Despite Aging, Proportions of Older Populations with Disabilities in Developed Countries Unlikely to Increase Much

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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 disabilities 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 the 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 disabilities into account. For developed countries, we provide forecasts of (1) age-specific proportions of remaining lifetimes at age 65 spent without severe disabilities, (2) the proportions of populations 60+ years old with severe disabilities, and (3) a new dependency ratio called the Adult Disability Dependency Ratio that takes severe disabilities into account. For simplicity, whenever we refer to disabilities in this paper, we mean severe disabilities.

We show that, on average, life expectancies without disabilities at age 65 in high income OECD countries are likely to increase by around 2.7 years between 2005-10 and 2045-50. Proportions of 60+ populations with disabilities are likely to be only marginally higher in 2045-50 than in 2005-10. We also show that the speed of increase of the Adult Disability Dependency Ratio is around one-fifth as fast as the conventional old age dependency ratio.

Introduction

The United Nations 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 2000-05. The UN predicts that by 2045-50 it would increase to 26.91 years[1]. 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[2,3] 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 disabilities. Forecasts of health care costs can be made more accurate by taking the predicted fraction of the population with disabilities into account[4].

While discussions of explicitly taking increases in life expectancy into account in the design of public policies has recently grown more common[5,6,7], consideration of the likely future of rates of disabilities is still the exception[8,9,10]. There are two important issues that have previously limited the possibility of making consistent multi-country forecasts involving disabilities. The first is the lack of appropriate data. While there are numerous studies of disabilitie rates[11], 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 disabilities[12] 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 disability rates. Age- and sex-specific disability 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 disability 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 disability rates 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 disabilities into account and apply it to the case of high income OECD countries.

Data

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

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 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. Previous studies also suggest that the trends in severe and mild disability rates are different.

Publicly available data on activity limitations from SILC come in the form of age-specific life expectancies without disabilities and unconditional life expectancies. Disability-free life expectancies are produced using the Sullivan method[13], in which age-specific disability 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 disabilities[14]. With the EU-SILC, there are now enough comparable data to find regularities that can be used in forecasting[15].

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[16] 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[17]. 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[18]. The methodology that we present here is not dependent on the UN life tables and can easily be used with alternative mortality forecasts (see Appendix 2 for a sensitivity analysis).

RESULTS

Tables 1, 2, and 3 show both standardized and unstandardized figures. The standardized life expectancies are computed assuming that the age- and sex-specific ratios of life expectancies disabilities to overall life expectancies are those estimated for Italy (see METHODS below). The Italian ratios are the closest to the mean ratios among all the countries studied. Roughly speaking, standardized magnitudes are based on the average European relationship between survival rates and disability rates. Standardized quantities are useful for three reasons. First, the standardized magnitudes allow us to expand the number of countries we study beyond the high income OECD countries in the EU-SILC dataset. This is especially helpful because changes in standardized figures are almost identical to changes in unstandardized ones. Therefore, even if the levels of the standardized quantities are not accurate for the countries outside of the EU-SILC sample, the changes in the rates over time are still quite informative. Second, deviations between the standardized and unstandardized magnitudes raise important questions about the reasons for those differences. Answering these questions can aid in the design of better questionnaires. Third, the standardized quantities 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[19,20].

A possible example of such an anomaly is the difference in the prevalence of disabilities 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 disabilities in the two places in 2005-2010 would be extremely different. Nevertheless, they are. The unstandardized disability rates for people in their sixties is around twice as high in Slovakia as in the Czech Republic (see Appendix 1, Table S2), but their standardized rates are only slightly different from one another. The suspicion that the Czech disability rates in the EU-SILC survey is reinforced by the observation that in 2006 those rates are considerably lower than those recorded in the SHARE survey.

Table 1 shows both the standardized and the unstandardized predicted disability-free life expectancies for men and women at ages 65 in selected high income OECD countries for the years 2005-2010, 2025-30, and 2045-50. 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 disabilities rises from 13.6 years in 2005-2010 to 16.2 years in 2045-50 for men and from 15.6 in 2005-10 to 18.4 for women. The forecasts show no convergence between the countries with the highest and lowest (standardized) disability-free life expectancies. Switzerland has the highest male disability-free life expectancy in both 2005-2010 and 2045-50. Hungary has the lowest level in both periods. The gain in the Swiss disability-free life expectancy is about 3.0 years and the comparable gain for Hungary is 2.4 years. Japan has the highest disability-free life expectancy for women in both periods. Hungary again has the lowest. Japanese female disability-free life expectancy is forecast to grow by 3.1 years. In Hungary that life expectancy is forecast to increase by 2.9 years.

In Tables 2 and 3, we add a disability dimension to the discussion of the extent and speed of aging. Table 2 shows the evolution of the proportions of populations 60+ years old with disabilities. These proportions change because of variations in the age structure of the 60+ population and with changes in age- and sex-specific disability rates. Populations over the age of 60 are themselves growing older (see Appendix 1, Table S4) and that would increase the proportion of the overall population with disabilities. But, over time age-specific disability rates are forecasted to be falling, so the proportion can move in either direction. In Table 2, we see that between 2005-10 and 2025-30, the proportions frequently fall slightly and then rise to 2045-50. On average, the forecasted proportions of the 60+ populations with disabilities are only marginally higher in 2045-50 than in 2005-10.

Table 2 shows a wide variety of time patterns for the percentages of the 60+ populations with disabilities. For Japanese men and women the proportion rises continuously to 2045-50. The increase from 2005-10 and 2025-30 there is due to the substantial increase in the mean age of the 60+ population (Appendix 1, Table S4). In the case of Irish men and women, we find the general U-shaped time path (Appendix 1, Table S4), but with the levels in 2045-50 slightly lower than they were in 2005-10.

Our forecasted disability rates allow us to show the dynamics of a new measure of disability that we call the Adult Disability Dependency Ratio (ADDR). The ADDR is the ratio of the number of adults 20+ years old with disabilities to the number of adults 20+ without them. We show these rates in Table 3. The ADDR is the ratio of those who need care to those who are capable of giving it.

For comparison, we also show two other old age dependency ratios, the conventional old age dependency ratio and the prospective old age dependency ratio[21,22]. 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 disabilities into account. Our new measure, the ADDR, counts adults as being dependent when they have disabilities, regardless of their age. These three ratios reflect different aspects of aging and which would be best to use depends on the context.

Table 3 shows conventional OADRs increase much faster than the other two measures. Prospective OADRs increase less rapidly, and the ADDR 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 2045-50. The prospective OADR increases from 0.27 to 0.31 over that period. But the ADDR 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 ADDR.

DISCUSSION

Life expectancies without disabilities, such as those in Table 1, 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 2046. But in the same interval, disability-free life expectancy is only expected to increase by around 2.4 years. So by 2046, using the UN forecasts, men in the UK would have slightly fewer years of pension receipt during which they are disability-free. There is currently pressure to increase the pension age more rapidly. If this were done, men in the UK would have even fewer years of disability-free pension receipt.

The proportion of the populations 60+ years old with disabilities in many countries is likely to be similar to what it is today. These forecasts can provide policy-makers with additional insights concerning likely increases in future health care costs[23].

The conventional old age dependency ratio is one of the most commonly cited measures in discussions of aging. But this measure can be very misleading, especially because the age at the onset of old age dependency, 65, is kept fixed over several decades. The age at the receipt of a full public pension in many countries is now changing and retirement from the labor market occurs over a wide span of ages. 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 disabilities . When we compute dependency rates based on disabilities, increases to mid-century are only around 20 percent as large as those based on a fixed chronological age. This provides us with an important supplementary view of the speed of aging.

The sensitivity of our results to the assumption that the speed of life expectancy increases will be slowing down is performed in Appendix 2 for the case of the UK. If the pace of life expectancy increase in the UK were to be the same as the average rate for low mortality rate countries over the last two decades, then we would predict that the life expectancy disabilities for UK males would increase by 4.15 years between 2005-2010 and 2045-50.

Importantly, the sensitivity analysis shows that the ADDR is relatively robust to uncertainties in forecasted life expectancy changes. This occurs because changes in the speed of life expectancy increase have two offsetting effects on the ADDR. When life expectancy increase is faster, there are more people at higher ages where disability rates are higher. The counterbalancing effect is the reduction in the age-specific disability rates with increasing life expectancy. The insensitivity of the ADDR to uncertainties about the future of mortality rates makes it especially useful in forecasting.

One disadvantage of the EU-SILC data is that they do not cover the institutionalized populations. Since the proportions of the elderly populations in institutions differ widely across EU countries and the institutionalized elderly are very likely to be disabled, we provide an analysis of the sensitivity of our results to the inclusion of the institutionalized population in Appendix 3. We show there that are results would only be marginally affected if included data on the institutionalized population.

METHODS

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

where e is life expectancy, e^{no} is disability-free life expectancy, 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 disabilities. 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 5-year intervals from age 30 to 85+, 17 high income OECD countries, and usually for three years, 2005-2007[24]. 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 Appendix 1, Table S4. The model fits the data quite well. The implication of this specification is that disability rates generally would decrease as life expectancies increase (see Appendix 4). This is generally consistent with observations on developed countries with at least a comparable decade long data series[25,26,27].

We use UN forecasts of life expectancies by age, sex, and country for 5-year periods from 2005-2010 to 2045-50 and equation (1) to forecast disability-free life expectancies 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.

Given the disability-free life expectancies in equation (2) and UN life tables, we can compute the prevalence of disability rates in each 5-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

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

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 without disabilities 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 people at age 85+ without disabilties can now be expressed as:

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

Working our way up the age range, we have:

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

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 disabilities.

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

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. We have reported our findings in terms of changes. For the EU-SILC countries, we have shown that those changes are robust to whether we use standardized or unstandardized magnitudes. For non-EU-SILC countries, only standardized values are available. For them, the changes that we computed based on those standardized rates are useful for policy analysis because they are likely to be closely related to the changes in the true rates.

For high income OECD countries we showed that, over the next four decades, life expectancies at 65 without disabilities 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 disabilities are unlikely to change very much, and that increases in the ADDR 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[28].

Our methodology provides a way of integrating mortality rate and disability rate forecasts. The importance of their interaction has long been noted[29], but to our knowledge this is the first attempt to link them in a formal way. The particular forecasts in this paper 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. This might not happen. If the pace of life expectancy increase does not slow, decreases in rates of disabilities will be faster than the forecasts in this paper.

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Table Legends
Table 1: Standardized and Unstandardized Life Expectancies at 65 Without Disabilities Selected High Income OECD Countries, 2005-2010, 2025-30, and 2045-50.
See Table S1 in Appendix 1 for all high income OECD countries.

Table 2: Standardized and Unstandardized Proportions of Populations 60+ With Disabilities, Selected High Income OECD Countries, 2005-2010, 2025-30, and 2045-50. See Table S2 in Appendix for all high income OECD countries.

Table 3: Standardized and Unstandardized Adult Disability Dependency Ratios (ADDR), Old Age Dependency Ratios (OADR), Prospective Old Age Dependency Ratios (POADR), Selected High Income OECD Countries, 2005-2010, 2025-30, and 2045-50. See Tables S3 and S4 in Appendix for all high income OECD countries.

Table 4: Regression Results

	Men			Women		
	2005-10	2025-30	2045-50	2005-10	2025-30	2045-50
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
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
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
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
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

Table 1: Standardized and Unstandardized Life Expectancies at 65 Without Disabilities, Selected High Income OECD Countries, 2005-2010, 2025-30, and 2045-50.
See Table S1 in Appendix 1 for all high income OECD countries.

	Men			Women		
	2005-10	2025-30	2045-50	2005-10	2025-30	2045-50
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
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
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
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
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

Table 2: Standardized and Unstandardized Proportions of Populations 60+ With Disabilities, Selected High Income OECD Countries, 2005-2010, 2025-30, and 2045-50. See Table S2 in Appendix 1 for all high income OECD countries.

	ADDR			OADR			POADR		
	2005-10	2025-30	2045-50	2005-10	2025-30	2045-50	2005-10	2025-30	2045-50
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						
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						
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						
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
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

Table 3: Standardized and Unstandardized Adult Disability Dependency Ratios (ADDR), Old Age Dependency Ratios (OADR), Prospective Old Age Dependency Ratios (POADR), Selected High Income OECD Countries, 2005-2010, 2025-30, and 2045-50. See Tables S3 and S4 in Appendix 1 for all high income OECD countries.

	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

Table 4: Regression Results

Appendix 1: Data

Table S1: Standardized and Unstandardized Life Expectancies at Age 65 Without Disabilities

	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

Table S2: Proportions of Populations 60+ Years Old With Disabilities

	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

Table S3: Comparison of Three Concepts of Old Age Dependency –Adult Disability Dependency Ratios

	ADDR		
	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

Table S4: 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 2: Sensitivity to Changes in the Rate of Mortality Improvement

The forecasts presented in this paper are based on UN population and mortality rate forecasts. The UN mortality rate forecasts assume a slowing down in the speed of life expectancy improvement that is not evident in the data (1). In the European Demographic Data Sheet (2) we produced forecasts of European populations to 2030 based, in part, on the assumption that the pace of life expectancy increases would not diminish. More on the methodology using in the European Demographic Data Sheet can be found in (3). For this Appendix, we extended the forecasts for the United Kingdom to 2050. The forecasts in the European Demographic Data Sheet differ slightly from those of the UN, but for the measures presented in the Table A3, the only difference that matters is the difference in the speed of life expectancy increases and, as a consequence, the number of people in older ages.

Table S5 shows changes in measures using our forecasts of disability rates for the United Kingdom using forecasts made by the UN and in the European Demographic Data Sheet (extended to 2050). For men in the UK, the forecasted increase in disability-free life expectancy at age 65 between 2005-2010 and 2045-50 would be 2.46 years using the UN life tables and 4.15 years using the assumption that life expectancy increases would not slow down. The analogous figures for women are 2.80 years and 4.43 years respectively.

The median age of the female population of the UK 60+ years old would increase by 2.89 years from 2005-2010 to 2045-50 and by 3.56 years using the European Demographic Data Sheet assumptions. Nevertheless, the proportion of the 60+ year old population with disabilities is not forecast to increase in either case. Increases in the median age due to the increased speed to life expectancy change are compensated by the lower rates of disabilities associated with those life expectancy increases.

A similar phenomenon can be seen when we look at dependency ratios. Increases in the speed of life expectancy improvement, naturally, cause the conventional old age dependency ratio to rise more rapidly. This is not the case, however, when we look at our new Adult Disability Dependency Ratio (ADDR). The ADDR is much more robust to differences in future mortality rate forecasts. Increases in the number of older people due to lower mortality rates are compensated, perfectly in the case of the UK, by changes in age-specific rates of disability.

Not all measures are equally sensitive to the uncertainties inherent in mortality rate forecasts. Some measures, such as disability-free life expectancies at various ages are quite sensitive. But measures, where the effects of life expectancy changes are offsetting, such as in proportions of populations 60+ with disabilities and the Adult Disability Dependency Ratio, are much more robust.

Appendix 2 References

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	UN Mortality Rates		European Demographic Datasheet Rates	
	(2025-2030)-(2005-2010)	(2045-2050)-(2005-2010)	(2025-2030)-(2005-2010)	(2045-2050)-(2005-2010)
MEN				
Disability-Free Life expectancy at age 65	1.24	2.46	1.91	4.15
Proportion 60 to 65 with Disabilities	-0.01	-0.01	-0.01	-0.02
Proportion 60+ with Disabilities	0.01	0	0	-0.01
Median age 60+	0.64	2.66	0.96	3.62
WOMEN				
Disability-Free Life expectancy at age 65	1.46	2.80	2.07	4.43

Proportion 60 to 65 with Disabilities	-0.01	-0.02	-0.01	-0.03
Proportion 60+ with Disabilities	0	0	0	0
Median age 60+	0.04	2.89	0.28	3.56
BOTH SEXES				
Adult Disability Dependency Ratio	0	0.01	0	0.01
Old Age Dependency Ratio	0.08	0.13	0.11	0.23
Prospective Old Age Dependency Ratio	0.02	0.04	0.02	0.06

Table S5: Changes in Magnitudes of Disability Measures Using Different Assumptions About the Time Path of Life Expectancy Changes, United Kingdom.
Source: European Demographic Datasheet rates are from the worksheets used to in producing the Datasheet (Vienna Institute of Demography (2008)).
Note: Measures based on forecasted disability rates. All use standardized figures.

Appendix 3: Sensitivity to the Omission of the Institutionalized Population

The EU-SILC survey does not cover people living in institutions such as nursing homes. Because people living in nursing homes are typically disabled according to our definition, their omission results in a downward bias in ADDR, one that potentially grows over time as populations age. In order to test the sensitivity of our results to the presence of this bias, we collected data on proportions of elderly populations in nursing homes by sex and by 5-year age groups from 60–64 to 80+. Eurostat provides these data for 13 of the 17 high-income OECD countries that we use in our statistical analysis for 2001[29].

To test for the importance of the exclusion of the elderly in nursing homes, we assumed that 100 percent of the elderly in nursing homes were disabled, kept the sex- and age-specific proportions of populations above the age of 60 constant, and adjusted our forecasted sex- and age-specific disability rates accordingly. These adjusted sex- and age-specific disability rates were then used to recalculate our ADDRs. The results are shown in Table S6.

There are four important features of Table S6. First, the downward bias in the data for 2008 is very small. For example, the adjusted ADDR for Austrian men was 0.1221 and the unadjusted figure was 0.1216. In all 13 countries in our table and for both sexes, the differences between the adjusted and unadjusted figures in 2008 are relatively small. Second, although the downward bias does grow over time, it is still relatively small in 2048. For example, the adjusted ADDR for Austrian men is 0.1524 and the unadjusted figure is 0.1481. Although the speed of change of the adjusted ADDR is very slightly higher for the adjusted ADDR compared to the unadjusted ADDR, both speeds are different from the speed at which the OADR changes. The final point is the most important. In this paper, we argue that we need new measures of aging that are not solely based on chronological age. The speed of change of the unadjusted ADDR is much smaller than the speed of change of the OADR. Because the differences between the adjusted and adjusted ADDRs are so small, this result statement is also true for the adjusted ADDRs. In other words, although the EU-SILC data do not include people in nursing homes, our main conclusion about the importance of adjusting aging measures for changes in disability rates still stands.

Table S6. Adult Disability Dependency Rates (ADDRs) Adjusted for the Inclusion of the Nursing Home Population, Unadjusted, and Old Age Dependency Rates. (**A**)For 13 EU Countries, 2008 and 2048, shows ADDRs for countries for which we had nursing home data from (19). (**B**) Shows OADRs for the same countries. There were computed as in Table S1.Source: Same as Table S1 with data on nursing homes from the Eurostat database (reference below).

(**A**)

	ADDR,men				ADDR,women			
	Unadjusted		Adjusted		Unadjusted		Adjusted	
Country	2008	2048	2008	2048	2008	2048	2008	2048
Austria	0.121	0.148	0.122	0.152	0.168	0.203	0.173	0.213
Belgium	0.075	0.086	0.078	0.092	0.107	0.122	0.115	0.141
Finland	0.120	0.134	0.121	0.136	0.149	0.170	0.151	0.177
France	0.084	0.096	0.087	0.103	0.100	0.122	0.106	0.139
Greece	0.080	0.098	0.081	0.099	0.092	0.113	0.093	0.116
Ireland	0.063	0.076	0.064	0.080	0.069	0.085	0.072	0.094
Italy	0.085	0.106	0.086	0.108	0.113	0.142	0.115	0.149
Luxembourg	0.075	0.081	0.076	0.084	0.091	0.097	0.097	0.108

Netherlands	0.080	0.096	0.081	0.102	0.080	0.098	0.085	0.114
Portugal	0.152	0.184	0.154	0.190	0.245	0.307	0.249	0.319
Slovakia	0.152	0.185	0.154	0.188	0.211	0.266	0.214	0.272
Spain	0.083	0.105	0.084	0.107	0.119	0.152	0.121	0.157
UnitedKingdom	0.087	0.092	0.088	0.093	0.104	0.112	0.107	0.117

(**B**)

	OADR,men		OADR,women	
Country	2008	2048	2008	2048
Austria	0.225	0.493	0.325	0.613
Belgium	0.239	0.444	0.337	0.571
Finland	0.221	0.412	0.327	0.554
France	0.234	0.440	0.328	0.593
Greece	0.256	0.539	0.326	0.673
Ireland	0.158	0.391	0.202	0.481
Italy	0.274	0.588	0.385	0.770
Luxembourg	0.188	0.329	0.267	0.407
Netherlands	0.206	0.430	0.275	0.540
Portugal	0.238	0.541	0.327	0.720
Slovakia	0.137	0.412	0.229	0.594
Spain	0.225	0.581	0.311	0.703

Additional reference Appendix 3.

Eurostat database, National level census 2001 round, http://epp.eurostat.ec.europa.eu/portal/page/portal/population/data/database downloaded on July 13, 2010

Appendix 4: Changes in Disability Rates Associated with Changes in Life Expectancies

The specification in equation (1) makes the ratio of disability-free life expectancies to unconditional life expectancies 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 implies decreases in the rates of disabilities.

Using standard life table notation, we know that:

$$e_{a,s,c} = \frac{\sum_{x=a}^{\omega} L_{x,s,c}}{l_a}, \qquad \text{(A1)}$$

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.

Disability-free life expectancy is:

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

where $\pi_{x,s,c}$ is the proportion of people without disabilities.

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

$$r_{a,s,c} = \sum_{x=a}^{\omega} \rho_{x,s,c} \pi_{x,s,c}, \qquad \text{(A3)}$$

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:

$$\sum_{x=a}^{b} \rho^{+}_{x,s,c} \leq \sum_{x=a}^{b} \rho_{x,s,c}, \qquad \text{(A4)}$$

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 equation (A4) holds for at least one value of x. This is a discrete version of the concept of stochastic dominance of degree 1. Equation (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 equation (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 diabilities.