DISABILITY TRENDS IN SELECTED EUROPEAN COUNTRIES: AN AGE-PERIOD-COHORT ANALYSIS

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Abstract. Disability is an important public health issue. Understanding the evolution of disability with age is critical for policy makers and researchers to develop effective interventions and allocate resources efficiently. The aim of this study is to describe disability trends in European countries, focusing on age, period and cohort effects.
We used data from the Survey of Health, Aging and Retirement in Europe (SHARE). The data were pooled from waves 1 to 9 (excluding wave 3) and we considered only Austria, Belgium, Denmark, France, Germany, Italy, Spain, Sweden and Switzerland, resulting in a sample of 72188 respondents and 234946 rows. The response variables were the global index of activity limitation (GALI), the number of limitations in instrumental (IADL) and non-instrumental activities of daily living (ADL). All three variables were dichotomized. A logistic age-period-cohort interaction model was used to estimate the prevalence for each of the three responses. Cohort effects were estimated as the interaction between age and period. The model was estimated using generalized estimating equation with an unstructured working correlation matrix. Gender and individual country-specific wealth quintile were included as covariates. We found that disability prevalence was lower in men than in women and exhibited a non-linear relationship with age. Additionally, prevalence increased over time, peaking in wave 7 (pre-Covid-19) for GALI only, and decreased with higher wealth quintiles. Country-specific differences were also observed. The cohort effect mitigated the impact of age, except in older cohorts for GALI and IADL.

1. Introduction

Disability poses a significant health and economic burden for the individual, the family of the disabled person, as well as for society and healthcare system (Mitra et al., 2017). In addition, disability affects various aspects of life and is associated with negative health consequences, both physical and psychological (Yang et al. 2005), including death (Landi et al. 2010). Given this profound impact, it is crucial to analyse trends in disability to develop public health and policy strategies, especially in European countries where the population is ageing (Eurostat, 2020).

In the literature, several authors have attempted to estimate the trend of disability in relation to age. Ahrenfeldt et al. (2018), for example, used data from the Survey of Health, Ageing and Retirement in Europe (SHARE) to estimate the cognitive and physical functioning of Europeans over the age of 50. It was found that cognitive function has improved across Europe and that there were significant regional differences in physical function. Verropoulou and Tsimbos (2017), also using SHARE, attempted to estimate differences in disability across European countries using 4 waves and 4 different indicators, stratified by gender and two age groups. The results were indicator-dependent but showed a large regional variability. Similarly, Jehn and Zajacova (2019) assessed disability trends using data from the Canadian Community Health Survey (CCHS) collected between 2001 and 2014. Respondents were categorised into two age groups (65 was the cut-off) and the prevalence of disability was examined over time as a function of age and gender. They also reported a reduction in disability in older people respect to older cohort, as previously found by Ahrenfeldt et al. (2018). In a related study using the U.S. National Health Interview Survey (NHIS), Martin and Schoeni (2014) found an overall decline in all but physical disabilities in the over-65 age group.

While interesting, these studies do not offer a complete overview of the phenomenon. Indeed, age is often grouped into broad categories, and it is impossible to distinguish between period effects and cohort effects. There are three papers in the literature that aim to fill this gap by using longitudinal data. The first is by Lin et al. (2012), who use NHIS from 1982 to 2009 to show how disability decreases in younger cohorts and in younger time periods and increases with age as expected. Another notable one is that of Yu et al. (2016), which used data collected in Hong Kong among community-dwelling older adults. In this case, although an increase in the prevalence of disability with age and a gender difference were found, there was no cohort effect. To compensate for the lack of such surveys in Europe, Beller and Epping (2021) estimated an age-period-cohort model using the European Social Survey (ESS) from 2002 to 2016. The main finding of the analysis was a strong U-shaped relationship between the cohort and the prevalence of disability. However, period effect was not significant.

The analysis by Beller and Epping (2021) confirmed the evidence for a non-linear relationship between age and disability prevalence in some of the European countries. Not all the countries participate in the ESS (e.g. Italy was excluded), nor is there a perfect match between the countries participating in the ESS and SHARE indeed. Moreover, the cited papers so far dealt with disability using different indicators. The most prevalent seem to be the Global Activity Limitation Indicator (GALI) (Van Oyen et al., 2006, Galenkamp et al., 2020), the Activity of Daily Living (ADL) (Steel et al. 2002, Yu et al. 2016) and the Instrumental Activity of Daily Living disability indicators (IADL) (Lawton and Brody, 1969, Nicholas et al. 2003). The work of Beller and Epping (2021) is based on the GALI, which is a well-validated single-item indicator. Compared to what has been said so far, SHARE has the advantage to include some of the countries excluded from the ESS, covers similar years and contains all three mentioned disability indicators.

Based on these considerations, the aim of this paper is to estimate an age-period-cohort model to understand the evolution of disability in Europe using SHARE data. The hypothesis is that disability increases with age but changes over time and in different cohorts; a period effect is expected to be detected during Covid-19 pandemic.

2. Data

SHARE is a multidisciplinary longitudinal study that measures health, socioeconomic status and social networks in 27 European countries and Israel (Börsch-Supan et al. 2013, Bergmann et al., 2019). The survey began in 2004 with country-specific sampling strategies. Eligible participants were people aged 50 or older at the time of the survey and living in the sampled household, except for persons who were imprisoned, hospitalized or institutionalized. Data is collected every two years. We used data from waves 1 (2003-2004) to 9 (2022) (SHARE-ERIC, 2024). Wave 3 was excluded as it mainly collected retrospective information and did not include the response variables of interest. For this study, we restricted the sample to individuals with less than 95 years. The inclusion of people older than 95 often caused quasi complete separation in statistical modelling. Moreover, we considered only the countries that participated in all waves, namely Austria, Belgium, Switzerland, Germany, Denmark, Spain, France, Italy and Sweden.

Three response variables were included, i.e. GALI, ADL and IADL, and dichotomized as indicated in the Manual of Scales and Multi-Item Indicators (Mehrbrodt et al., 2019). The GALI measures long-standing activity limitations (six months or more) due to health problems affecting usual activities with a single question with modalities "severely limited," "limited but not severely," or "not limited”. It was then reclassified as "not limited" (0) or "limited" (1). The ADL index assesses limitations in basic self-care activities, including dressing, walking, bathing, eating, getting in or out of bed, and toileting, with a score ranging from 0 (no limitations) to 6 (maximum limitations) and was reclassified as "no ADL limitations" (0) or "1+ ADL limitations" (1). Similarly, the IADL index evaluates limitations in more complex activities, such as meal preparation, shopping, transportation, and financial management, with a score ranging from 0 to 7, and reclassified as "no IADL limitations" (0) or "1+ IADL limitations" (1). Age was calculated based on the year of birth of the respondent while period corresponded to the progressive number of the wave. Gender was also included in the analysis along with country specific quintile of wealth, defined according to Miceli et al. (2019), The selected sample comprised 72188 respondents and 234946 rows. The imputations provided by SHARE were used (Bergmann and Börsch-Supan, 2021). Since the imputation for ADL and IADL were not available, further 1024 respondents were excluded from the analysis of only these variables.

3. Statistical analysis

Dataset preparation and graphical presentation was done with R (Team R. C., 2004, R: A language and environment for statistical computing, R Foundation for Statistical Computing). While model estimation was performed with Stata/SE 18.0 for Windows (64-bit x86-64), revision 25 Apr 2023.

We used a model similar to Luo and Hodges (2022), where the cohort effect was represented by the interactions between age and period, but considering age and period as continuous variables.

$$
\begin{aligned}
logit(\pi_{i,j}) = {} & \mu_0 + \sum_{l=1}^{4} \alpha_l \cdot ns_l(Age_{i,j}) + \beta \cdot M_i + \sum_{l=2}^{5} \gamma_l \cdot 1_{Wealth_{i,j}} \\
& + \sum_{l=2}^{9} \delta_l \cdot 1_{Country_{i,j}}(l) + \varepsilon \cdot p_{i,j} + \sum_{l=1}^{4} \zeta_l \cdot ns_l(Age_{i,j}) \\
& \cdot M_i \\
& + \sum_{l=1}^{4} \sum_{m=2}^{9} \eta_{l,m} \cdot ns_l(Age_{i,j}) \cdot 1_{\{Country_{i,j}\}}(m) \\
& + \sum_{l=1}^{4} \theta_{l,j} \cdot ns_i(Age_{i,j}) \cdot p_{i,j} \\
& + \sum_{l=1}^{4} \sum_{m=2}^{9} \iota_{q,i} \cdot ns_i(Age_{i,j}) \cdot M \cdot 1_{\{Country_{i,j}\}}(m) \\
& + \sum_{l=2}^{9} \kappa_s \cdot M_i \cdot 1_{Country_{i,j}}(l)
\end{aligned}
\tag{1}
$$

The logistic model in equation (1) was fitted for each response variable. Greek letters represent the parameters to be estimated, the letter i is the index for the individual and j for the repeated measures (varying from 1 to 9). In the linear predictor, $ns_{(\cdot)}(Age_{i,j}, 4)$ indicates a natural spline transformation of age with 4 degrees of freedom (estimated with the R package splines), $\mathrm{M_i} = 1_{Gender}(\mathrm{Male})$, where $1_X(\mathrm{x})$ is an indicator function, and p_{ij} is the wave index of the j-th observation of the i-th participant. The correlation arising from repeated observations of the same respondent over time was handled using generalised estimating equations and assuming an unstructured working correlation matrix. For further details and a non-technical explanation of the model, please refer to the online appendix available at https://osf.io/m4jw8/?view_only=2ef8d42cdac94b1594315cc5e3ab00a1. Another appendix can be found at the same link to complement what is presented in the next section. In the appendix Table A.1 provides descriptive statistics by wave and country, including the prevalence of GALI, ADL, and IADL, calculated only for eligible respondents. Table A.2 presents the prevalence of GALI, ADL, and IADL across wealth quintiles for each wave. Tables A.3, A.5, and A.7 contain the model coefficients for GALI, ADL, and IADL, respectively. Tables A.4, A.6, and A.8 present the estimated working correlation matrices for GALI, ADL, and IADL. Table A.9 summarizes the descriptive marginal effects of the wealth variable on the prevalence of GALI, ADL, and IADL, providing a clear depiction of the wealth gradient in these measures.

4. Results and discussion

The aim of this analysis was to describe the development of disability prevalence in Europe and to shed light on the relationship between the effects of age, period and cohort using SHARE data.

Observing Figure 1, it is immediately apparent how the prevalence of disability increases with age, as expected and confirming what has been described in previous studies (Ahrenfeld et al. 2018, Verropoulou and Tsimbos, 2017, Jehn and Zajacova, 2019, Martin and Schoeni, 2014, Lin et al, 2012, Yu et al. 2016, Beller and Epping, 2021). However, the trend seems to differ from country to country and depending on the indicator used. The GALI asks about the perception of disability in the last six months, while ADL and IADL refer to specific activities. Furthermore, the questions used to determine ADL and IADL score investigate the inability to perform rather simple tasks and therefore refer to more severe forms of disability. In support of this observation, we have evidence that the prevalence of ADL and IADL increases abruptly after the age of 75 in almost all countries.

Another remarkable aspect is the systematic difference in prevalence between men and women in almost all countries, with women showing more disability than men. The exceptions are France, Denmark and Germany, where the gender differences in prevalence in both GALI and ADL is much less pronounced and even almost non-existent in certain ages.

The period effect is represented in Figure 2, but interpretation should be done carefully due to the interaction between period and age. The prevalence increases with wave's number for all three indicators and has a peak corresponding to wave 7 (pre Covid-19). The ε coefficient, which corresponds to the wave effect, is significantly different from zero and positive only in the model for GALI. This finding is apparently in conflict with what have been reported by Beller and Epping (2021), who did not find a period effect. However, their period of analysis was different and ended in 2016, which should be noted. The positive slope of the line representing period effects could be related to a higher prevalence estimate only in one of the most recent periods. In Wave 7, part of the sample participated only to SHARELIFE interview, determining a different sampling strategy. This would be coherent with Beller and Epping (2021), as it would shift the period effect to years later than those investigated by the two authors.

Figure 1 – *Model based prevalence estimates GALI, ADL and IADL by gender and country, marginalized respect to wealth and wave counter.*

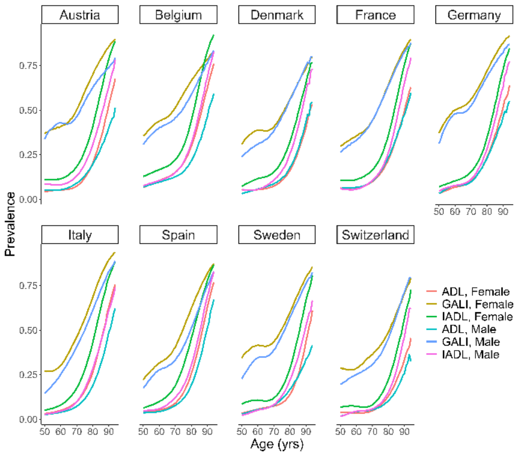


Figure 2 does not indicate a distinct effect of the Covid-19 pandemic, which primarily occurred during wave 8. Instead, it shows a consistent increase across the observed periods, even if not statistically significant for all the response variables.
In the model defined in Equation 1, the cohort effect is governed by four parameters. The hypothesis of absence of a cohort effect, i.e. $\theta_1 = \theta_2 = \theta_3 = \theta_4 = 0$, was tested with a Wald test and rejected for all three models (for GALI we had $\chi^2_4 = 34.62, p < 0.0001$, for ADL $\chi^2_4 = 18.75, p = 0.0009$ and for IADL $\chi^2_4 = 27.85, p < 0.0001$). The evidence therefore supports the inclusion of the cohort effect in the model. Then, as explained in Appendix 2, a separate effect measure in the logit scale (namely $\sum_{l=1}^{4} \theta_{lj} \cdot ns_i\left(Age_{i,j}\right) \cdot p_{i,j}$) can be estimated for each cohort in each period of observation. For instance, if a cohort is included in all periods of the analysis (excluding the third wave), it will have eight effect measures.

These effect measures can be visualized in a two-dimensional graph, sorted either by age or by period or by cohort, as all these variables allow a unique ordering. An upward trend in the effect as the age index increases, for example, would suggest an accumulation of cohort deficits with age (Additional examples of interpretation can be found in Luo and Hodges 2022.) In our attempt to interpret the cohort effect, we have therefore resorted to this type of representation.

Figure 2 – *Model based prevalence estimates of GALI, ADL and IADL across the waves of the survey, marginalized respect to age, wealth, country and gender.*

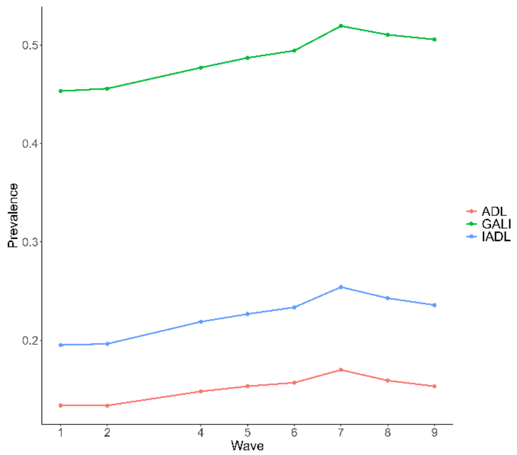
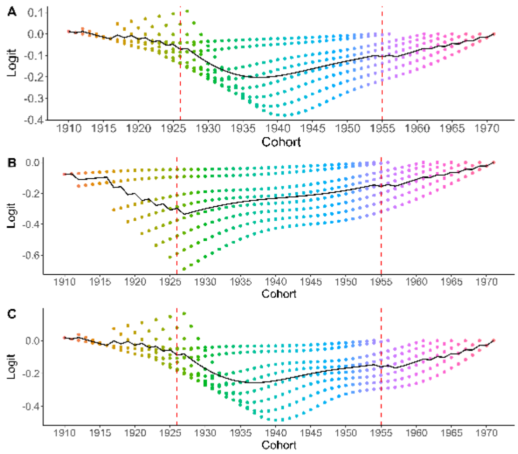


Figure 3 shows the estimates of the cohort effect in the linear predictor scale against the cohort for all three response variables. The continuous black line represents the average size of the effect. The GALI and IADL indicators show an almost identical pattern, with the older cohorts showing a positive effect, the middle and younger cohorts a negative one, albeit quite smaller for the latter. This pattern is very similar to that described by Beller and Epping (2021) for the GALI indicator. However, the cited study includes cohorts up to 2005, and it appears that the increase in reported disabilities is due precisely to these extremely young cohorts, that are not part of our sample. The last cohort examined in our analysis, i.e. those born in 1970, coincides with the lowest estimate of disability in the reference study. However, the size of the effect is hard to compare because our model does not force the intercept and the linear component of the cohort effect to be null (Luo and Hodges, 2020).

The cohort effect found in this study respect to the GALI allows for several interpretations. Firstly, it is possible that older and younger subjects tend to rate their perception of disability higher because the former have potentially severe forms of disability, while the latter have only experienced milder forms. Hence, they may have a different anchor than the middle age groups, who still have sufficient life experience but at the same time have not yet been affected by severe forms of disability (Furnham and Boo, 2011). A second possible interpretation lies in the "failure hypothesis" (Gruenberg, 1977). Essentially, it is possible that older cohorts experienced a stronger selection because most of the people who would have suffered from a disability have died instead. This is not the case in the middle cohorts due to the impact of medical advances. Two other possible competing explanations could be that the selected older people live independently and therefore prove to be a population with a lower level of disability than those living in residential care. In addition, the observation period is quite short, so that some cohorts can only be observed in certain age groups, impacting the prediction process.

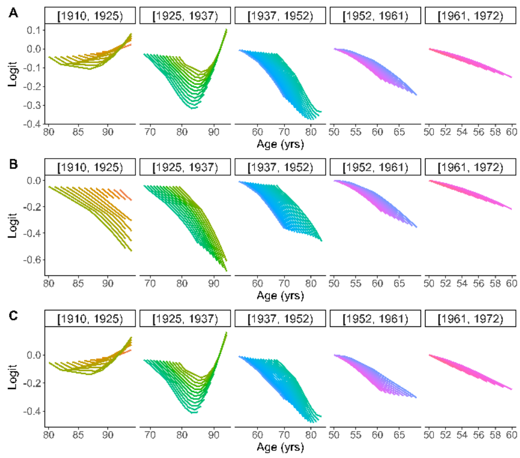
Figure 3 – *Model-based estimates of cohort effects ($\sum_{l=1}^{4} \boldsymbol{\theta_l} \cdot \boldsymbol{ns_i}(\boldsymbol{Age_{i,j}}) \cdot \boldsymbol{p_{i,j}}$) on GALI (Panel A), ADL (Panel B) and IADL (Panel C), on the linear predictor scale. All the cohort borned between 1926 and 1955 (dashed vertical red lines) were included in all the 8 waves of SHARES considered in the analysis. The black line indicates the average cohort effect.*



The ADL indicator, on the other hand, shows a very different pattern: it appears that the older cohorts show a more negative effect while the effect decreases in the younger ones. The older cohorts are the only ones observed at older ages, and the selection of non-institutionalised older people could be a selection bias towards the more resilient individuals, and this could be relevant for ADL where the considered questions are more related to physical limitations.

Figure 4 shows the cohort effect in relation to age. For ease of reading, four cohort groups with similar trends were formed. Note also that the scale of the values on the x-axis is not the same, as no cohorts were observed for any of the age groups considered. As with the previous graphs, GALI and IADL appear to be quite similar. For the older cohorts, it appears that the cohort effect assumes a parabolic relationship with respect to time and therefore there is a reduction in the logit only in the middle age groups where this cohort was observed. For younger cohorts, the effect is decreasing and resembles a straight line. The same is true for ADL, but for all cohorts. The cohort effect is basically higher at older ages and should reduce the logit due to the negative sign. To a certain extent, the cohort effect mitigates the effect of age.

Figure 4 – *Model-based estimates of cohort effects ($\sum_{l=1}^{4} \boldsymbol{\theta_l} \cdot \boldsymbol{ns_i}(\boldsymbol{Age_{i,j}}) \cdot \boldsymbol{p_{i,j}}$) on GALI (Panel A), ADL (Panel B) and IADL (Panel C), on the linear predictor scale. Cohorts were separated according to the type of pattern observed.*



Finally, Table A.9 clearly shows how belonging to higher wealth quintiles is associated with a lower prevalence of disability for all indicators, confirming previous results (Makaroun et al., 2017). This can be explained considering that access to healthcare is not free in all included countries and awareness on how to access the national healthcare systems may be low in lower wealth. Additionally, a dose-response relationship between wealth and depressive symptoms in people with disabilities (Torres et al., 2016) may contribute to a higher GALI among lower wealth individuals.

5. Conclusion

This study provides a comprehensive analysis of disability prevalence across Europe, leveraging SHARE data to examine the interplay of age, period, and cohort effects. Disability prevalence increases with age, but the patterns vary by country and the indicator used, reflecting differences in how disability is perceived and measured. Gender differences are evident, with women generally reporting higher disability rates than men, although exceptions exist. The observed period effects suggest an overall increase in disability prevalence, particularly in specific waves, but no clear impact of the COVID-19 pandemic was detected. Cohort effects reveal nuanced patterns, with older cohorts potentially benefiting from selective survival and younger cohorts displaying distinct perceptions of disability. Finally, wealth emerges as a significant factor, consistently associated with lower disability prevalence across all indicators, underscoring the influence of socioeconomic factors. The proposed model has the advantage of adopting a parametric form for the cohort effect, so it can be used to predict future disability trends by including all three components (even if they are out-of-range extrapolations). Therefore, it would allow the prediction of perceived disability trends in Europe taking into account changes in the demographic pyramid of the population.

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