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MPIDR Working Paper WP 2023-030 l July 2023
https://doi.org/10.4054/MPIDR-WP-2023-030

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This working paper has been approved for release by: Christian Dudel (dudel@demogr.mpg.de),
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Multistate analysis and decomposition of disability-free life expectancy trends in Italy 2004-2019

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Abstract

Italy has witnessed increases in life expectancy and severe population ageing, raising concerns about their impact on population health. Disability status greatly affects the participation of older adults in various aspects of life. This study examines the long-term trend of disability-free life expectancy (DFLE) in Italy and explores the drivers in terms of disability onset and recovery dynamics, as well as changes in disability-specific mortality. By using IT-SILC longitudinal data (2004-2019), transition probabilities and DFLE between ages 50 and 79 are calculated, and the drivers of DFLE evolution are analysed through decomposition. DFLE among mid-to-older Italians has progressed overall over the last decades, albeit not as favourably as life expectancy. The trends indicate compression of disability in recent years. Changes in disability transitions have the greatest influence on DFLE patterns, while less the changes in disability-specific mortality. The greatest contributions come from increases in the probability of recovery from disability.

Keywords: disability-free, expectancy, SILC, multistate, decomposition, ageing, Italy

Introduction

The overall share of the population in mid-to-older ages has increased rapidly in Italy in recent decades due to steadily increasing longevity and sustained low fertility. This ongoing change in population structure has had and will have lasting implications for Italian society in general and the economic and healthcare systems in particular. Much is known about mortality trends and levels, but less is known about long-term population health, and its dynamics. Mortality and population health are strongly related to each other. Still, we do not know (i) whether improvements in health and mortality move in the same direction and at the same relative speed (dynamic equilibrium, Manton, 1982), or (ii) whether survival increases faster (expansion of poor health, Gruenberg, 1977; Kramer, 1980) or slower (compression of poor health, Fries, 1980, 1983) than improvements in health. We answer these questions for Italy, the country with the highest share of population aged 65+ in Europe and among the highest in the world. First, we estimate recent trends (from 2004 to 2019) in disability-free life expectancy (DFLE) by gender through incidence-based multistate life tables. This approach allows us to (i) directly assess which of the scenarios of expansion, compression, or dynamic equilibrium of disability has prevailed in the last decades in Italy, and (ii) to disentangle the health and mortality drivers of changes in DFLE using a novel multistate decomposition approach.

We begin by providing background, describing the Italian context and the measurement of disability status. Then we describe the data source, the methods for transition probability estimation, expectancy calculation, and decomposition. We then analyse the long-term trend of disability-free life expectancy (DFLE) and life expectancy with disability (DLE) between ages 50 and 79, covering the years 2004-2019. We further examine these trends to address the question of compression, equilibrium, or expansion of disability over recent decades in Italy. Next, we decompose DFLE changes over time into the age-specific contributions of the changes in the transition probabilities.

Background

In recent decades, most countries saw a dramatic increase in life expectancy (either at birth or at mid and older ages) with an increase in the record-holding country of almost 3 months per year (Oeppen & Vaupel, 2002). The increase for Italy was particularly remarkable, reaching levels that rank among the highest in the world (United Nations, 2022). In the last two decades, Italian women and men have gained about 3 and more than 4 years of life expectancy, respectively (Caselli et al., 2021). Italy also ranks among the countries with the lowest fertility in Europe, with a TFR of 1.27 in 2019 (Istat, 2019). The combined effects of increased longevity and sustained low fertility have led to rapid population ageing (Grundy & Murphy, 2017; Istat, 2020). Italy experienced a steep increase in the share of older individuals, becoming in 2020 the first country in Europe (and second in the world, just after Japan) by the share of the population aged 65 and over (23.2%) (Eurostat, 2021; United Nations, 2022). Population ageing may have major implications for Italian society and has caused great concern regarding the sustainability of its social, economic and healthcare systems (Christensen et al., 2009; Harper, 2014; Istat, 2020). A primary concern is whether increasing life expectancy coincides with improvements in population health.

Health expectancy offers an assessment of the health changes linked to population ageing. It is based on an operationalization of health where health status is specified in an attempt to capture the health-related quality in which life years are lived (Robine et al., 1999). Health expectancy combines health and mortality information, allowing for age-standardised comparisons between different populations (or the same population over time) on both dimensions.

Functional limitations and disability status are major determinants of the quality of life, especially at older ages. Disability status offers a proxy for autonomy and limitations in daily activities, which can be a crucial determinant of a person's actual capability of being involved in family, social, and economic contexts (Newsom & Schulz, 1996). Therefore, disability status also indicates the ability to engage in the labour force, and especially during the years around retirement. It also focuses on the functional consequences of diseases, and it can inform on the type and amount of care needed (Ferrucci et al., 2007; Guralnik & Ferrucci, 2003), both from the economic and health systems, but also from the families. Finally, disability is one of the most consistently measured dimensions of self-reported health for older individuals, when compared to other dimensions (e.g. global self-rated health), as it is the least sensitive to reporting bias or subjective perception (Lazarevič, 2023; Robine et al., 2020). For these reasons, disability-free life expectancy (DFLE, the average number of years free from disability) is one of the most valuable and used indicators among the different versions of health expectancy.

Three theories exist on the potential pattern of morbidity relative to survival. First, the theory of expansion of morbidity (Gruenberg, 1977; Kramer, 1980) states that increasing life expectancy is linked to an expansion of morbidity in the population, due to the increase in poor health conditions over age and the increased survival of individuals with underlying diseases and poor functional health. A more optimistic view, the dynamic equilibrium theory (Manton, 1982), agrees with an expansion of morbidity for less lethal diseases, but predicts a postponement of more severe conditions to older and older ages. Finally, according to the compression of morbidity theory (Fries, 1980), increased longevity is complemented by the postponement of all degenerative processes, and physical and mental deterioration, into every older ages.

Robine et al. (2020), revising the global evidence on the evolution of DFLE, found that most countries experienced either a relative compression or a dynamic equilibrium of disability. In contrast, a systematic review by Spiers et al. (2021) concludes that the increase in life expectancy in good health and without disability has not kept pace with the increase in overall life expectancy. The two studies reach different conclusions although they consider different populations and health dimensions, with the second having even less up-to-date references and bringing together several different measures of health expectancies (and not just disability-free life expectancy). When compared to other European countries, Southern ones, including Italy, are generally found to have lower mortality but poorer health profiles and higher probabilities of health deterioration (Eikemo et al., 2008; Solé-Auró & Gumà, 2022).

Despite several studies reporting the evolution of mortality and life expectancy in Italy (among the most recent, Nigri et al., 2022), there are only a few studies that explore trends in DFLE for the country. Frova et al. (2010) found that, between 1994 and 2005, both life expectancy and DFLE increased, and that gender differences in DFLE gradually reduced. Moreover, Demuru & Egidi (2016), found that DFLE at age 65 from 1991 to 2013 underwent a relative morbidity compression since the number of years without functional limitations increased more than the number of years with disability. More recently, Caselli et al. (2021) showed that DFLE at age 65 between 2010 and 2017 increased from around 9 years for both genders to 9.3 and 10 years for women and men, respectively.

To our knowledge, all previous studies for Italy are based on cross-sectional data and are limited to the analysis of health prevalence and related measures. Instead, we use longitudinal data to follow individuals over time and evaluate health changes as they age and ultimately estimate expectancies through incidence-based multistate life tables. We expect levels and trends of health expectancy to be substantially consistent between prevalence-based and incidence-based multistate approaches. However, the multistate approach is advantageous because it allows us to better understand recent trends in population health by using demographic decomposition to disentangle the role of health and mortality dynamics in producing changes in DFLE over time in the country. Further, as this method relies on panel data, we model the transitions between health states controlling for individual characteristics, e.g. education and area of residence, that are sources of heterogeneity and compositional differences.

Data and methods

Data

We use the longitudinal version of the European Union Statistics on Income and Living Conditions (EU-SILC) for Italy. EU-SILC is the reference source for comparative statistics on income and living conditions for all countries in the European Union. It is also the source used by Eurostat to calculate Healthy Life Years (HLY) to monitor population health in Europe using a prevalence-based approach. Member States conduct the survey annually, collecting nationally representative individual and household-level data. The longitudinal version of EU-SILC is based on a four-year rotational panel; each year, a new sample representative of the population of Italy enters the study, and it is followed for four years. We use data covering the period 2004-2019 by analysing separately all panels from 2004-2007 to 2016-2019. From these waves, all individuals aged 50 years and over are selected and classified by gender and functional health (disability) status.

Functional health status is measured using a question on self-rated long-term limitations in activities due to health problems, via the harmonised Global Activity Limitation Indicator (GALI). Respondents are asked: “For at least the past 6 months, to what extent have you been limited due to a health problem to perform the activities that people usually do?”. We group together responses “Severely limited” or “Limited, but not severely” as with disability, whereas those declaring “No limitations” are coded as disability-free.

Methods

Transition probabilities

To study the dynamic of disability accounting for differential mortality risks, we use discrete-time Markov-chain multistate models. Individuals change or remain in the same health states as they age, and either die or are censored at age 79. Health and disability are transient states, meaning that individuals can move between them, whereas death is the sole absorbing state (i.e. a permanent condition). The possible transitions in our model are depicted as a state space diagram in Figure 1.

[Figure 1 here]

We estimate mortality and health transitions using discrete-time event history models based on multinomial logistic regression, where age is the time scale and is modelled with restricted cubic splines. Specifically, we consider (i) transitions within disability states (remain disability-free or with disability), (ii) transitions between the two transient disability states, and (iii) the disability-specific transition to death. In each model, stratified by gender, we control for educational attainment (based on the highest ISCED level attained, classified as “low” for those who have lower secondary education or less, “mid” for those who have (upper) secondary education, and “high” for those who have more than secondary education) and geographical area of residence (classified as North, Centre, and South).

Survival probabilities estimated using survey data are generally less accurate (and typically higher) than those obtained through population registers and provided in the vital statistics. Indeed, reference populations in survey data are usually individuals living in households and exclude the institutionalised population, which has a higher mortality risk. Moreover, loss to follow-up may be more common among unhealthy individuals than healthy individuals. We adjust our estimate to obtain a meaningful benchmark with population-level data, by matching the transition probabilities with the corresponding survival probabilities of the official period life tables published by the Italian National Institute of Statistics (Istat). The matching procedure follows an approach similar to the one proposed by Dudel & Myrskylä (2017). Specifically, the matching procedure does not modify the relationship between the disability trajectories and the trajectories to death, but only scales the overall levels of estimated probabilities to match the official life tables’ survival probabilities. The procedure leans on the idea that, at age $x+1$, the unconditional survival probability is a weighted average of the disability-specific survival probabilities at age x, with weights given by the prevalence of individuals, at age x. Thus, averaging the survival probabilities estimated with our models should result in a value close to the one provided by Istat’s life tables. When this is not the case, and the estimated average survival does not match the official one, the transition probabilities are scaled by the ratio between the weighted probabilities and the corresponding survival probabilities of the life tables. This approach does not assume constant mortality across disability states and genders. An example of its application is provided in the Supplementary Materials and the detailed computation can be found in the repository containing the reproducible code (see later).

Formally, individuals alive at each age x can either be disability-free (DF) or with disability (WD). At age $x+1$, they can stay in the previous disability state, transition to the other disability state, or die. Then, for each age and level of the variable of interest, (e.g. gender) we have four transition probabilities from and to transient states:

$$P(DF \mid DF, X = x)$$

$$P(DF \mid WD, X = x)$$

$$P(WD \mid WD, X = x)$$

$$P(WD \mid DF, X = x)$$

and two transitions probabilities to the absorbing state:

$$P(death \mid DF, X = x)$$

$$P(death \mid WD, X = x)$$

The unconditional survival probability from age x to age $x+1$, is therefore:

$$P(alive \mid X = x) =$$

$$\{P(WD \mid X = x) * [P(DF \mid WD, X = x) + P(WD \mid WD, X = x)]\} +$$

$$\{P(DF \mid X = x) * [P(WD \mid DF, X = x) + P(DF \mid DF, X = x)]\}$$

That is, the unconditional probability of surviving from age x to age $x+1$ can be expressed as a weighted average of the probabilities of transitioning to (or remaining in) the health states (and thus not transiting to the death state), weighted by the prevalence of individuals in the two health states. Once $P(alive \mid X = x)$ is estimated, it is used to compute the scaling factor by dividing it to the corresponding probability from official life tables. This scaling factor is then applied to all transition probabilities so that our adjusted estimate of $P(alive \mid X = x)$ is matched with that of official life tables.

This correction approach exploits the empirical distribution of states at each age, which differs from the Dudel & Myrskylä (2017) approach which matches the marginal distribution of the states within the Markov chain. The life table distribution is the limiting distribution for both methodologies, thus the two produce very close (if not equal) results, but our proposal has the advantage of being a faster approximation of the Dudel & Myrskylä's (2017) procedure.

Expectancy estimation

Starting from these adjusted transition probabilities we derive disability-free life expectancy (DFLE) and life expectancy with disability (DLE) between ages 50 and 79, by gender, between 2004-2007 and 2016-2019, through Markov Chain multistate life tables. We first use the estimated transition probabilities to build the transition matrix (*U*), then transpose and invert *U* to obtain the fundamental matrix (*N*) (Kemeny & Snell, 1983). From the *N*, we finally derive all the relevant quantities, such as the unconditional average time spent in the two transient states; a detailed overview is provided by Dudel (2021). Confidence intervals for the expectancies are obtained through non-parametric bootstrap; we use 1000 replications of the SILC data through a sampling procedure that preserves the observed longitudinal structure.

Decomposition

Finally, we use demographic decomposition to determine the different age-specific contributions of the changes in the transition probabilities to the observed changes in DFLE over time. For a more straightforward interpretation of results, we decompose DFLE changes by reparameterizing DFLE calculations in terms of only mortality and transitions between health states, and which omit transitions within states. This differs from standard matrix algebra calculations, which use transitions within and between states as parameters, and which exclude mortality. Specifically, for purposes of decomposition, we calculate DFLE using the following four probabilities, each a vector over the full age range.

$P(DF \mid WD, X = x)$

$P(WD \mid DF, X = x)$

$P(death \mid DF, X = x) = 1 - P(WD \mid DF, X = x) - P(DF \mid DF, X = x)$

$P(death \mid WD, X = x) = 1 - P(DF \mid WD, X = x) - P(WD \mid WD, X = x)$

These four vectors are organised into a single vector, θ, which contains all parameters required to calculate the matrices U, N, and our final DFLE estimate. Given the function DFLE = $f(\theta)$, we can then decompose the difference in DFLE implied by two versions of θ, in our case relating to different time periods. To decompose, we use the pseudo-continuous decomposition approach proposed by Horiuchi et al (2008) and implemented in the R package DemoDecomp (Riffe, 2020). The result of the decomposition is a vector of age-specific contributions from each difference in the parameter vector θ to the difference in DFLE.

Materials

All data analysis was performed in the R language (R Core Team, 2021), and all steps are documented in an open-access reproducibility repository https://osf.io/fm7zw/?view_only=44b4dd51398f4e86831d276e021f06a2 (Note this link will be de-anonymized after review). R packages used include VGAM (Yee TW, 2023), data.table

(Dowle & Srinivasan, 2023), tidyverse (Wickham et al., 2019), foreach (Microsoft & Weston, 2022a), and doParallel (Microsoft & Weston, 2022b).

Results

DFLE trend

DFLE between ages 50 and 79 for Italian men and women in 2007 was around 16.7 and 15.2, respectively (Figure 2). By 2019 DFLE for both women and men increased, reaching almost 20 years for both genders (19.7 for men and 19.6 for women). In the same period, DLE between ages 50 and 79 decreased, faster for women than for men (from 12.2 and 8.7 to 8.7 and 6.8 years, respectively).

[Figure 2 here]

The two periods indicated in the figure with dashed lines (between 2009 and 2011 and between 2015 and 2016) denote data and comparability issues that will be further elaborated in the limitations section. Given these breaks in DFLE trends, we consider separately the changes in DFLE in three different periods: between 2007 and 2009, between 2011 and 2015, and between 2016 and 2019. First, we evaluate whether each period is characterised by a scenario of the compression, expansion, or dynamic equilibrium of disability. We do so by considering trends in DFLE, DLE, and the proportion of disability-free years over total life expectancy in this age range (H indicator), as in Table 1. A detailed scheme linking the evolution of these indicators to the three theories can be found in Kreft & Doblhammer (2016). In the first period (2007-2009), the DFLE of women increased (+0.7 years) while that of men remained almost constant. In the same period life expectancy increased for both genders but faster for men than for women. Consequently, in this period, for men the H indicator decreased (Table 1). These changes represent a scenario compatible with the absolute expansion of disability. Women showed increases in DFLE, decreases in DLE and increases in the H indicator in the same period, consistent with compression of disability (Table 1).

In the second period (2011-2015), DFLE decreased for both genders and especially between 2011 and 2013. The change between 2011 and 2015 is slightly larger for men (-1 year) than for women (-0.8 years). For both genders, given that life expectancy increased in the same period, the decrease in DFLE is accompanied by an increase in DLE and a decrease in the H indicator, implying an absolute expansion of disability (Table 1).

In the last period (2016-2019), both older women and men experienced an increase in DFLE (from 18.0 to 19.6 and 18.8 to 19.7, respectively). In this way, men recovered the loss of disability-free years experienced in the previous period (2011-2015), while women continued the progress in DFLE observed in the first period (2007-2009). Given that in this period, together with an increase in DFLE, the DLE decreased, and the H indicator increased, we observe an absolute compression of disability for both genders (Table 1).

[Table 1 here]

Decomposition

The decomposition of the observed changes in DFLE over the three periods measures the respective contributions of changes in disability onset, recovery from disability, and disability-specific mortality to the observed differences. The age-specific contributions of the changes in the transition probabilities to the changes in DFLE in the three different periods are shown in Figure 3. Values greater than zero denote positive contributions to the evolution of DFLE, indicating that the transitions under consideration have driven DFLE towards higher values in the period. Conversely, negative values represent contributions towards a decline in DFLE.

In the first period (2007-2009), men experienced stagnation in DFLE. Mortality in each disability state improved slightly, positively contributing to DFLE change. This improvement was however offset by two negative contributions. First, a decrease in the recovery probability (from being with disability to being disability-free) between around age 60 to age 70. Second, an increase in the probability of disability onset (from being disability-free to being with disability) in the same ages. In contrast, these two transition probabilities contributed positively up until age 57 and after age 75. Over the same period, women experienced a rather small increase in DFLE almost entirely driven by decreases in disability onset, i.e. the probability for women of becoming with disability in 2009 was lower than that in 2007.

In the second period (2011-2015), women and men experienced decreases in DFLE of -0.8 years and -1 year, respectively. In this period, for both genders, the major negative contribution to DFLE's trend was given by the decrease in the recovery probabilities at all ages. For men, slightly worse mortality for the disability-free also contributed negatively, whereas improved mortality of those with disability contributed positively to DFLE the change. The latter contribution indicates that men with disabilities in 2015 had a better chance of survival than in 2011. This contributed positively to DFLE change as individuals with disabilities who survive longer also had opportunities to recover, and thus to add disability-free years to their remaining lifetime. Women experienced a slight increase in the probability of recovery at all ages, giving a small but positive contribution, which partially offset the other negative contributions.

In the last period (2016-2019), both men and women experienced an increase in DFLE, larger for women (1.6 years) than for men (0.9 years). The different transition probabilities contributed similarly for the two genders in this period. Specifically, both genders gained DFLE years due mostly to the large positive contribution of increases in recovery. Another relevant contribution to the increase in DFLE, for both men and women, comes from changes in the onset of disability. In particular, for men, the probability of the onset of disability decreased below age 60 and then rose, whereas for women onset decreases occurred up to the age of 66 and rose thereafter. Men also experienced a larger increase in the probability of disability onset at older ages, resulting in an overall smaller increase in DFLE in this period. In this period as well, the changes in mortality from both disability states contributed only slightly to

DFLE evolution for both genders. To DFLE changes, the contribution of the transition to death for both being disability free and with disability are negligible.

[Figure 3 here]

Discussion

In this article, we measure recent trends in DFLE, from the early 2000s up until the most recent years, among Italian men and women between ages 50 and 79. Together with the trend in DLE, information on DFLE allows us to assess whether the country experienced an expansion, compression, or dynamic equilibrium of disability over the last decades in this age range. Furthermore, we decompose DFLE changes over time with the aim of understanding the main drivers of DFLE trends. We express the contributions to changes in DFLE in terms of the underlying changes in disability-specific mortality and the dynamics of disability onset and recovery.

During the last two decades, DFLE around retirement age progressed, even if not always as favourably as life expectancy. Between ages 50 and 79, women and men show disability compression in more recent years, whereas both experienced periods of disability expansion previously. Specifically, between 2007 and 2019, women consistently show evidence of absolute compression of disability in the age range considered, except for the period from 2011 to 2015 when they experience an absolute expansion of disability. At the same ages, men experienced an absolute compression of disability limited to the years between 2016 and 2019, while they experienced absolute expansions of disability in earlier years. The trends observed in DFLE from mid-to-older ages exhibit a more favourable trend for women than men. Indeed, women's disadvantage in DFLE shrank from around 1.5 years in 2007 to almost zero by 2019. Through the decomposition of period changes, we show that the major drivers of DFLE change between ages 50 and 79 were changes in the transition into and out of disability. Changes in disability-specific mortality have been rather inconsequential in these ages. Although in other populations or other comparisons (e.g., a decomposition of the gender gap (Moretti & Strozza, 2022)), mortality is likely to be an important driver of DFLE differences, our results simply highlight that mortality changes in these periods and ages were very small. In contrast, mortality differences between those with and without a disability have been very high. In such a mortality context, changes in disability onset and recovery have been very consequential for DFLE. Changes in the recovery probability (in both directions) and the decrease (increase) in the onset probability have been the most important forces for the increasing (decreasing) DFLE around retirement age. Women were particularly advantaged over men in terms of the greater decrease in the probability of disability onset.

Comparison with evidence in the literature

The disability compression we found in the most recent years is in line with results for other countries (such as the review of Robine et al. (2020)) and specifically for Italy (such as the more recent of Caselli et al. (2021)). Nevertheless, studies referring to Italy are old and based on cross-sectional data, thus analysing prevalence-based measures.

A more unexpected finding was that of the expansion of disability in previous years. This finding is nevertheless supported by the evidence of rising activity limitations found by Mackenbach et al. (2018), referring to European countries (including Italy), using the same data source (SILC). An expansion of disability was also found in France by Cambois et al. (2013) when considering a similar age range spanning mid-to-older ages. Specifically, the authors observed that, in the early 2000s, while the trend in DFLE from age 65 onward showed a dynamic equilibrium, DFLE between 50 and 65 declined (for various dimensions of disability). This may suggest that, even for Italy, the improvements found in the literature relating to not-truncated DFLE (e.g. 65+, as in Caselli et al. (2021)) may be mostly attributable to greater improvements in disability at older ages (80+) than at younger ones (50-79), with the former outweighing the latter.

Specifically, we observed an expansion of disability for both genders in 2011-2015, with a particularly sharp decline from 2011 to 2013. Major economic shocks mark this period due to the Great Recession. The Italian context was characterised by increased employment instability (Lorenti, Dudel, Myrskyla 2019) and health risks (Sarti and Zella, 2016). Egidi & Demuru (2018) highlighted the consequences of the recession on mortality and health in Italy, in line with our results. Egidi & Demuru found a stalling and in some cases even a worsening, of severe functional limitations. This is true especially among younger-to-older adults, while older individuals were less affected. Finally, the authors highlight the concerning decrease in the use of preventive and health care services. This may be linked to the costs associated with these services, which may have represented a too heavy burden for those hit the hardest by the recession. These points bring light to the detrimental impact of the recession, together with the implementation of economic measures such as austerity, on the overall welfare and well-being of individuals.

Limitations and strengths

This study presents some notable advantages and some limitations. First of all, there is no longitudinal survey focusing on health and disability in Italy that is accurate and representative of the Italian population, while also covering such a long period. The only data sources specifically designed for the study of health and its determinants at the national level (for example the European Health Survey and the survey Aspects of Daily Living) are cross-sectional. SILC is a longitudinal data source conducted by Istat at the national level that also includes some questions on health conditions.

There are several advantages to drawing on a longitudinal data source, like SILC, in DFLE computation, compared to a cross-sectional one. It allows considering the dynamics of (un)healthy ageing, by estimating the transition probabilities among disability states and the disability-specific mortality. From these transition probabilities, it is possible to compute multistate estimates of health expectancies (in this study, disability-free estimates), allowing to control for relevant aspects of observed heterogeneity while assessing the dynamics of health and survival.

Nevertheless, our use of SILC also entails some drawbacks for the objectives of this research. First, the purpose of SILC is primarily to collect data on income, poverty, social exclusion and living conditions, while questions on health conditions remain marginal. Specifically, the SILC questionnaire only incorporates the three-question-set of the Minimum European Health Module (MEHM), which includes the GALI question. Despite having its own limitations, being a self-reported single-item question, GALI has been shown to be a good indicator of participation restriction due to health problems, also in terms of validity and reliability (Van Oyen et al., 2018).

The second limitation of the use of SILC for our objectives, and common to most survey data, is that it suffers from attrition, weak mortality follow-up, and representativity. Specifically, the target population are individuals living in households, thus excluding those living in institutions, probably in worse health conditions. For these reasons, mortality underestimation (and therefore life expectancy overestimation) when compared to vital registration estimates, is inevitable. To overcome this issue, we propose a correction method that allows SILC mortality and life expectancy estimates to be comparable to those at the population level.

Third, SILC interviews are conducted annually, which means that, in estimating the transition probabilities of individuals followed longitudinally (for at least two survey occasions), it is assumed that they make a single transition (to the same state or to another state) within the year. This is a reasonable assumption given the small interval and that GALI refers to long-term limitations in activities ("...for at least the past six months…").

A fourth and crucial limitation concerns the variations in SILC questionnaires and survey techniques over time, which prevent direct comparisons between estimates over the long timespan considered (2004-2019) and instead constrains our analysis to be broken into three distinct periods. As shown in Figure 2 from the results section, the DFLE trend has two breaks (represented by the dotted lines in 2010 and between 2015 and 2016) that are fully attributable to data issues.

Starting from the break of 2010, DFLE (and DLE) estimate for this year is not included in our trend, because the result is strongly influenced by reasons not attributable to health and mortality changes, making the estimate unreliable. In particular, until 2010 interviews were conducted face-to-face with a paper-and-pencil (PAPI) survey technique, which was substituted by a computer-assisted (CAPI) technique (Istat, 2010, 2021). Moreover, before 2010 the recruitment, training, and fielding of the survey were carried out through the municipal survey network, while from 2010 onwards the survey was outsourced to private survey networks managed by contracted companies. Finally, the 2010 SILC survey for Italy includes an ad-hoc module ("Health Conditions" in: Individual Questionnaire, Section 3) with several questions relating to disability and specifically to limitations in the Activities of Daily Living. These three factors may have affected answers related to GALI and, for this reason, health data from the 2010 survey is considered unreliable, both by Istat and Eurostat's Healthy Life Years monitoring. These issues are also explicitly noted in the country reports for Italy provided by the European Health and Life Expectancy Information System (EHLEIS Information System, 2018), within the EurOhex project (http://www.eurohex.eu/), stating that the GALI prevalence from the 2010 SILC was not validated and it was estimated as the mean prevalence of 2009 and 2011.

The steep increase in DFLE (about 2 years) between 2015 and 2016 is mostly attributable to data issues and specifically to the fact that between 2015 and 2016 the survey technique switched from CAPI to a mixed one, in which most of the interviews were conducted by telephone (CATI). The whole questionnaire also changed accordingly (with the aim of making it more convenient in a telephone interview) and, together with the modified interview setting (no longer face-to-face), may have modified attitudes towards disability reporting.

Another limitation is that all ages above 79 in EU-SILC are aggregated in a unique "80+" category. This is a relevant drawback for the analysis of health status, especially in an ageing country like Italy (where the age class 80+ may be very heterogeneous), forcing the analyses to be truncated after age 79. This prevents us from making more general observations as to whether poor health or disability are being compressed or expanded throughout the life course over age 50, and especially at older ages.

Finally, among the limitations, due to the small numbers of respondents in different strata, this study does not consider that DFLE is unequally distributed within the country and between social groups (Moretti & Strozza, 2022) and its trends may be different in these strata. For this reason, the results shown here lie between what can be observed in the different regions and macro areas or between different levels of education. However, controlling for area and education in the models for estimating transition probabilities, we provide estimates that are net of compositional effects relating to these dimensions. Moreover, another limitation is that we condensed the disability status into a dichotomous variable, irrespective of its severity (GALI distinguished between mild or severe disability). The results, in fact, do not allow us to capture whether the compression (expansion) experienced by the men and women over time is attributable to improvements (worsening) of mild and/or severe disabilities. The disability expansion, for example, can result from an increase in severe disability but a decrease in the milder ones, or the opposite.

The limitations identified in this work mainly stem from the urgent need for broader and reliable data sources to obtain a comprehensive understanding of the topic in question. In particular, the lack of a robust and reliable longitudinal data source for the country that focuses explicitly on health, including functional health, its multidimensionality and temporal dynamics, is a significant limitation. The availability of such a data source would be crucial in unravelling the complexities of the health status of individuals and identifying the factors that contribute to successful healthy ageing. By conducting longitudinal studies that follow individuals in depth over time (acquiring their health history) can allow us to obtain valuable information on the determinants of health and their patterns of evolution throughout life.

Despite these limitations and the challenges arising from some of them, our study presents several advancements compared to the state of the literature, using various methodological and analytical strategies to minimise possible sources of bias. This is the first study for Italy that uses longitudinal data to estimate transition probabilities among disability states and to death to estimate incidence-based DFLE and its recent trends. Moreover, using a decomposition method that has been applied in a novel way to multistate models, we isolate the main ages and transitions driving DFLE changes over time.

Conclusions

The DFLE of mid-to-older Italians has improved over time in recent decades, but not always as much as their life expectancy. Recent DFLE trends show that Italian women and men around retirement age have experienced compression of disability, while both genders faced disability expansion in earlier years. The key factors behind these patterns are the changes in the onset and recovery from disability, with changes in disability-related deaths playing a smaller role. In recent years, improvements in the probability of recovery from disability have had the biggest impact on the DFLE trends at the examined ages.

Ageing societies face complex challenges. Italy is witnessing a rapid population ageing process due to longer life expectancies and declining birth rates. While ageing reflects progress in healthcare, medical advancements, and preventive measures, it may also pose several challenges threatening the sustainability of social, economic, and healthcare systems. The expected increase in the number of individuals potentially in poor health or with disabilities requires far-sighted strategies. Indeed, an increased share of frail older people may place a considerable strain on healthcare and social systems, with repercussions at individual levels. Reduced quality of life in middle and older ages can potentially exacerbate social inequalities, as individuals who are already disadvantaged are at an increased risk of experiencing poorer health and shorter lifespans. In countries with a strong familistic welfare system, like Italy, the health of older family members can also significantly impact other family members’ lives in various ways.

Therefore, health estimates (such as incidence-based health expectancies) are essential for better understanding the mid- to old-age population's health dynamic, and to help policymakers develop and implement effective measures targeting health interventions. Such information is crucial in countries such as Italy, where the evidence on the dynamics of health deterioration is scarce and based on cross-sectional data.

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Supplementary materials

Correction Method

Figure 4 shows an example, for the year 2013, of the application of the correction method that has been explained in the methods section. In particular, the figure shows the age-specific progression of the probability of death by disability status (the transitions from being disability-free or with disability to death) from SILC, before (Panel A) and after (Panel B) the correction, in comparison with the population-level mortality rate provided by Istat (qx, from the life tables). The correction procedure does not modify the ratio between the disability-specific risk of death, but it only scales the levels (and thus of all transition probabilities) to match the death probabilities from the life tables.

[Figure 4 here

Trends in transition probabilities among transient (disability) states over time

Figure 5 shows the yearly evolution over time (2007-2019) of the age-specific transition probabilities among transient states, namely the probability of staying disability-free, the onset probability (transition from being disability-free to being with disability), the probability of staying with disability and the recovery probability (transition from being with disability to being disability-free), by gender.

[Figure 5 here

Number of transitions observed among states for each year and by gender

Table 2 contains, for the two genders and each year/panel, the number of transitions observed among the states of interest in IT-SILC data.

[Table 2 here

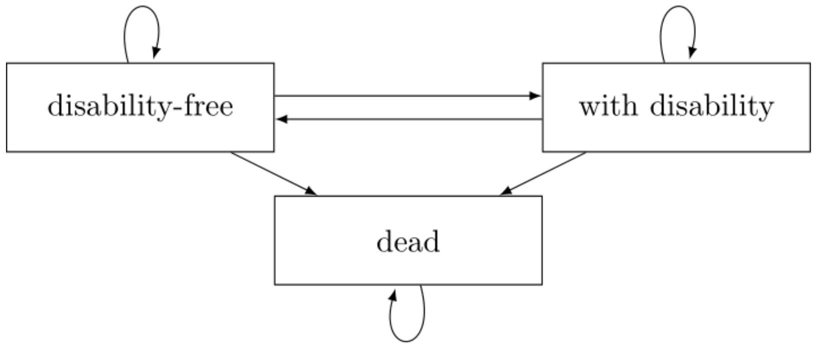

Figure 1: State-space diagram of the disability model

Note: Squares represent states and arrows represent the possible transitions.

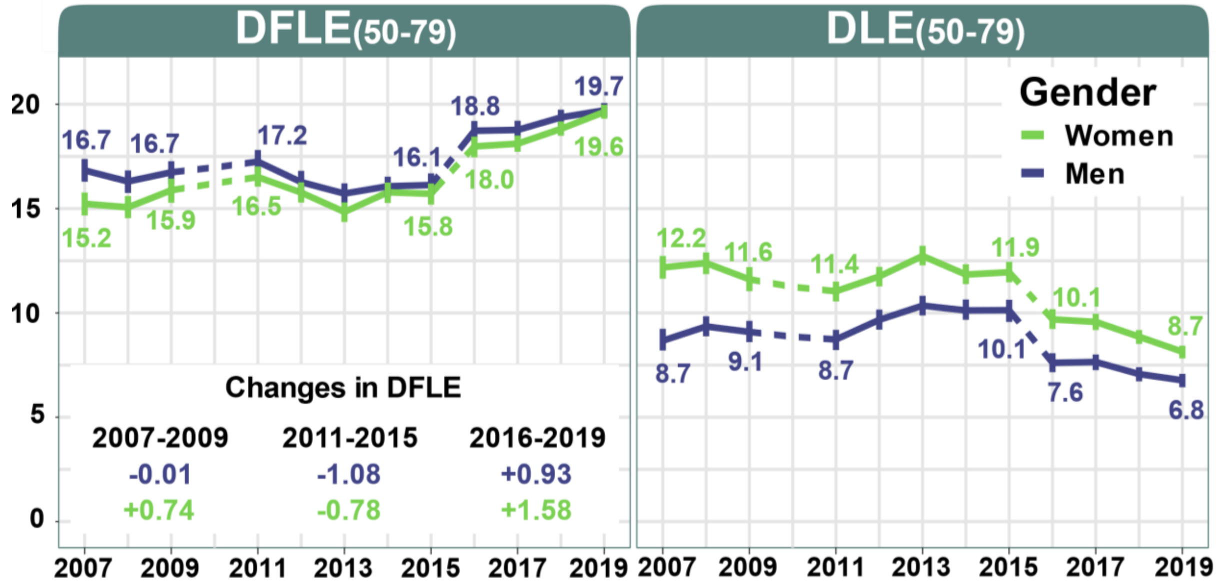

Figure 2: Trend in life years disability-free (DFLE) and with disability (DLE), age 50-79, men and women, 2007-2019

Table 1: Observed changes in the indicators of interest (DFLE, DLE, LE and H) between ages 50 and 79.

	2007	2009	↑↓=	2011	2015	↑↓=	2016	2019	↑↓=
					Women				
DFLE	15.2	15.9	↑	16.5	15.7	↓	18.0	19.6	↑
DLE	12.2	11.6	↓	11.0	11.9	↑	10.1	8.1	↓
LE	27.4	27.5		27.5	27.6		27.7	27.8	
H	55.5	57.8	↑	59.9	56.9	↓	65.0	70.7	↑
					Men				
DFLE	16.7	16.7	=	17.2	16.1	↓	18.8	19.7	↑
DLE	8.7	9.1	↑	8.7	10.1	↑	7.6	6.8	↓
LE	25.4	25.8		25.9	26.2		26.3	26.5	
H	65.7	64.8	↓	66.4	61.5	↓	71.1	74.5	↑

Note: values of DFLE, DLE, and H indicators are reported for the analysed periods. Arrows indicate whether the indicator has increased (↑), decreased (↓), or remained stable (=) over the period.

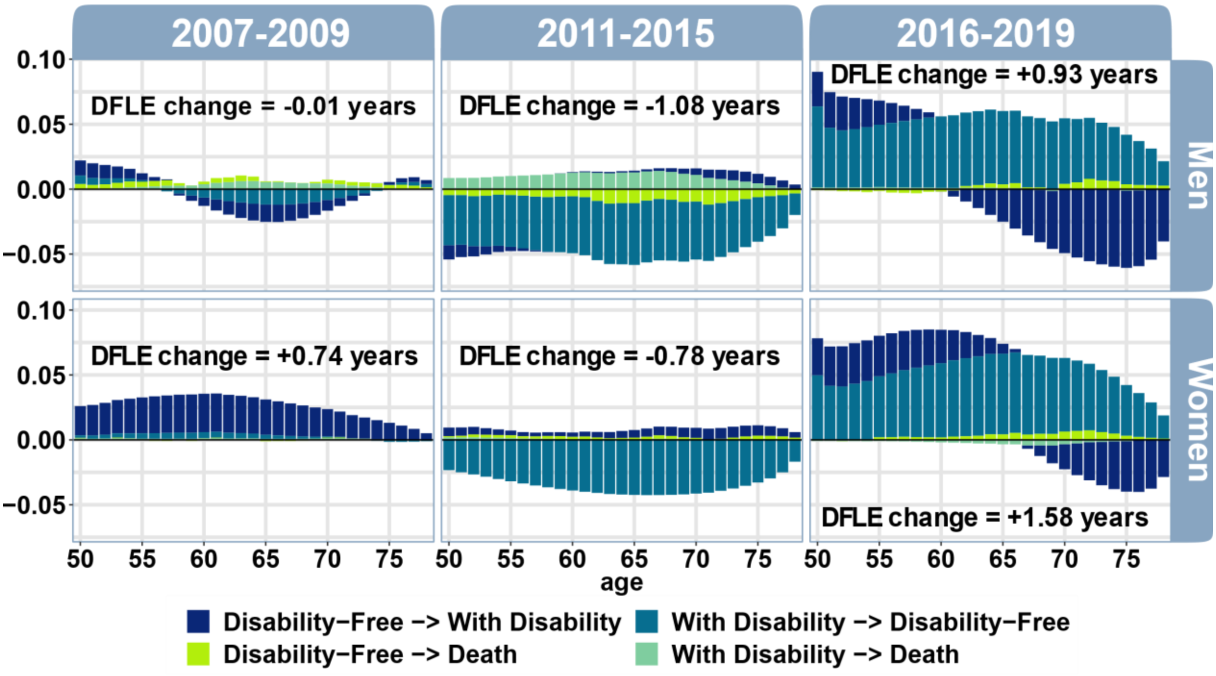

Figure 3: Age-specific contributions to DFLE (50-79) change, 2009-2007, 2015-2011, 2019-2016, men and women

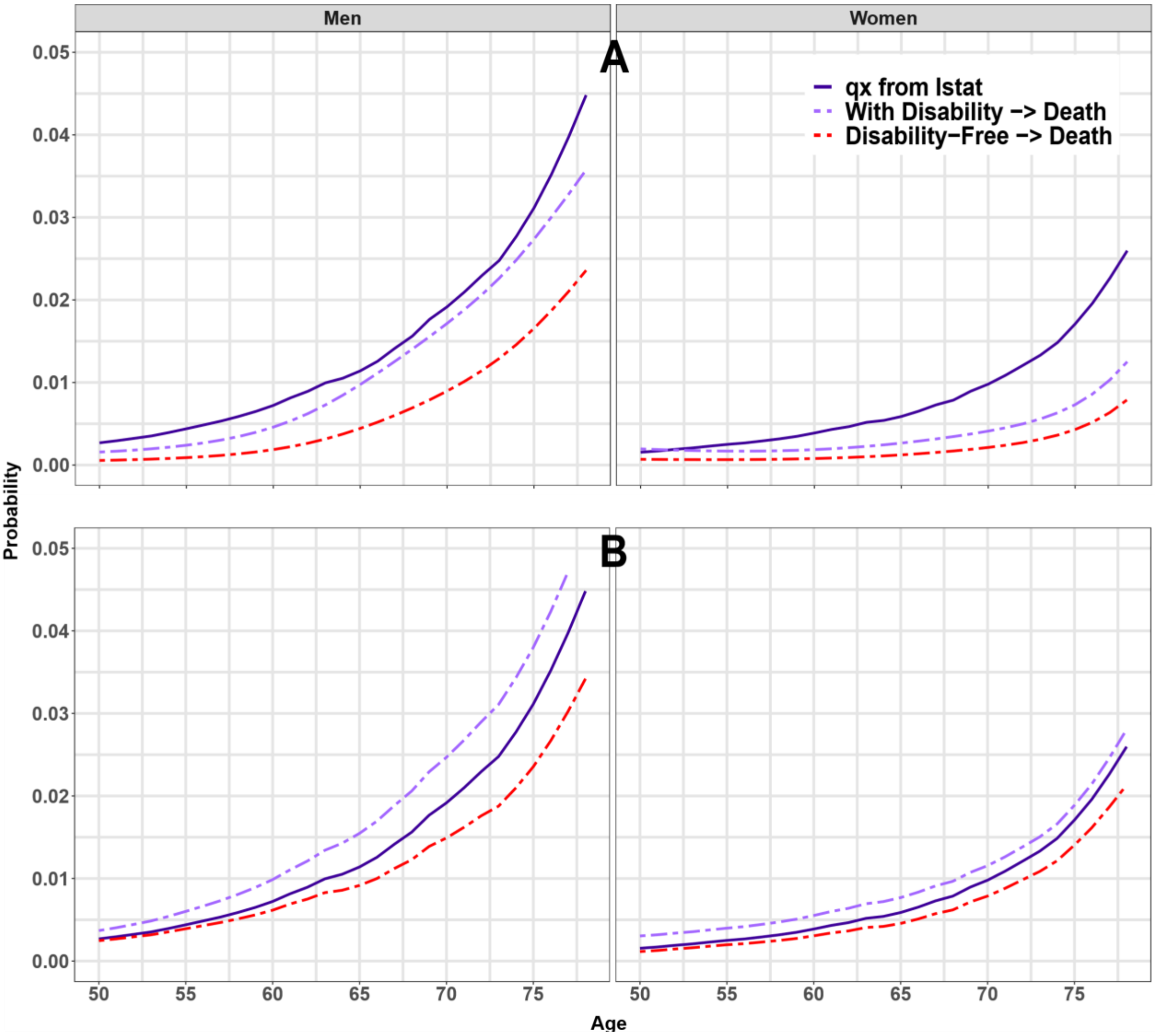

Figure 4: Age-specific probability of death at the population level from Istat compared to the probability of death by disability status from SILC in 2013 by gender

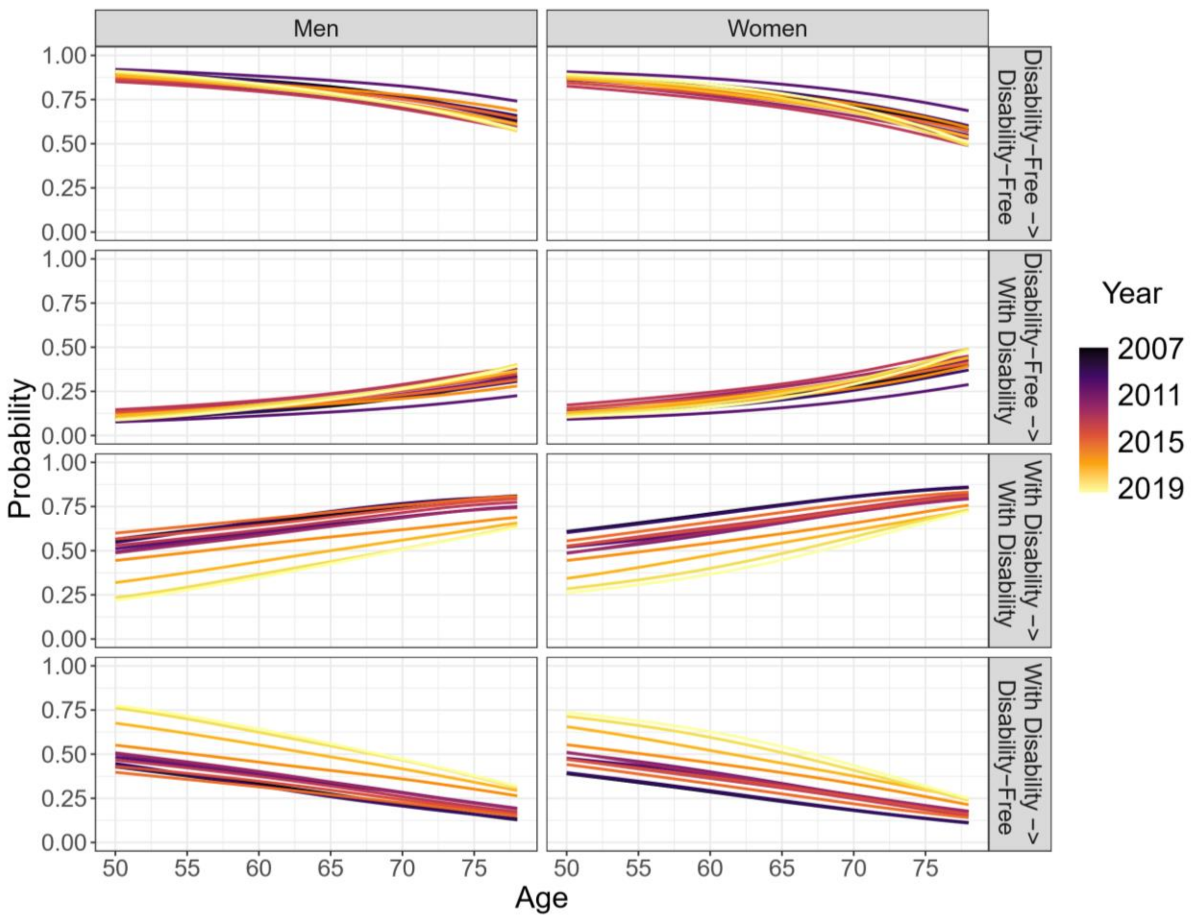

Figure 5: Transition probabilities among transient (disability) states, by gender, from 2007 to in 2019

Table 2: Number of transitions among states, by gender, from 2007 to 2019

Women

	From disability-free to:			From with disability to:		
	Disability-free	**With Disability**	**Death**	**Disability-free**	**With Disability**	**Death**
2007	22333	3361	27	1803	5622	121
2008	20499	3170	27	2137	6480	131
2009	19616	2736	28	2383	6894	124
2010	19284	1990	25	3032	6338	94
2011	17604	2757	39	2451	5152	104
2012	15844	2934	35	2352	5056	96
2013	14807	2935	30	2293	5437	88
2014	16159	2832	17	2705	6236	85
2015	16088	2520	18	2357	6068	109
2016	15337	2352	14	2990	4958	97
2017	16178	2953	17	3116	4303	83
2018	16718	3042	20	3159	4299	99
2019	18962	3197	26	3529	4993	124

Men

	From disability-free to:			From with disability to:		
	Disability-free	**With Disability**	**Death**	**Disability-free**	**With Disability**	**Death**
2007	22291	2572	71	1553	3592	143
2008	20877	2598	65	1812	4077	154
2009	19967	2271	57	1976	4417	142
2010	19758	1729	53	2396	4194	133
2011	17852	2297	68	2049	3470	141
2012	16035	2455	41	1805	3385	116
2013	15158	2433	40	1812	3744	104
2014	16347	2374	23	2122	4340	73
2015	16313	2087	29	1951	4396	85
2016	15552	1883	26	2521	3454	95
2017	16335	2504	30	2499	2787	101
2018	16697	2532	50	2654	2724	120
2019	18729	2659	65	2938	3167	177