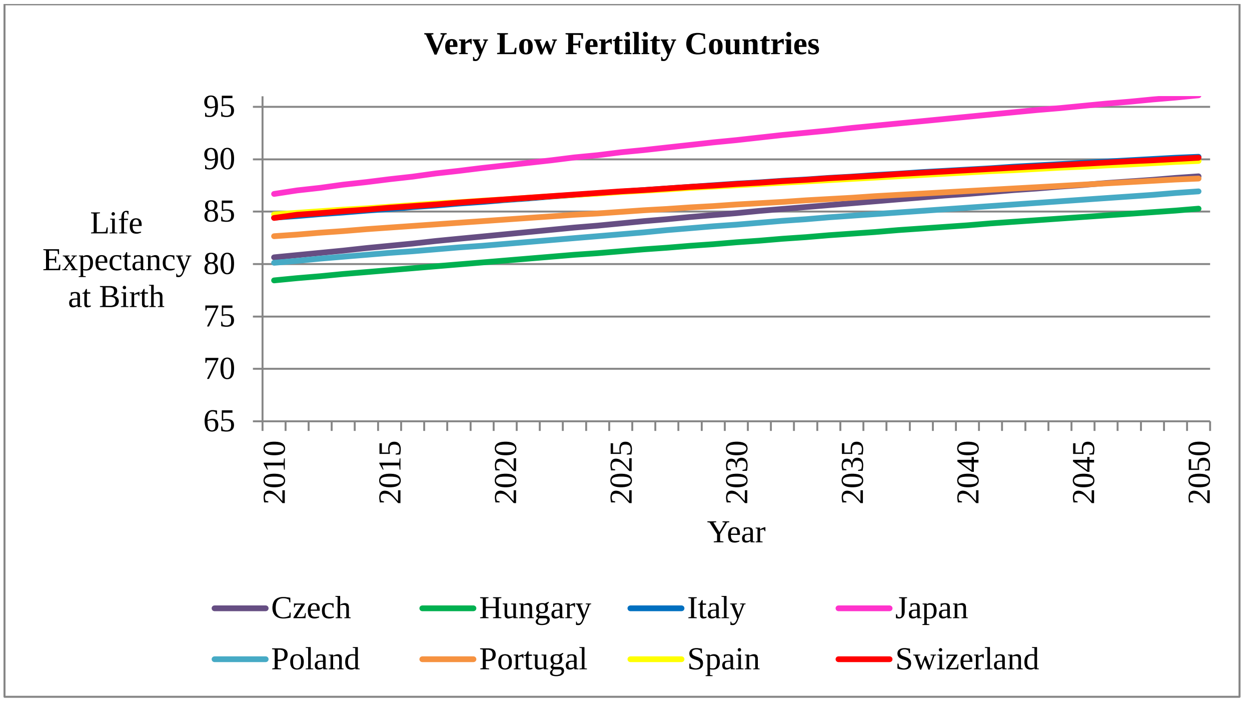


Figure 2: Forecast Changes in Female Life Expectancy at Birth: Selected Countries 2010-2050



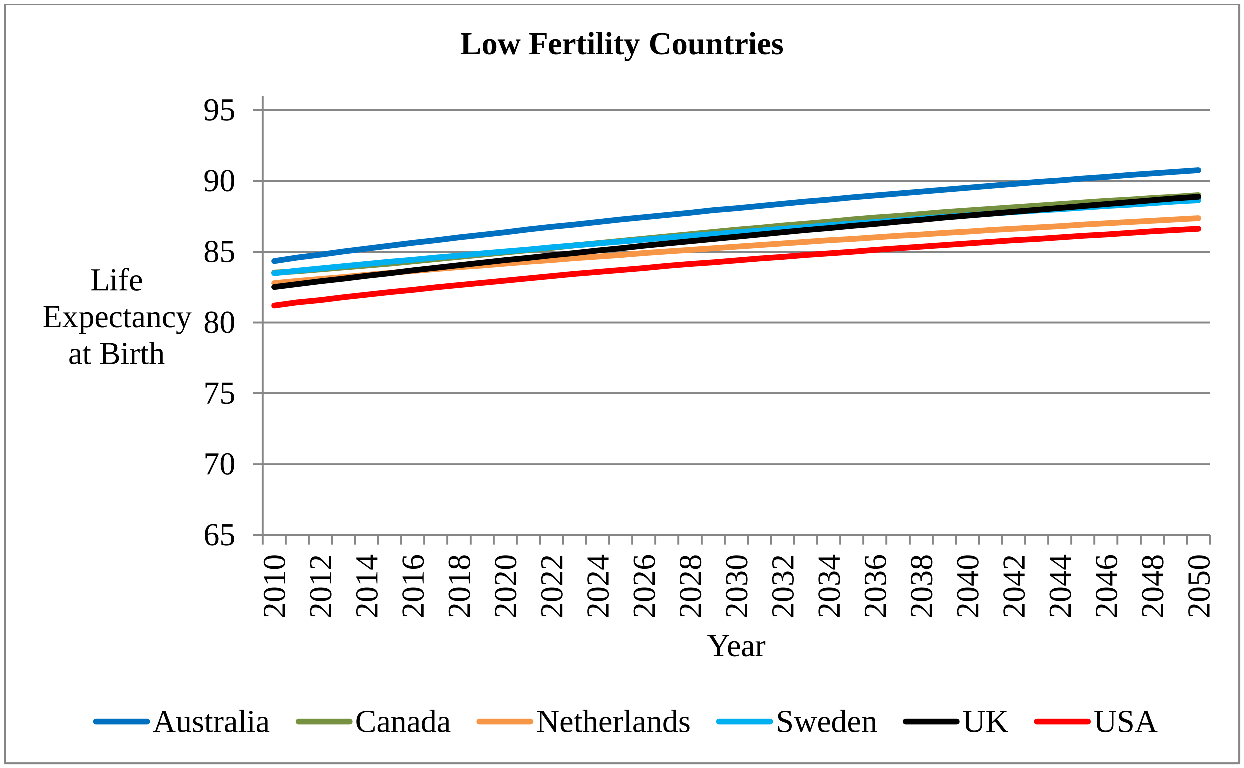


Figure 3: Plot of Forecast Change in Male Life Expectancy at Birth 2010-2050 Against TFR for 2010

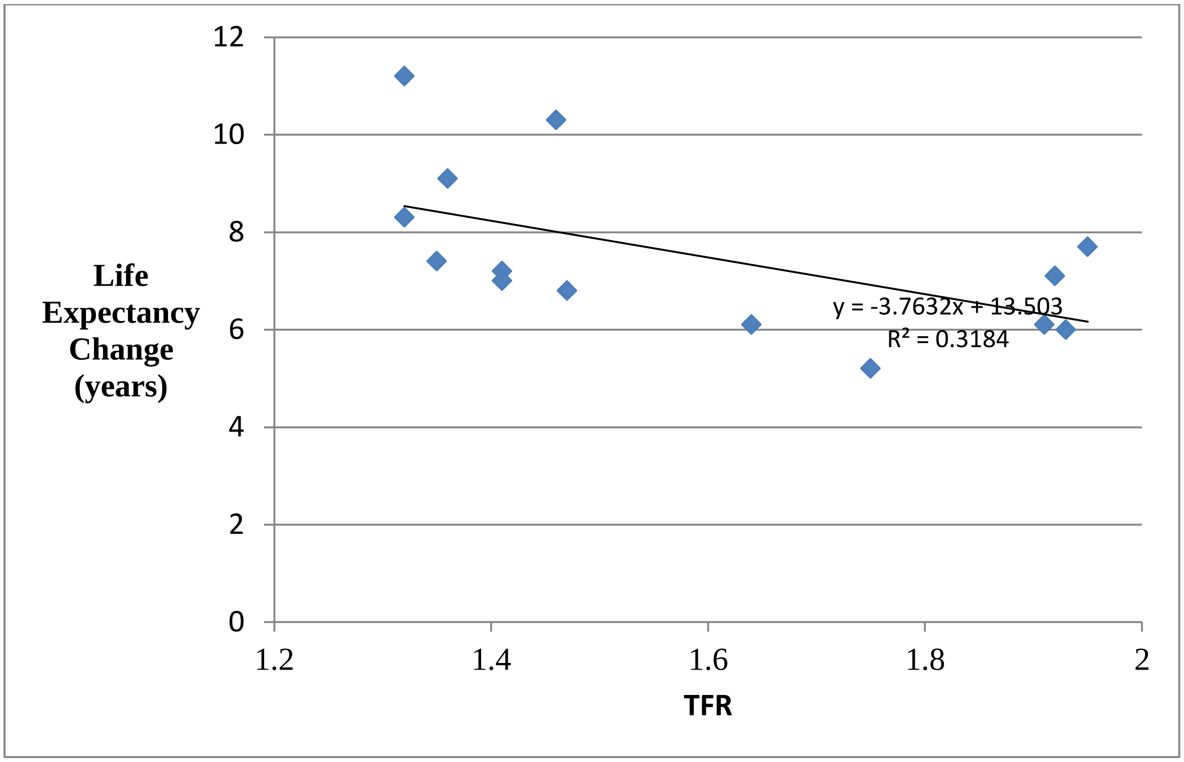
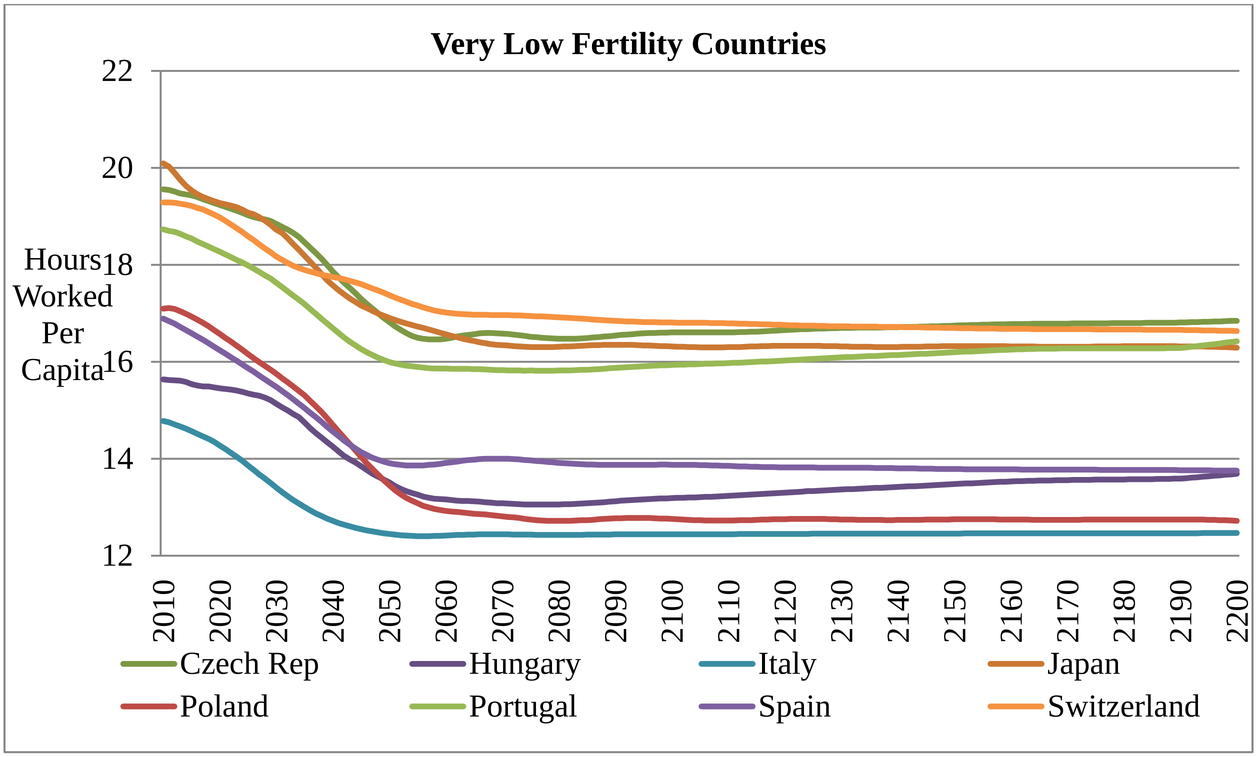


Figure 4: Projected Support Ratios: Very Low Fertility Countries and Low Fertility Countries 2010-2200



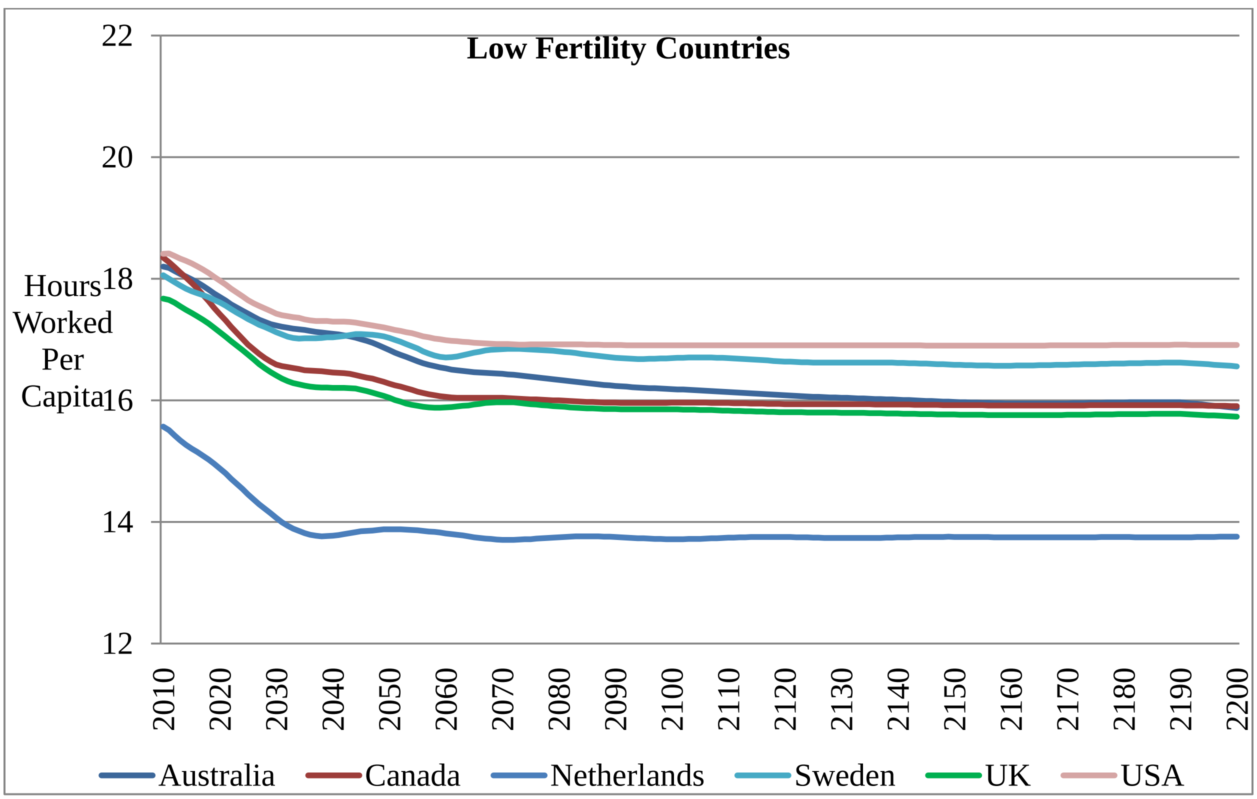


Table 1: Changes in Life Expectancy 1970-2010

Country	Life Expectancy at Birth			Change in Life Expectancy at Birth		
Male	1970	1990	2010	1970-1990	1990-2010	1970-2010
Australia	67.8	73.8	79.2	6.00	5.40	11.40
Canada	69.4	74.0	78.5	4.60	4.50	9.10
Czech	66.2	67.8	74.3	1.60	6.50	8.10
Hungary	66.5	65.1	70.4	-1.40	5.30	3.90
Italy	68.7	73.6	78.9	4.90	5.30	10.20
Japan	69.6	76.0	79.3	6.40	3.30	9.70
Netherlands	70.8	73.8	78.5	3.00	4.70	7.70
Poland	66.3	66.5	72.1	0.20	5.60	5.80
Portugal	63.9	70.7	76.3	6.80	5.60	12.40
Spain	69.0	73.3	78.4	4.30	5.10	9.40
Sweden	72.2	74.8	79.2	2.60	4.40	7.00
Switzerland	70.0	74.0	79.7	4.00	5.70	9.70
UK	68.7	72.9	77.8	4.20	4.90	9.10
USA	67.0	71.7	75.9	4.70	4.20	8.90
Female						
Australia	74.6	80.0	83.8	5.40	3.80	9.20
Canada	76.2	80.3	82.7	4.10	2.40	6.50
Czech	73.3	75.5	80.7	2.20	5.20	7.40
Hungary	72.2	73.9	78.4	1.70	4.50	6.20
Italy	74.6	80.2	83.9	5.60	3.70	9.30
Japan	74.9	82.0	85.9	7.10	3.90	11.00
Netherlands	76.6	80.1	82.6	3.50	2.50	6.00
Poland	73.2	75.5	80.5	2.30	5.00	7.30
Portugal	70.6	77.8	82.3	7.20	4.50	11.70
Spain	74.6	80.5	84.2	5.90	3.70	9.60
Sweden	77.1	80.5	83.5	3.40	3.00	6.40
Switzerland	76.2	81.0	84.5	4.80	3.50	8.30
UK	75.0	78.3	81.9	3.30	3.60	6.90
USA	74.6	78.6	80.5	4.00	1.90	5.90

Source: Wang et al. 2012.

Table 2: Summary Measures of Input Demographic Data

Country	Total Population in Millions (2010)	% Aged 0-19 (2010)	% Aged 65+ (2010)	TFR	Annual Net Migration in Thousands	Net Migration Rate (per 1000)
Australia	22.3	25.7	13.5	1.95	234.6	8.8
Canada	34.0	22.5	15.5	1.64	200.2	5.9
Czech Rep.	10.5	20.1	15.2	1.46	59.3	5.6
Hungary	10.0	20.8	16.6	1.32	21.6	2.2
Italy	60.3	19.0	20.2	1.41	382.3	6.3
Japan	128.1	17.9	23.0	1.32	-54.9	-0.4
Netherlands	16.6	23.7	15.3	1.75	33.2	2.6
Poland	38.2	21.8	13.5	1.36	-27.7	-0.7
Portugal	10.6	20.5	17.9	1.35	13.5	1.3
Spain	46.0	19.8	16.8	1.41	425.4	9.2
Sweden	9.3	23.4	18.1	1.91	54.8	5.9
Switzerland	7.8	21.0	16.8	1.47	70.4	9.0
UK	62.0	23.8	16.5	1.92	203.5	3.3
USA	309.4	26.9	13.1	1.93	725.0	2.3

Table 3: Age-Standardised* Labour Force Participation Rates, Employment Rates, Hours Worked Per Employed Person, Hours Worked Per Person Aged 15+ and Mean Age of Full-time Equivalent Worker

Country	LFPR (%)		Employment Rate (%)		Mean Hours Worked Per Employed		Mean Hours Worked Per Person Aged 15+		Mean Age of Full-Time Equivalent Workers	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Australia	71.5	58.9	95.5	95.5	39.2	29.7	27.7	17.3	40.8	39.5
Canada	70.6	62.7	92.5	93.9	37.9	31.4	25.5	19.2	41.0	39.9
Czech Rep.	65.7	52.2	93.2	91.3	41.2	37.1	26.9	19.0	41.2	41.2
Hungary	56.7	46.6	89.9	89.7	39.4	37.2	21.1	16.6	40.4	40.7
Italy	60.7	41.5	92.2	89.3	40.3	33.5	23.3	12.6	41.2	40.0
Japan	74.2	54.2	95.0	95.8	43.0	33.5	32.2	18.0	42.8	40.7
Netherlands	71.4	60.4	96.6	96.0	32.8	22.3	24.5	14.1	40.5	38.5
Poland	60.3	48.8	91.0	89.6	40.5	35.8	23.5	16.8	40.3	39.5
Portugal	68.2	58.5	91.8	89.8	39.4	35.6	25.6	19.5	41.9	40.7
Spain	66.4	51.3	87.6	85.0	40.6	34.6	24.1	15.3	41.0	39.3
Sweden	71.5	66.0	92.1	92.0	36.2	31.2	25.4	20.6	41.9	41.7
Switzerland	75.0	64.3	96.6	95.8	37.8	27.0	29.1	17.7	40.4	38.5
UK	70.7	59.2	92.8	94.6	38.9	29.1	27.1	17.5	40.7	39.5
USA	70.5	59.2	92.3	93.4	39.4	34.9	26.5	19.7	41.9	41.4

*****: Direct standardisation using persons aged 15+ in Australia by age as the standard.

Table 4: Forecast Life Expectancy at Birth for Males and Females for Selected Countries 2010, 2030 and 2050

	Life Expectancy at Birth			Absolute Change 2010-2050	Percentage Change 2010-2050
Country	2010	2030	2050		
Males					
Australia	80.0	84.3	87.7	7.7	9.6
Canada	79.2	82.4	85.2	6.1	7.7
Czech Republic	74.4	80.1	84.7	10.3	13.8
Hungary	70.5	74.8	78.8	8.3	11.8
Italy	79.4	83.3	86.7	7.2	9.1
Japan	79.9	85.9	91.1	11.2	14.0
Netherlands	78.7	81.5	83.9	5.2	6.7
Poland	71.7	76.5	80.8	9.1	12.6
Portugal	76.7	80.7	84.1	7.4	9.7
Spain	78.8	82.4	85.8	7.0	8.9
Sweden	79.5	82.9	85.7	6.1	7.7
Switzerland	80.0	83.8	86.9	6.8	8.6
UK	78.3	82.1	85.5	7.1	9.1
USA	76.4	79.2	82.4	6.0	7.9
Females					
Australia	84.4	88.1	90.8	6.4	7.6
Canada	83.5	86.6	89.0	5.5	6.6
Czech Republic	80.6	84.9	88.4	7.7	9.6
Hungary	78.4	82.1	85.3	6.8	8.7
Italy	84.4	87.7	90.2	5.8	6.9
Japan	86.7	91.8	96.1	9.4	10.8
Netherlands	82.8	85.4	87.4	4.6	5.5
Poland	80.1	83.8	86.9	6.8	8.5
Portugal	82.7	85.7	88.2	5.5	6.7
Spain	84.7	87.5	89.8	5.1	6.0
Sweden	83.5	86.4	88.6	5.2	6.2
Switzerland	84.4	87.6	90.1	5.7	6.8
UK	82.5	86.1	88.9	6.4	7.7
USA	81.2	84.4	86.6	5.4	6.7

Table 5: Projected Values of Support Ratios

Country	Support Ratio*				Percentage Change	
	2010	2030	2050	Terminal Stable Population	2010-2050	2010 to Terminal Stable Population
Australia	18.2	17.1	16.8	15.5	-7.9	-14.8
Canada	18.8	16.8	16.2	15.9	-13.8	-15.4
Czech Republic	19.6	18.8	16.8	17.5	-14.4	-10.7
Hungary	15.6	15.1	13.5	14.4	-13.6	-7.7
Italy	14.8	13.4	12.5	12.6	-15.8	-14.9
Japan	20.1	18.7	16.9	16.2	-15.9	-19.4
Netherlands	15.6	14.1	13.9	13.8	-10.9	-11.5
Poland	17.1	15.8	13.5	12.9	-21.3	-24.6
Portugal	18.7	17.6	16.0	17.1	-14.6	-8.6
Spain	16.9	15.5	13.9	13.9	-17.6	-17.8
Sweden	18.1	17.0	17.0	15.7	-5.7	-13.3
Switzerland	19.3	18.2	17.4	16.7	-9.9	-13.5
UK	17.7	16.4	16.0	15.5	-9.3	-12.4
USA	18.4	17.4	17.2	16.7	-6.7	-9.2

Notes: * Hours per week per head of population.

Table 6: Projected Effect of Mortality Change on Support Ratio for 2010-2030, 2030-2050, 2010-2050 and 2010 to Terminal Stable Population

Country	2010-2030	2030-2050	2010-2050	Percentage of Change Due to Mortality 2010-2050	2010 to Terminal Stable Population
Australia	-0.2	-0.3	-0.5	34.3	-0.8
Canada	-0.1	-0.4	-0.5	18.5	-0.7
Czech Rep.	-0.4	-0.8	-1.3	43.4	-1.3
Hungary	-0.4	-0.5	-0.9	40.4	-0.8
Italy	-0.2	-0.4	-0.7	28.3	-0.7
Japan	-0.4	-0.8	-1.2	36.9	-1.6
Netherlands	-0.2	-0.3	-0.5	29.6	-0.6
Poland	-0.3	-0.6	-0.9	25.2	-1.1
Portugal	-0.2	-0.5	-0.7	25.6	-0.7
Spain	-0.2	-0.4	-0.7	21.8	-0.7
Sweden	-0.3	0.0	-0.2	22.3	-0.8
Switzerland	-0.2	-0.5	-0.7	36.6	-0.9
UK	-0.2	-0.5	-0.7	42.1	-0.9
USA	-0.1	-0.3	-0.4	28.5	-0.6

Table 7: Components of Value of Effects of Projected Effect of Mortality Change for Selected Countries

	Difference from Baseline Series[a,b]			Difference in Total Value[a]	
Country	Stable Population Component	Transition Path Component	Total Social Value	As % of Social Value of Constant Mortality Series	As % of Social Value for 2010[c]
Australia	-164.8	34.7	-130.1	-3.8	-839.6
Canada	-126.8	14.8	-112.0	-3.3	-702.8
Czech Rep.	-256.2	-10.4	-266.2	-7.0	-1,521.7
Hungary	-173.4	16.3	-189.7	-6.2	-1,319.6
Italy	-142.7	5.6	-137.1	-5.0	-1,085.3
Japan	-319.1	34.0	-285.1	-7.7	-1,756.1
Netherlands	-119.3	13.6	-105.7	-3.6	-763.3
Poland	-242.7	10.9	-231.8	-7.8	-1,804.1
Portugal	-136.2	-8.1	-144.3	-4.1	-841.8
Spain	-147.3	5.6	-141.7	-4.7	-1,019.2
Sweden	-166.1	-38.2	-127.7	-3.7	-811.7
Switzerland	-168.1	11.3	-156.8	-4.3	-936.8
UK	-185.7	23.9	-156.5	-4.6	-1,007.8
USA	-140.4	40.4	-100.0	-2.8	-600.5

Notes: a. Using L/N relative to unweighted population, with g = 1.5% p.a. and ρ = 2.00% p.a.,
b. Multiple of consumption value of 1 hour worked per week per capita.
c. As percent of 2010 *L/N* for country.