International Institute for
Applied Systems Analysis
Schlossplatz 1
A-2361 Laxenburg, Austria

Tel: +43 2236 807 342
Fax: +43 2236 71313
E-mail: publications@iiasa.ac.at
Web: www.iiasa.ac.at

Interim Report IR-09-047

Future Trends in the Prevalence of Severe Activity Limitations in Developed Countries

Warren C. Sanderson (wsanderson@notes.cc.sunysb.edu)
Sergei Scherbov (scherbov@iiasa.ac.at)

Approved by

Wolfgang Lutz
Leader, World Population Program

December 9, 2009

Contents

Abstract

Life expectancies at older ages continue to increase in most developed countries. But how these additional years will be divided between those with and without severe activity limitations (SALs) has remained an important open question. The answer to this question is important for a variety of issues including the ability of people to continue working in the labor market at ever older ages and forecasting the growth of health care expenditures.

We use the harmonized data on severe activity limitations from the Survey of Income and Living Conditions (SILC) and predicted life tables from the United Nations to produce forecasts of demographic quantities that take the prevalence of severe activity limitations into account. For developed countries, we provide forecasts of (1) age-specific proportions of remaining lifetimes at age 65 spent without severe activity limitations, (2) the proportions of populations 60+ years old with severe activity limitations, and (3) a new dependency ratio called the Genuine Adult Dependency Ratio (GADR) that takes severe activity limitations into account.

We show that, on average, life expectancies without severe activity limitations at age 65 in high income OECD countries are likely to increase by around 2.7 years between 2005-2010 and 2045-2050. Proportions of 60+ populations with severe activity limitations are likely to be only marginally higher in 2045-2050 than in 2005-2010. We also show that the speed of increase of the Genuine Adult Dependency Ratio is around one-fifth as fast as the conventional old age dependency ratio.

About the Authors

Warren Sanderson is Co-Chair of the Department of Economics and Professor of History at Stony Brook University and an Institute Scholar with the World Population Program at IIASA.

Sergei Scherbov is a Senior Research Scholar at IIASA's World Population Program and Research Group Leader at the Vienna Institute of Demography of the Austrian Academy of Sciences.

Future Trends in the Prevalence of Severe Activity Limitations in Developed Countries

Warren C. Sanderson and Sergei Scherbov

1 Introduction

The United Nations (UN) forecasts life expectancies at older ages to continue to increase. In Western Europe, for example, life expectancy (both sexes combined) at age 60 was 22.31 years in 2000-2005. The UN predicts that by 2045-2050 it would increase to 26.91 years (United Nations 2009). Whether these additional years are reasonably healthy ones is an important question for public policy. Currently, many developed countries are increasing the age at which people can receive a full public pension (OECD 2007, 2009) and thus, encouraging people to stay longer in the labor market. If retirement ages increase more rapidly than the number of years people live in good health, an increasing fraction of people's retirement would be spent in poor health. Health care costs are especially high for people with severe activity limitations. Forecasts of health care costs can be made more accurate by taking the predicted fraction of the population with those activity limitations into account (Bhattacharya et al. 2004).

While discussions of explicitly taking increases in life expectancy into account in the design of public policies has recently grown more common (Sanderson and Scherbov 2005, 2008; Schultz and Shoven 2008), consideration of the likely future of rates of severe activity limitations (SALs) is still the exception (Bhattacharya et al. 2004; Jacobzone et al. 1998; Lafortune et al. 2007). There are two important issues that have previously limited the possibility of making consistent multi-country forecasts involving severe activity limitations. The first is the lack of appropriate data. While there are numerous studies of activity limitation rates (Robine et al. 2006a), they are generally based on questions that are not consistent across countries and or over time. With the publication of data from the EU Survey on Income and Living Conditions (EU-SILC), this problem has now been substantially mitigated. EU-SILC contains a standardized question on SALs (Robine et al. 2003) for most of the countries of the EU, often for the period 2004-2007. While the EU-SILC data represent a substantial step forward, they do not immediately solve another data problem. The time span of the data is too brief to make the data immediately useful in forecasting models.

The second issue that limits the possibility of making consistent multi-country forecasts is the interrelated nature of age- and sex-specific severe activity limitation rates. Age- and sex-specific severe activity limitation rates for a given time and place are interrelated and must be forecasted together in an integrated way. If the interrelationships in the age- and sex-specific severe activity limitation rates are not taken into account, anomalous age and gender patterns in the forecasted rates are likely to arise. But producing integrated forecasts is especially difficult in an environment where there is little time series data to use. In particular, making forecasts by extrapolating trends in age-specific rates of SALs from a few observations over a short period of time is especially problematic.

In this paper, we introduce a new methodology for producing consistent multi-country forecasts of demographic variables of interest for public policy that take rates of severe activity limitations into account and apply it to the case of high income OECD countries.

2 Methods

2.1 Data

We use two sources of data, age- and sex-specific life expectancies without SALs from EU-SILC and age- and sex-specific life expectancies, forecasted by the United Nations.

2.1.1 EU-SILC

The survey question in the EU-SILC (PH030) asks about activity limitations due to health problems. It makes no distinction between physical and mental health. Activity limitations are subjectively assessed on the basis of what people usually do. An activity limitation is only included if it persisted for half a year or more. Three answers are allowed to the question whether the individual has any activity limitations. In English, these are: (1) “no, not limited”, (2) “yes, limited”, and (3) “yes, strongly limited”.

In this paper, we report on the proportions of people who respond that they are “strongly limited”. We use only these responses because the category of being “limited” is less definitive. The combination of an unclear definition of what “limited” means, different translations of the survey question and different cultures can cause the resulting data to be noisy.

Publicly available data on activity limitations from SILC come in the form of age-specific life expectancies without any activity limitations and life expectancies without SALs (“strongly limited”). These are produced using the Sullivan method (Sullivan 1971), in which age-specific SAL prevalence rates are combined with existing life tables. Similar measures using the Sullivan method are widely available, but they are derived from a variety of questions about health or activity limitations (Robine et al. 2006b). With the EU-SILC, there are now enough comparable data to find regularities that can be used in forecasting.

2.1.2 UN Life Tables

The United Nations publishes the most widely used national level demographic forecasts. These are based on forecasts of fertility, mortality, and migration. The UN publishes the life tables (United Nations 2009) used in making those forecasts and these are the life tables that we use in this paper. There is a great deal of historical data on the evolution of age- and sex-specific survival rates and this makes the forecasting of their joint evolution over time easier. Nevertheless, there is still some controversy over the path of future survival rate changes (Lutz et al. 2004). The UN takes a middle path between the competing possibilities and assumes that in the future the speed of life expectancy changes in today's richer countries will be slower than it has been in the recent past, although evidence from this decade does not indicate any slowing (Christensen et al. 2009). The methodology that we present here is not dependent on the UN life tables and can easily be used with alternative mortality forecasts (see Discussion below).

2.2 Estimation

Let $r_{a,s,c} = \dfrac{e^{no}_{a,s,c}}{e_{a,s,c}}$,

where e is life expectancy, e^{no} is life expectancy with no severe activity limitations, a is age, s is sex, and c refers to the country. The ratio is the fraction of person-years lived from age a onward that are free from severe activity limitations. The $r_{a,s,c}$ are computed from EU-SILC data.

Using ordinary least squares, we estimate a simple linear specification that makes the r's a function of age, sex, and country-specific dummy variables.

$$\log\left(\frac{r_{a,s,c}}{1-r_{a,s,c}}\right) = \beta_0 + \beta_1 a^2 + \beta_2 D_f + \sum_{c=2}^{17} \chi_c D_c + \sum_{c=2}^{17} \delta_c D_c D_f + \varepsilon_{a,s,c} \qquad (1)$$

where the β's, χ's, and δ's are parameters to be estimated, D_f is a dummy variable for females, D_c's are country-specific dummy variables, and ε is an independently distributed normally distributed random error term. We used data for five-year intervals from age 30 to 85+, 17 high income OECD countries, and usually for three years, 2005-2007 (European Health Expectancy Monitoring Unit 2009). All told, we have 1,200 observations and our regression has 1,165 degrees of freedom. We investigated using age as well as the square of age in the regression, but the linear term was statistically insignificant, substantively insignificant, and had virtually no effect on the fit of the model to the data.

The estimated coefficients are shown in Table 1. The model fits the data quite well. The implication of this specification is that the rates of SALs generally would decrease as life expectancies increase (see Appendix B). This is generally consistent with observations on developed countries with at least a comparable decade long data series (Lafortune et al. 2007; Crimmins et al. 2009; Manton et al. 2006).

We use UN forecasts of life expectancies by age, sex, and country for five-year periods from 2005-2010 to 2045-2050 and Eq. (1) to forecast life expectancies without SALs by age, sex, and country for those time periods.

$$\hat{e}^{no}_{a,s,c} = e^{UN}_{a,s,c}\hat{r}_{a,s,c} , \qquad (2)$$

where $e^{UN}_{a,s,c}$ are age-, sex- and country-specific life expectancies forecasted by the UN and a caret (^) over a variable indicates it is our forecasted value.

Table 1. Regression results.

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	2.06e+00	2.69e-02	76.55	< 2e-16 ***
Age squared	-2.26e-04	3.45e-06	-65.51	< 2e-16 ***
Women	-2.99e-01	3.34e-02	-8.95	< 2e-16 ***
Country Dummies				
Belgium	5.10e-01	3.42e-02	14.92	< 2e-16 ***
Czech Republic	6.23e-01	4.06e-02	15.36	< 2e-16 ***
Finland	5.31e-02	3.37e-02	1.57	0.11584
France	3.69e-01	3.03e-02	12.19	< 2e-16 ***
Germany	3.74e-01	3.37e-02	11.08	< 2e-16 ***
Greece	4.43e-01	2.74e-02	16.20	< 2e-16 ***
Hungary	-3.37e-01	3.18e-02	-10.60	< 2e-16 ***
Ireland	5.30e-01	3.73e-02	14.21	< 2e-16 ***
Italy	3.89e-01	4.18e-02	9.30	< 2e-16 ***
Luxembourg	4.30e-01	3.86e-02	11.13	< 2e-16 ***
Netherlands	3.93e-01	3.52e-02	11.16	< 2e-16 ***
Portugal	-1.71e-01	3.27e-02	-5.23	2.1e-07 ***
Slovakia	-2.02e-01	3.34e-02	-6.05	1.9e-09 ***
Spain	3.47e-01	2.78e-02	12.51	< 2e-16 ***
Sweden	5.95e-01	5.73e-02	10.38	< 2e-16 ***
United Kingdom	3.58e-01	3.03e-02	11.79	< 2e-16 ***
Country-sex interactions				
Belgium:*Women	-5.01e-02	5.16e-02	-0.97	0.33220
Czech Republic:*Women	-8.40e-02	5.29e-02	-1.59	0.11239
Finland:*Women	8.33e-02	5.04e-02	1.65	0.09878 .
France:*Women	9.90e-02	4.09e-02	2.42	0.01556 *
Germany:*Women	-1.89e-01	4.99e-02	-3.79	0.00016 ***
Greece:*Women	1.69e-01	3.92e-02	4.32	1.7e-05 ***
Hungary:*Women	1.07e-01	4.13e-02	2.60	0.00948 **
Ireland:*Women	1.57e-01	4.53e-02	3.47	0.00054 ***
Italy:*Women	2.68e-02	5.47e-02	0.49	0.62413
Luxembourg:*Women	9.39e-02	8.84e-02	1.06	0.28849
Netherlands:*Women	3.00e-01	5.74e-02	5.23	2.1e-07 ***
Portugal:*Women	-1.90e-01	4.41e-02	-4.31	1.8e-05 ***
Slovakia:*Women	-4.44e-02	5.34e-02	-0.83	0.40576
Spain:*Women	-7.11e-02	3.85e-02	-1.85	0.06486 .
Sweden:*Women	1.63e-02	8.86e-02	-0.18	0.85376
United Kingdom:*Women	1.21e-01	4.20e-02	2.87	0.00413 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.176 on 1165 degrees of freedom
Multiple R-Squared: 0.914, Adjusted R-squared: 0.911
F-statistic: 362 on 34 and 1165 DF, p-value: <2e-16
Omitted country dummy is for Austria
Robust standard errors

Given the life expectancies without SALs in Eq. (2) and UN life tables, we can compute the prevalence of severe activity limitations in each five-year age group by working sequentially from the oldest age group, 85+, to the youngest, 30-34.

Using standard life table notation, we know that

$$\hat{T}^{no}_{85+,s,c} = \hat{e}^{no}_{85+,s,c} l^{UN}_{85+,s,c} , \tag{3}$$

where $\hat{T}^{no}_{85+,s,c}$ (and $\hat{L}^{no}_{85+,s,c}$) is the forecasted number of person-years lived from age 85 onwards with no SALs and $l^{UN}_{85+,s,c}$ is the number of people in the forecasted UN life table who have survived to exact age 85.

The proportion of person-years at age 85+ with no SALs can now be expressed as:

$$\hat{\pi}^{no}_{85+,s,c} = \frac{\hat{T}^{no}_{85+,s,c}}{T^{UN}_{85+,s,c}} = \frac{\hat{L}^{no}_{85+,s,c}}{L^{UN}_{85+,s,c}} . \tag{4}$$

Working our way up the age range, we have:

$$\hat{L}^{no}_{80,s,c} = \hat{e}^{no}_{80,s,c} l^{UN}_{80,s,c} - \hat{T}^{no}_{85+,s,c} \tag{5}$$

and

$$\hat{\pi}^{no}_{80,s,c} = \frac{\hat{L}^{no}_{80,s,c}}{L^{UN}_{80,s,c}} ,$$

where $\hat{L}^{no}_{80,s,c}$ is the number of person-years lived between age 80 and 85 without SALs.

We can continue working our way down the age distribution in this way, using information derived from later ages to compute proportions without SALs at earlier ones.

3 Results

Table 2 can provide input into discussions of raising the age of eligibility for a full public pension. It shows the predicted life expectancies without severe activity limitations for men and women at ages 65 in selected high income OECD countries for the years 2008, 2028, and 2048. These standardized life expectancies are computed using the values of the dummy variables for Italy. The values of the dummy variables for Italy were consistently in the middle of the distribution of the values of those dummies. We use this standardization in Tables 2, 3, and 4. It holds constant the age- and sex-specific ratios of life expectancies without SALs to life expectancies at the levels that we estimate for Italy. Standardized quantities are useful for two reasons. First, they allow us to expand the number of countries we study beyond the high income OECD countries in the EU-SILC dataset. Second, they eliminate country-specific anomalies that could be due to differences in the translation of the question on disabilities, culture, how the surveys were conducted, how non-responses were treated and differences in the ease of receiving a disability pension (Einerhand and Van der Stelt 2005; Ekholm and Bronnum-Hansen 2009).

Table 2. Standardized and unstandardized life expectancies at 65 without severe activity limitations, selected high income OECD countries, 2005-2010, 2025-2030, and 2045-2050.

See Appendix Table A1 for all high income OECD countries.

	Men			Women		
	2005-10	2025-30	2045-50	2005-10	2025-30	2045-50
AT (std)	13.78	15.62	16.89	15.56	17.1	18.54
AT (unstd)	12.67	14.37	15.53	13.92	15.3	16.59
AU (std)	14.82	16.28	17.44	16.53	17.89	19.21
CH (std)	14.99	16.68	17.93	16.71	18.1	19.44
CZ (std)	11.44	12.92	14.44	13.59	15.44	17.02
CZ (unstd)	11.9	13.43	15.02	13.96	15.86	17.48
DE (std)	13.51	14.92	16.24	15.6	17.1	18.5
DE (unstd)	13.47	14.88	16.2	14.72	16.14	17.46
ES (std)	14.15	15.93	17.15	16.48	17.93	19.1
ES (unstd)	14.04	15.8	17.02	15.93	17.34	18.46
FI (std)	13.26	14.69	15.86	15.77	17.31	18.72
FI (unstd)	12.35	13.68	14.77	14.69	16.13	17.44
FR (std)	14.38	16.08	17.26	17.11	18.39	19.7
FR (unstd)	14.32	16.02	17.2	17.32	18.61	19.93
GB (std)	13.51	14.75	15.97	15.28	16.74	18.09
GB (unstd)	13.43	14.66	15.88	15.5	16.98	18.34
GR (std)	13.56	14.72	15.91	14.31	16.41	17.97
GR (unstd)	13.7	14.86	16.07	14.92	17.11	18.74
HU (std)	10.51	11.59	12.91	13.05	14.65	15.98
HU (unstd)	8.78	9.69	10.8	10.81	12.14	13.24
IE (std)	13.48	14.76	16.03	15.51	17.01	18.38
IE (unstd)	13.81	15.13	16.42	16.4	17.98	19.43
IS (std)	14.99	16.22	17.5	15.99	17.46	18.85
IT (std)	14.31	15.5	16.74	16.57	17.98	19.35
IT (unstd)	14.31	15.5	16.74	16.57	17.98	19.35
JP (std)	14.77	16.28	17.37	18	19.75	21.07
KR (std)	12.98	14.31	15.49	15.58	17.11	18.54
NL (std)	13.7	15.13	16.49	15.39	16.69	17.88
NL (unstd)	13.7	15.14	16.5	16.28	17.67	18.92
SE (std)	14.16	15.63	16.89	15.89	17.21	18.36
SE (unstd)	14.66	16.18	17.49	16.46	17.82	19.02
SK (std)	10.85	11.85	13.32	13.29	14.91	16.26
SK (unstd)	9.45	10.32	11.6	10.94	12.28	13.39
US (std)	14.14	15.12	15.87	15.82	16.95	17.98

A possible example of such an anomaly is the difference in the prevalence of SALs that we observe between the Czech Republic and Slovakia. These two countries were unified from the end of World War I until January 1, 1993, and had common economic, social, and healthcare systems. We would not expect that the prevalence of SALs in the two places in 2005-2010 would be extremely different. Nevertheless, they are. The unstandardized prevalence rates of SALs for people in their 60s is around twice as high in Slovakia as in the Czech Republic (see Appendix Table A2), but their standardized rates are only slightly different from one another.

In Table 2, we also present unstandardized figures for high income OECD countries, if they were included in SILC. These are computed with the countries' own dummy variables. The levels of the standardized and unstandardized life expectancies differ, but their trends are the same.

The average of the standardized number of years of life expectancy at 65 without severe activity limitations rises from 13.6 years in 2005-2010 to 16.2 years in 2045-2050 for men and from 15.6 in 2005-2010 to 18.4 for women.

Life expectancies without SALs can add one more element to the public policy dialog on increasing the normal pension age. In the UK, that pension age is now scheduled to increase from 65 currently to 68 in 2044. But in the same interval, life expectancy without severe activity limitations is only expected to increase by around 2.4 years. So by 2044, men in the UK will have slightly fewer years of pension receipt during which they have no SALs. Women in the UK will have their normal pension ages increased from 60 to 68, which would reduce the number of pensionable years to something closer to that of men.

In Tables 3 and 4, we add a disability dimension to the discussion of the extent and speed of aging. Table 3 shows the evolution of the proportions of populations 60+ years old with SALs. These proportions change because of variations in the age structure of the 60+ population and with changes in age- and sex-specific severe activity limitation rates. Populations over the age of 60 are themselves growing older and that would increase the proportion of the overall population with SALs. But over time age-specific activity limitation rates are forecasted to be falling, so the proportion can move in either direction. In Table 3, we see that between 2005-2010 and 2025-2030, the proportions frequently fall slightly and then rise to 2045-2050. On average, the forecasted proportions of the 60+ populations with SALs is only marginally higher in 2045-2050 than in 2005-2010.

Table 3 shows a wide variety of time patterns for the percentages of the 60+ populations with SALs. For Japanese men and women the proportion rises continuously to 2045-2050. The increase from 2005-2010 and 2025-2030 is due to the substantial increase in the mean age of the 60+ population (see Appendix Table A4). In the case of Irish men and women, we find the general U-shaped time path, but with the levels in 2045-2050 slightly lower than they were in 2005-2010. Knowledge of the magnitudes and directions of changes in the percentage of populations 60+ with severe activity limitations can help policy makers cope with those changes.

Table 3. Standardized and unstandardized proportions of populations 60+ with severe activity limitations, selected high income OECD countries, 2005-2010, 2025-2030, and 2045-2050.

See Appendix Table A3 for all high income OECD countries.

	Men			Women		
	2005-10	2025-30	2045-50	2005-10	2025-30	2045-50
AU (std)	0.148	0.149	0.157	0.187	0.182	0.196
AT (std)	0.151	0.148	0.163	0.197	0.187	0.203
AT (unstd)	0.209	0.205	0.223	0.271	0.26	0.279
CH (std)	0.148	0.149	0.164	0.191	0.183	0.2
CZ (std)	0.155	0.16	0.157	0.196	0.199	0.198
CZ (unstd)	0.127	0.13	0.129	0.177	0.18	0.179
DE (std)	0.152	0.152	0.167	0.196	0.191	0.208
DE (unstd)	0.154	0.154	0.169	0.236	0.23	0.249
ES (std)	0.156	0.148	0.157	0.194	0.187	0.196
ES (unstd)	0.162	0.154	0.162	0.217	0.209	0.219
FI (std)	0.15	0.158	0.163	0.191	0.194	0.206
FI (unstd)	0.199	0.208	0.214	0.239	0.243	0.255
FR (std)	0.154	0.153	0.162	0.193	0.19	0.206
FR (unstd)	0.157	0.155	0.165	0.185	0.182	0.197
GB (std)	0.156	0.155	0.16	0.197	0.19	0.2
GB (unstd)	0.16	0.159	0.165	0.188	0.18	0.19
GR (std)	0.158	0.155	0.16	0.196	0.194	0.201
GR (unstd)	0.151	0.148	0.153	0.167	0.165	0.171
HU (std)	0.163	0.163	0.158	0.201	0.203	0.199
HU (unstd)	0.287	0.287	0.281	0.325	0.327	0.323
IE (std)	0.15	0.149	0.151	0.188	0.181	0.185
IE (unstd)	0.133	0.132	0.134	0.15	0.144	0.147
IS (std)	0.149	0.143	0.154	0.189	0.18	0.193
IT (std)	0.154	0.153	0.164	0.194	0.193	0.205
IT (unstd)	0.154	0.153	0.164	0.194	0.193	0.205
JP (std)	0.148	0.162	0.163	0.181	0.201	0.206
KR (std)	0.144	0.145	0.162	0.178	0.177	0.202
NL (std)	0.149	0.152	0.167	0.192	0.188	0.208
NL (unstd)	0.148	0.152	0.166	0.152	0.149	0.166
SE (std)	0.153	0.156	0.161	0.196	0.195	0.201
SE (unstd)	0.128	0.131	0.135	0.171	0.17	0.176
SK (std)	0.159	0.157	0.155	0.197	0.193	0.196
SK (unstd)	0.255	0.252	0.25	0.323	0.319	0.322
US (std)	0.152	0.149	0.159	0.192	0.184	0.199

Our forecasted severe disability prevalence rates allow us to show the dynamics of a new measure of disability that we call the Genuine Adult Dependency Ratio (GADR). The GADR is the ratio of the number of adults 20+ years old with SALs to the number of adults 20 to 64 years old who have no SALs. We show these rates in Table 4.

For comparison, we also show two other old age dependency ratios (OADRs), the conventional old age dependency ratio and the prospective old age dependency ratio (POADR) (Sanderson and Scherbov 2005, 2008). The conventional measure is the ratio of people aged 65+ to those who are 20 to 64. It uses chronological age to categorize people as being dependent starting when they turn 65. As normal public pension ages increase and increasing proportions of people above age 65 living healthy and productive lives, this measure is becoming more and more anachronistic. An alternative is the prospective old age dependency ratio. This ratio defines the beginning of old age dependency as depending on remaining life expectancy. As life expectancies increase, the onset of old age dependency occurs at ever old ages. Neither of these takes the prevalence of SALs into account. Our new measure, the GADR, counts adults as being dependent when they have SALs, regardless of their age. These three ratios reflect different aspects of aging and which would be best to use depends on the context.

Table 4 shows that conventional OADRs increase much faster than the other two measures. Prospective OADRs increase less rapidly, and the GADR increases most slowly. Sweden is a country that is aging relatively slowly. The conventional OADR there increases from 0.30 to 0.44 from 2005-2010 to 2045-2050. The prospective OADR increases from 0.27 to 0.31 over that period. But the GADR increases only from 0.10 to 0.11. In general, the percentage increases in the conventional OADR are over five times what we estimate for the GADR. How we view the speed of aging depends importantly on whether we define old age dependency based on chronological age, remaining years of life expectancy or on the prevalence of SALs.

Table 4. Standardized and unstandardized genuine adult dependency ratios, old age dependency ratios, prospective old age dependency ratios, selected high income OECD countries, 2005-2010, 2025-2030, and 2045-2050.

See Appendix Tables A5a and A5b for all high income OECD countries.

	GADR			OADR			POADR		
	2005-10	2025-30	2045-50	2005-10	2025-30	2045-50	2005-10	2025-30	2045-50
AT (std)	0.1	0.1	0.12	0.28	0.41	0.55	0.23	0.27	0.36
AT (unstd)	0.14	0.16	0.18						
AU (std)	0.08	0.09	0.1	0.22	0.36	0.43	0.19	0.26	0.29
CH (std)	0.09	0.1	0.11	0.27	0.41	0.48	0.23	0.28	0.33
CZ (std)	0.1	0.11	0.12	0.23	0.36	0.52	0.2	0.26	0.29
CZ (unstd)	0.08	0.09	0.1						
DE (std)	0.1	0.11	0.13	0.33	0.48	0.63	0.27	0.32	0.41
DE (unstd)	0.12	0.13	0.15						
ES (std)	0.09	0.1	0.12	0.27	0.37	0.64	0.24	0.26	0.4
ES (unstd)	0.1	0.11	0.13						
FI (std)	0.1	0.11	0.11	0.27	0.46	0.48	0.23	0.33	0.3
FI (unstd)	0.13	0.15	0.15						
FR (std)	0.09	0.1	0.11	0.28	0.44	0.51	0.24	0.31	0.35
FR (unstd)	0.09	0.1	0.11						
GB (std)	0.1	0.1	0.1	0.27	0.36	0.41	0.24	0.26	0.27
GB (unstd)	0.1	0.1	0.1						
GR (std)	0.1	0.11	0.12	0.29	0.39	0.6	0.27	0.29	0.37
GR (unstd)	0.09	0.09	0.11						
HU (std)	0.11	0.11	0.12	0.26	0.34	0.48	0.22	0.25	0.26
HU (unstd)	0.21	0.22	0.23						
IE (std)	0.08	0.09	0.1	0.18	0.27	0.44	0.14	0.17	0.22
IE (unstd)	0.07	0.07	0.08						
IS (std)	0.08	0.09	0.1	0.19	0.32	0.48	0.16	0.22	0.3
IT (std)	0.1	0.11	0.12	0.33	0.45	0.68	0.29	0.32	0.45
IT (unstd)	0.1	0.11	0.12						
JP (std)	0.1	0.12	0.13	0.35	0.55	0.78	0.3	0.42	0.51
KR (std)	0.08	0.1	0.13	0.16	0.35	0.65	0.12	0.2	0.37
NL (std)	0.09	0.11	0.11	0.24	0.41	0.48	0.21	0.3	0.34
NL (unstd)	0.08	0.09	0.1						
SE (std)	0.1	0.1	0.11	0.3	0.4	0.44	0.27	0.31	0.31
SE (unstd)	0.08	0.09	0.09						
SK (std)	0.1	0.11	0.12	0.18	0.32	0.5	0.16	0.22	0.27
SK (unstd)	0.18	0.2	0.23						
US (std)	0.09	0.1	0.1	0.21	0.34	0.38	0.19	0.27	0.29

4 Conclusions

With a few exceptions, policy discussions on aging have been based on forecasts of age structure that ignored the dynamics of disability. In this paper, we demonstrated a methodology for making consistent multi-country forecasts of severe disability rates and incorporated new forecasted disability rates into demographic magnitudes that can provide inputs into policy-making. For high income OECD countries we showed that, over the next four decades, life expectancies at 65 without SALs is likely to increase by around by around 2.7 years, that despite increases in the mean ages of the 60+ populations, proportions of 60+ year old populations without SALs are unlikely to change very much, and that increases in the GADR will only be about one-fifth as large as those in the conventional old age dependency ratio. Disability-based forecasts are useful in formulating policies and in assessing the realism of policy targets (Jagger et al. 2008).

Our forecasts are based on the UN life tables used in its demographic forecasts. These life tables build in the assumption that the pace of life expectancy increase for high income OECD countries will generally slow down from its current pace, although such a deceleration is not yet evident in the data. If the pace of life expectancy increase does not slow, decreases in rates of SALs will be faster than the forecasts in this paper.

There are now a number of excellent methodologies for making probabilistic mortality forecasts (Booth et al. 2006; Lee and Carter 1992; Lutz et al. 2004). One next step is to combine our SILC-based estimates with probabilistic life expectancy forecasts to produce fully probabilistic disability forecasts. Another development of our methodology would be to take advantage of available high-quality education forecasts (KC et al. 2008) and the relationship between disabilities and educational attainment in making disability forecasts.

5 References

Bhattacharya, J., D. Cutler, D. Goldman, M. Hurd, G. Joyce, D. Lakdawalia, C. Panis, and B. Shang. 2004. Disability forecasts and future Medicare costs. *Frontiers in Health Policy Research* 7: 75-94.

Booth, H., R. Hyndman, L. Tickle, and P. de Jong. 2006. Lee-Carter mortality forecasting: A multi-country comparison of variants and extensions. *Demographic Research* 15(9): 289-310.

Christensen, K., G. Doblhammer, R. Rau, and J. Vaupel. 2009. Ageing populations: The challenges ahead. *Lancet* 374: 1196-1208.

Crimmins, E., M. Haywood, A. Hagedorn, Y. Saito, and N. Brouard. 2009. Change in disability-free life expectancy for Americans 70 years old and older. *Demography* 46(3): 627-646.

Einerhand, M. and H. Van der Stelt. 2005. Growing disability rates – the gender issue: The Dutch case in international perspective. *International Social Security Review* 58(1): 65-84.

Ekholm, O. and H. Bronnum-Hansen. 2009. Cross-national comparisons of non-harmonized indicators may lead to more confusion than clarification. *Scandinavian Journal of Public Health* 37: 661-663.

European Health Expectancy Monitoring Unit. 2009. Data on Activity Limitation from Statistics on Income and Living Conditions (SILC) Survey. Accessed on October 30, 2009: http://www.ehemu.eu

Jacobzone, S., E. Cambois, and J-M Robine. 1998. The Health of Older Persons in OECD Countries: Is it Improving Fast Enough to Compensate for Population Ageing? Labour Market and Social Policy Papers, No. 37. Paris: Organisation for Economic Co-operation and Development, Directorate for Employment, Labour, and Social Affairs.

Jagger, C., C. Gillies, F. Moscone, E. Cambois, H. Van Oyen, W. Van Oyen, W. Nusselder, J-M Robine, and the EHLEIS Team. 2008. Inequalities in healthy life years in the 25 countries of the European Union: A cross-national meta-regression analysis. *The Lancet* 372: 2124-2131.

KC, S., B. Barakat, A. Goujon, V. Skirbekk, and W. Lutz. 2008. Projection of Populations by Level of Educational Attainment, Age, and Sex for 120 Countries for 2005-2050. Interim Report IR-08-038. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Lafortune, G., G. Balestat, and the Disability Study Expert Group Members. 2007. Trends in Severe Disability Among Elderly People: Assessing Evidence in 12 OECD Countries and Future Implications. OECD Health Working Papers, No. 26. Paris: Organisation for Economic Co-operation and Development.

Lee, R. and L. Carter. 1992. Modeling and forecasting U.S. mortality. *Journal of the American Statistical Association* 87: 659-675.

Lutz, W., W. Sanderson, and S. Scherbov. 2004. The end of world population growth. Pages 17-84 in W. Lutz, W. Sanderson, and S. Scherbov (eds.), *The End of World Population Growth in the 21st Century: New Challenges for Human Capital Formation and Sustainable Development*. London: Earthscan.

Manton, K., X.L. Gu, and V. Lamb. 2006. Changes in chronic disability from 1982 to 2004/2005 as measured by long-term changes in function and health in the U.S. elderly population. *Proceedings of the National Academy of Sciences* 103(48): 18374-18379.

OECD. 2007. *Pensions at a Glance 2007: Public Policies Across OECD Countries*. Paris: Organisation for Economic Co-operation and Development.

OECD. 2009. *Pensions at a Glance 2009: Retirement-Income Systems in OECD Countries*. Paris: Organisation for Economic Co-operation and Development.

Robine, J-M, C. Jagger, and the Euro-REVES Group. 2003. Creating a coherent set of indicators to monitor health across Europe: The Euro-REVES 2 Project. *European Journal of Public Health* 13(suppl.): 6-14.

Robine, J-M, I. Romieu, and J-P Michel. 2006a. Trends in health expectancies. Pages 75-104 in J-M Robine, C. Jagger, C. Mathers, E. Crimmins, and R. Suzman, (eds.), *Determining Health Expectancies*. Chichester,UK: Wiley.

Robine, J-M, C. Jagger, C. Mathers, E. Crimmins, and R. Suzman, Eds. 2006b. *Determining Health Expectancies*. Chichester, UK: Wiley.

Sanderson, W. and S. Scherbov. 2005. Average remaining lifetimes can increase as human populations age. *Nature* 435(7043): 811-813.

Sanderson, W. and S. Scherbov. 2008. Rethinking age and aging. *Population Bulletin* 63(4): 1-16.

Schultz, G.P. and J. Shoven. 2008. *Putting our House in Order: A Guide to Social Security and Health Care Reform*. New York: W.W. Norton & Company.

Sullivan, D. 1971. A single index of mortality and morbidity. *HSMHA Health Reports* 86(4): 374-54.

United Nations. 2009. *World Population Prospects: The 2008 Revision*. New York: United Nations, Department of Social and Economic Affairs, Population Division.

Appendix A. Data

Appendix Table A1. Standardized and unstandardized life expectancies at age 65 without severe activity limitations.

	Men			Women		
	2005-10	2025-30	2045-50	2005-10	2025-30	2045-50
AT (std)	13.78	15.62	16.89	15.56	17.1	18.54
AT (unstd)	12.67	14.37	15.53	13.92	15.3	16.59
AU (std)	14.82	16.28	17.44	16.53	17.89	19.21
BE (std)	13.47	15.17	16.46	15.68	17.77	19.14
BE (unstd)	13.76	15.49	16.81	15.84	17.94	19.33
CA (std)	14.47	15.93	17.17	16.15	17.51	18.82
CH (std)	14.99	16.68	17.93	16.71	18.1	19.44
CZ (std)	11.44	12.92	14.44	13.59	15.44	17.02
CZ (unstd)	11.9	13.43	15.02	13.96	15.86	17.48
DE (std)	13.51	14.92	16.24	15.6	17.1	18.5
DE (unstd)	13.47	14.88	16.2	14.72	16.14	17.46
DK (std)	13.03	14.28	15.37	14.9	16.34	17.46
ES (std)	14.15	15.93	17.15	16.48	17.93	19.1
ES (unstd)	14.04	15.8	17.02	15.93	17.34	18.46
FI (std)	13.26	14.69	15.86	15.77	17.31	18.72
FI (unstd)	12.35	13.68	14.77	14.69	16.13	17.44
FR (std)	14.38	16.08	17.26	17.11	18.39	19.7
FR (unstd)	14.32	16.02	17.2	17.32	18.61	19.93
GB (std)	13.51	14.75	15.97	15.28	16.74	18.09
GB (unstd)	13.43	14.66	15.88	15.5	16.98	18.34
GR (std)	13.56	14.72	15.91	14.31	16.41	17.97
GR (unstd)	13.7	14.86	16.07	14.92	17.11	18.74
HU (std)	10.51	11.59	12.91	13.05	14.65	15.98
HU (unstd)	8.78	9.69	10.8	10.81	12.14	13.24
IE (std)	13.48	14.76	16.03	15.51	17.01	18.38
IE (unstd)	13.81	15.13	16.42	16.4	17.98	19.43
IS (std)	14.99	16.22	17.5	15.99	17.46	18.85
IT (std)	14.31	15.5	16.74	16.57	17.98	19.35
IT (unstd)	14.31	15.5	16.74	16.57	17.98	19.35
JP (std)	14.77	16.28	17.37	18	19.75	21.07
KR (std)	12.98	14.31	15.49	15.58	17.11	18.54
LU (std)	13.25	15.04	16.26	15.49	16.9	18.27
LU (unstd)	13.35	15.15	16.38	15.86	17.3	18.7
NL (std)	13.7	15.13	16.49	15.39	16.69	17.88
NL (unstd)	13.7	15.14	16.5	16.28	17.67	18.92
NO (std)	14.02	15.47	16.72	15.79	17.22	18.59
NZ (std)	14.35	15.84	16.99	15.77	17.12	18.41

PT (std)	12.9	14.27	15.41	15.21	16.74	17.94
PT (unstd)	11.34	12.54	13.54	12	13.2	14.15
SE (std)	14.16	15.63	16.89	15.89	17.21	18.36
SE (unstd)	14.66	16.18	17.49	16.46	17.82	19.02
SK (std)	10.85	11.85	13.32	13.29	14.91	16.26
SK (unstd)	9.45	10.32	11.6	10.94	12.28	13.39
US (std)	14.14	15.12	15.87	15.82	16.95	17.98

Appendix Table A2. Standardized and unstandardized proportion of people 60-65 with serious activity limitations.

	Men			Women		
	2005-10	2025-30	2045-50	2005-10	2025-30	2045-50
AT (std)	0.097	0.088	0.081	0.109	0.100	0.091
AT(unstd)	0.141	0.129	0.120	0.164	0.152	0.141
AU (std)	0.092	0.084	0.078	0.103	0.095	0.086
BE (std)	0.099	0.090	0.083	0.109	0.096	0.087
BE(unstd)	0.088	0.080	0.074	0.104	0.091	0.083
CA (std)	0.094	0.086	0.080	0.106	0.097	0.089
CH (std)	0.091	0.082	0.076	0.102	0.093	0.085
CZ (std)	0.110	0.102	0.094	0.122	0.110	0.100
CZ(unstd)	0.088	0.081	0.075	0.108	0.098	0.088
DE (std)	0.099	0.091	0.085	0.109	0.100	0.091
DE(unstd)	0.100	0.093	0.086	0.137	0.126	0.116
DK (std)	0.101	0.095	0.089	0.114	0.105	0.098
ES (std)	0.095	0.086	0.080	0.103	0.094	0.087
ES (unstd)	0.099	0.090	0.083	0.119	0.109	0.102
FI (std)	0.100	0.093	0.087	0.108	0.098	0.089
FI (unstd)	0.137	0.128	0.121	0.142	0.131	0.121
FR (std)	0.094	0.086	0.079	0.100	0.092	0.083
FR(unstd)	0.096	0.087	0.081	0.094	0.087	0.079
GB (std)	0.099	0.092	0.086	0.112	0.102	0.094
GB(unstd)	0.102	0.095	0.089	0.105	0.096	0.088
GR (std)	0.098	0.092	0.086	0.117	0.104	0.094
GR(unstd)	0.093	0.088	0.082	0.096	0.085	0.076
HU (std)	0.115	0.109	0.102	0.126	0.115	0.107
HU(unstd)	0.216	0.208	0.197	0.224	0.210	0.199
IE (std)	0.099	0.092	0.086	0.110	0.100	0.092
IE (unstd)	0.086	0.080	0.074	0.084	0.076	0.068
IS (std)	0.091	0.085	0.078	0.107	0.098	0.089
IT (std)	0.095	0.088	0.082	0.103	0.094	0.086
IT (unstd)	0.095	0.088	0.082	0.103	0.094	0.086
JP (std)	0.092	0.084	0.079	0.094	0.083	0.075

KR (std)	0.102	0.095	0.089	0.109	0.100	0.091
LU (std)	0.100	0.091	0.084	0.110	0.101	0.092
LU(unstd)	0.096	0.087	0.081	0.099	0.090	0.082
NL (std)	0.098	0.090	0.083	0.111	0.102	0.095
NL(unstd)	0.097	0.090	0.083	0.084	0.077	0.071
NO (std)	0.096	0.089	0.082	0.108	0.099	0.090
NZ (std)	0.094	0.087	0.081	0.108	0.100	0.092
PT (std)	0.102	0.095	0.089	0.112	0.102	0.094
PT (unstd)	0.170	0.161	0.153	0.230	0.217	0.206
SE (std)	0.095	0.088	0.081	0.107	0.099	0.092
SE (unstd)	0.078	0.071	0.066	0.091	0.084	0.077
SK (std)	0.113	0.108	0.100	0.124	0.114	0.105
SK(unstd)	0.191	0.183	0.172	0.225	0.211	0.200
US (std)	0.096	0.091	0.087	0.108	0.101	0.094

Appendix Table A3. Proportions of populations 60+ years old with severe activity limitations.

	Men			Women		
	2005-10	2025-30	2045-50	2005-10	2025-30	2045-50
AU (std)	0.148	0.149	0.157	0.187	0.182	0.196
AT (std)	0.151	0.148	0.163	0.197	0.187	0.203
AT (unstd)	0.209	0.205	0.223	0.271	0.260	0.279
BE (std)	0.157	0.152	0.164	0.198	0.189	0.204
BE (unstd)	0.141	0.137	0.148	0.191	0.182	0.197
CA (std)	0.148	0.146	0.157	0.187	0.181	0.199
CH (std)	0.148	0.149	0.164	0.191	0.183	0.200
CZ (std)	0.155	0.160	0.157	0.196	0.199	0.198
CZ (unstd)	0.127	0.130	0.129	0.177	0.180	0.179
DE (std)	0.152	0.152	0.167	0.196	0.191	0.208
DE (unstd)	0.154	0.154	0.169	0.236	0.230	0.249
DK (std)	0.152	0.156	0.167	0.193	0.193	0.208
ES (std)	0.156	0.148	0.157	0.194	0.187	0.196
ES (unstd)	0.162	0.154	0.162	0.217	0.209	0.219
FI (std)	0.150	0.158	0.163	0.191	0.194	0.206
FI (unstd)	0.199	0.208	0.214	0.239	0.243	0.255
FR (std)	0.154	0.153	0.162	0.193	0.190	0.206
FR (unstd)	0.157	0.155	0.165	0.185	0.182	0.197
GB (std)	0.156	0.155	0.160	0.197	0.190	0.200
GB (unstd)	0.160	0.159	0.165	0.188	0.180	0.190
GR (std)	0.158	0.155	0.160	0.196	0.194	0.201
GR (unstd)	0.151	0.148	0.153	0.167	0.165	0.171
HU (std)	0.163	0.163	0.158	0.201	0.203	0.199

HU (unstd)	0.287	0.287	0.281	0.325	0.327	0.323
IE (std)	0.150	0.149	0.151	0.188	0.181	0.185
IE (unstd)	0.133	0.132	0.134	0.150	0.144	0.147
IS (std)	0.149	0.143	0.154	0.189	0.180	0.193
IT (std)	0.154	0.153	0.164	0.194	0.193	0.205
IT (unstd)	0.154	0.153	0.164	0.194	0.193	0.205
JP (std)	0.148	0.162	0.163	0.181	0.201	0.206
KR (std)	0.144	0.145	0.162	0.178	0.177	0.202
LU (std)	0.153	0.146	0.156	0.196	0.180	0.192
LU (unstd)	0.148	0.141	0.151	0.179	0.164	0.176
NL (std)	0.149	0.152	0.167	0.192	0.188	0.208
NL (unstd)	0.148	0.152	0.166	0.152	0.149	0.166
NO (std)	0.152	0.151	0.160	0.197	0.187	0.198
NZ (std)	0.150	0.148	0.159	0.188	0.180	0.199
PT (std)	0.159	0.155	0.161	0.195	0.193	0.202
PT (unstd)	0.250	0.244	0.252	0.347	0.344	0.356
SE (std)	0.153	0.156	0.161	0.196	0.195	0.201
SE (unstd)	0.128	0.131	0.135	0.171	0.170	0.176
SK (std)	0.159	0.157	0.155	0.197	0.193	0.196
SK (unstd)	0.255	0.252	0.250	0.323	0.319	0.322
US (std)	0.152	0.149	0.159	0.192	0.184	0.199

Appendix Table A4. Mean ages of populations 60+ years old.

	Men			Women		
	2005-10	2025-30	2045-50	2005-10	2025-30	2045-50
AT	69.30	69.87	73.82	71.76	71.43	75.61
AU	69.31	70.88	72.74	71.05	71.91	74.51
BE	70.41	70.56	73.34	72.79	72.40	75.67
CA	69.20	70.29	72.32	71.03	71.56	74.48
CH	69.46	70.84	74.57	71.87	71.77	75.64
CZ	67.93	70.55	71.11	70.23	72.99	72.99
DE	69.81	69.95	74.16	71.96	71.89	76.45
DK	68.46	70.59	73.42	70.46	72.37	75.30
ES	70.82	70.09	72.89	72.81	71.93	74.52
FI	68.68	71.52	72.20	71.44	73.50	75.30
FR	70.52	71.55	73.57	73.23	73.28	76.22
GB	69.75	70.39	72.41	71.77	71.80	74.66
GR	70.96	70.49	72.31	71.54	72.02	74.35
HU	68.90	70.27	70.26	71.04	72.79	72.62
IE	68.74	69.71	71.08	70.63	71.08	72.48
IS	69.67	69.96	72.16	71.35	71.25	73.73

IT	70.54	70.54	73.91	72.70	72.88	76.19
JP	69.72	73.37	73.81	71.89	76.20	76.58
KR	68.05	68.83	72.66	69.97	70.41	75.18
LU	69.52	69.23	72.05	72.20	70.42	73.78
NL	68.70	70.51	74.11	71.07	71.86	75.70
NO	68.92	70.64	73.10	71.69	72.09	74.70
NZ	69.34	70.27	72.64	70.85	71.01	74.67
PT	70.25	70.26	72.22	71.84	72.26	74.37
SE	69.20	71.53	73.13	71.56	73.26	74.75
SK	68.40	69.42	69.77	70.57	71.57	72.04
US	69.37	70.32	71.78	71.25	71.57	73.98

Appendix Table A5a. Comparison of three concepts of old age dependency – genuine adult dependency ratios.

	GADR		
	2005-10	2025-30	2045-50
AT (std)	0.10	0.10	0.12
AT (unstd)	0.14	0.16	0.18
AU (std)	0.08	0.09	0.10
BE (std)	0.10	0.10	0.11
BE (unstd)	0.09	0.10	0.10
CA (std)	0.09	0.10	0.11
CH (std)	0.09	0.10	0.11
CZ (std)	0.10	0.11	0.12
CZ (unstd)	0.08	0.09	0.10
DE (std)	0.10	0.11	0.13
DE (unstd)	0.12	0.13	0.15
DK (std)	0.10	0.11	0.11
ES (std)	0.09	0.10	0.12
ES (unstd)	0.10	0.11	0.13
FI (std)	0.10	0.11	0.11
FI (unstd)	0.13	0.15	0.15
FR (std)	0.09	0.10	0.11
FR (unstd)	0.09	0.10	0.11
GB (std)	0.10	0.10	0.10
GB (unstd)	0.10	0.10	0.10
GR (std)	0.10	0.11	0.12
GR (unstd)	0.09	0.09	0.11
HU (std)	0.11	0.11	0.12
HU(unstd)	0.21	0.22	0.23

IE (std)	0.08	0.09	0.10
IE (unstd)	0.07	0.07	0.08
IS (std)	0.08	0.09	0.10
IT (std)	0.10	0.11	0.12
IT (unstd)	0.10	0.11	0.12
JP (std)	0.10	0.12	0.13
KR (std)	0.08	0.10	0.13
LU (std)	0.09	0.09	0.10
LU (unstd)	0.08	0.08	0.09
NL (std)	0.09	0.11	0.11
NL (unstd)	0.08	0.09	0.10
NO (std)	0.09	0.10	0.10
NZ (std)	0.09	0.09	0.10
PT (std)	0.10	0.11	0.12
PT (unstd)	0.20	0.22	0.25
SE (std)	0.10	0.10	0.11
SE (unstd)	0.08	0.09	0.09
SK (std)	0.10	0.11	0.12
SK (unstd)	0.18	0.20	0.23
US (std)	0.09	0.10	0.10

Appendix Table A5b. Comparison of three concepts of old age dependency – old age dependency ratios and prospective old age dependency ratios.

	OADR			POADR		
	2005-10	2025-30	2045-50	2005-10	2025-30	2045-50
AT	0.28	0.41	0.55	0.23	0.27	0.36
AU	0.22	0.36	0.43	0.19	0.26	0.29
BE	0.29	0.43	0.51	0.26	0.29	0.33
CA	0.22	0.39	0.47	0.19	0.28	0.31
CH	0.27	0.41	0.48	0.23	0.28	0.33
CZ	0.23	0.36	0.52	0.20	0.26	0.29
DE	0.33	0.48	0.63	0.27	0.32	0.41
DK	0.27	0.40	0.45	0.23	0.29	0.31
ES	0.27	0.37	0.64	0.24	0.26	0.40
FI	0.27	0.46	0.48	0.23	0.33	0.30
FR	0.28	0.44	0.51	0.24	0.31	0.35
GB	0.27	0.36	0.41	0.24	0.26	0.27
GR	0.29	0.39	0.60	0.27	0.29	0.37
HU	0.26	0.34	0.48	0.22	0.25	0.26
IE	0.18	0.27	0.44	0.14	0.17	0.22
IS	0.19	0.32	0.48	0.16	0.22	0.30
IT	0.33	0.45	0.68	0.29	0.32	0.45

JP	0.35	0.55	0.78	0.30	0.42	0.51
KR	0.16	0.35	0.65	0.12	0.20	0.37
LU	0.23	0.29	0.37	0.20	0.20	0.24
NL	0.24	0.41	0.48	0.21	0.30	0.34
NO	0.25	0.35	0.44	0.21	0.25	0.29
NZ	0.21	0.35	0.42	0.18	0.24	0.28
PT	0.28	0.40	0.63	0.25	0.29	0.39
SE	0.30	0.40	0.44	0.27	0.31	0.31
SK	0.18	0.32	0.50	0.16	0.22	0.27
US	0.21	0.34	0.38	0.19	0.27	0.29

Appendix B. Changes in Disability Rates Associated with Changes in Life Expectancies

The specification in Eq. (1) makes the ratio of life expectancies without SALs to life expectancy a function of age, and dummy variables for sex and country. In this Appendix, we demonstrate that, holding those three independent variables constant, increases in life expectancy generally imply decreases in the rates of SALs.

Using standard life table notation, we know that:

$$e_{a,s,c} = \frac{\sum_{x=a}^{\omega} L_{x,s,c}}{l_a}, \tag{A1}$$

where $e_{a,s,c}$ is the life expectancy of someone of age a, and sex s who lives in country c, $L_{x,s,c}$ is the number of person-years lived between age x and x+1, l_a is the number of people who have survived to exact age a, and ω is the highest possible age.

Life expectancy without SALs is:

$$e^{no}_{a,s,,c} = \frac{\sum_{x=a}^{\omega} \pi_{x,s,c} L_{x,s,c}}{l_a}, \tag{A2}$$

where $\pi_{x,s,c}$ is the proportion of person-years lived without SALs.

Therefore, the ratio of life expectancy without SALs to life expectancy can be written as a weighted average of the proportions of person-years lived without SALs, where the weights are the fraction of remaining life-years lived at each age.

$$r_{a,s,c} = \sum_{x=a}^{\omega} \rho_{x,s,c} \pi_{x,s,c}, \tag{A3}$$

where $r_{a,s,c}$ is the ratio of the life expectancies, and

$$\rho_{x,s,c} = \frac{L_{x,s,c}}{\sum_{x=a}^{\omega} L_{x,s,c}}.$$

Realistic life expectancy increases are generally ones in which proportions of life-years lived at older ages increase causing an associated decrease in the proportions of life-years lived at younger ages because the $\rho_{x,s,c}$ must sum to unity.

We formalize these realistic life expectancy increases as follows:

$$\sum_{x=a}^{b} \rho^{+}_{x,s,c} \leq \sum_{x=a}^{b} \rho_{x,s,c}, \tag{A4}$$

where $\rho^{+}_{x,s,c}$ are the values of ρ associated with the higher life expectancy, $a \leq b \leq \omega$, and where the strict inequality in Eq. (A4) holds for at least one value of x. This is a discrete version of the concept of stochastic dominance of degree 1. Eq. (A4) says that the distribution of person-years lived in the case of the higher life expectancy dominates the analogous distribution in the case of the lower life expectancy according to the definition of stochastic dominance of degree 1.

The $\pi_{a,s,c}$ are monotonically decreasing with age. It follows from this monotonic relationship and Eq. (A4) that if the $\pi_{a,s,c}$ are constant, then the ratio of the life expectancies ($r_{a,s,c}$) must decrease as life expectancy increases.

Our specification maintains that the ratio of life expectancies is constant, once we control for age, sex, and country. In order to make this happen, increases in life expectancy must be associated with increases in the $\pi_{a,s,c}$, or in other words, with decreases in prevalence of SALs.