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Health Expectancy: Increasingly Used, but Not Well Understood

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Abstract: Good health is central to human happiness and well-being. It contributes substantially to economic progress, as healthy populations live longer and are more productive. The corresponding public health policies are typically assessed based on a structural indicator for "Health Expectancy" (HE) such as the EU's "Healthy Life Years" (HLY) or the WHO's "Health-Adjusted Life Expectancy" (HALE). Unfortunately, HE estimates are extremely sensitive to methodological choices, an issue that is widely overlooked. First, the common practice of measuring population health by the distribution of responses to specific survey questions is ambiguous and not straightforward. Consequently, levels and trends of HE vary significantly depending on the underlying data and health indicators. Moreover, HE estimates are also highly sensitive to technical features, such as the age range and partitioning selected for analysis, as well as the technique chosen to add the health dimension to the life table; an issue that has gone remarkably unrecognized. With the aim of filling this important research gap, the European Research Council (ERC) funded a Consolidator Grant project entitled "Levels and trends of health expectancy: understanding its measurement and estimation sensitivity" (LETHE). This special issue of *Comparative Population Studies* (CPoS) marks the completion of this project. It contains five articles, each dealing with a specific aspect of HE computation or a concrete empirical application based on HE indicators. This editorial summarizes the insights gained during the LETHE project and aims to make users of HE aware of its methodological sensitivities through illustrative empirical examples. A better understanding of these issues is essential to ensure the indicators' appropriate usage in research as well as in advising policy makers and public health officials.

Keywords: Population health · Health expectancy · Healthy life years · Health-adjusted life expectancy · GALI · Compression of morbidity · Expansion of morbidity

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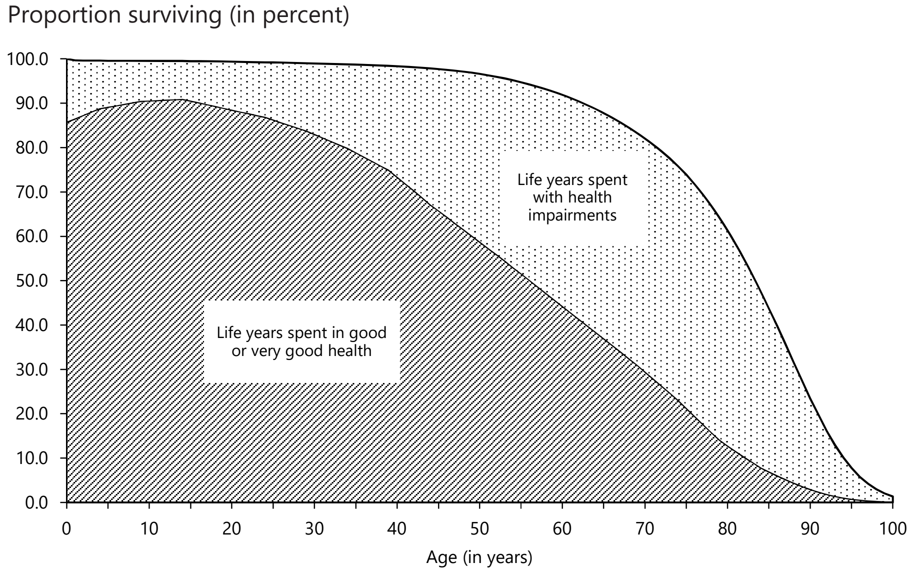
1 Introduction

The current demographic development of European societies is characterized by the ageing of populations, i.e., the absolute and relative increase in older people compared to younger people (*Golini* 2003; *Rechel et al.* 2013). Demographic projections show that population ageing is unavoidable in any population of the industrialized world (*Lutz et al.* 2008; *Powell* 2010). The numerical and percentage increase in the older population is already having direct and relevant social consequences today, including a growing demand for social services, healthcare, and social security systems (*Harper* 2000, 2014). The extent of these consequences largely depends on the health status of the population (*Muszyńska/Rau* 2012; *Prince et al.* 2015; *Solé-Auró/Gumà* 2023; *Steptoe et al.* 2015). Improving citizens' health condition is therefore one of the most important and effective ways to reduce the burdens of demographic ageing (*Beard/Bloom* 2015). Accordingly, the promotion of health was defined by the European Union (EU) as an integral part of "Europe 2020," the EU's ten-year strategy for economic growth from 2010 to 2020 (*European Commission* 2010). As part of this programme, the pilot initiative "European Innovation Partnership on Active and Healthy Ageing" (EIP-AHA) was launched in 2011. Its main objective was to increase the average healthy lifespan in the EU by two years by 2020 (*Jagger* 2020; *Jagger et al.* 2013).

Assessing the progress of such public health programmes toward their target requires a reliable indicator to monitor the levels and trends of population health. Several indicators have been developed for this purpose, for which we use the umbrella term "health expectancy" (HE). According to the general understanding, HE is simply an extension of the classic average life expectancy (LE) by one dimension. Technically speaking, this is correct, because the total number of years lived by the life table population – which form the basis of LE – is divided into two quality dimensions: life years spent in good health and those spent in poor health. Figure 1 illustrates this methodological concept with data for Germany in 2010. The bold line shows the reduction of people alive from birth to age 100 due to mortality ("survivorship function"). The area below the line represents the total number of years lived by the population (80.3 years on average, i.e., the average LE) which is subdivided into the two basic health states, resulting in an average number of 68.4 years (85.2 percent) spent in good or very good health and 11.9 years (14.8 percent) spent with health impairments.

The derivation of the number (or proportion) of life years spent in good or poor health is intuitive. However, an overly simple interpretation of HE obscures the great complexity inherent in adding the health dimension to the life table. Unlike LE, this makes HE extremely sensitive to various aspects related to its estimation. This can lead to considerable distortions in the interpretation of levels and trends, but also in the analysis of differentials in population health, as noted by *Robine* and *Ritchie* (1991). This is a serious problem because HE is not only increasingly used in health research, but has also become the most important structural indicator in health policy.

Fig. 1: Life years spent in good or very good health and life years spent with health impairments, 2009/2011 for Germany (women and men)



Source: *Luy* (2016: 132).

In contrast to mortality, health is multi-dimensional and difficult to measure, and the common method for quantifying individuals' health statuses through self-assessments based on survey questions is ambiguous and not straightforward (*McHorney/Tarlov* 1995). Consequently, statistics on levels and trends of HE vary significantly depending on the underlying survey data and health indicators (see, e.g., *Jagger et al.* 2011; *Mathers et al.* 2001). The data itself, i.e., the specific survey, can also have a significant impact on the estimated levels and trends of HE. *Börsch-Supan* and *Mariuzzo* (2005) and *Croezen et al.* (2016) compared the prevalence of "good" and "very good" self-perceived health across several European countries according to different European surveys, including European Union Statistics on Income and Living Conditions (EU-SILC), the Survey on Health, Ageing and Retirement in Europe (SHARE), the European Social Survey (ESS), and the European Community Household Panel (ECHP). Both studies found substantial differences caused by multiple factors, including study size, response rate, sampling strategy, survey mode, and survey design (see also similar studies of *Bowling/Windsor* 2008; *Lee/Grant* 2009; *Lumsdaine/Exterkate* 2013). Notably, the same problem exists across different surveys of the same population (*Freedman et al.* 2004; *Freedman et al.* 2013; *Salomon et al.* 2009; *Tipping et al.* 2010).

Even less recognized is that HE estimates are also highly sensitive to technical estimation features. These include, e.g., the age range and its partitioning into groups, and the technique used for adding the health dimension to the life table. Among these issues, only the latter has been addressed and discussed in detail (e.g., *Crimmins et al.* 1993; *Mathers* 2002; *Robine et al.* 2001). Nonetheless, these methodological controversies have neither been resolved nor has the choice of method been taken into account when empirically analysing levels and trends of HE. The other technical features have largely escaped the attention of researchers so far, although they can significantly affect the estimates as well. With the aim of filling this important research gap, the European Research Council (ERC) funded a Consolidator Grant project entitled "Levels and trends of health expectancy: understanding its measurement and estimation sensitivity" (LETHE). This special issue of *Comparative Population Studies* (CPoS) marks the completion of the ERC project LETHE. It contains five articles, each dealing with a specific aspect of HE computation or a concrete empirical application based on HE indicators.

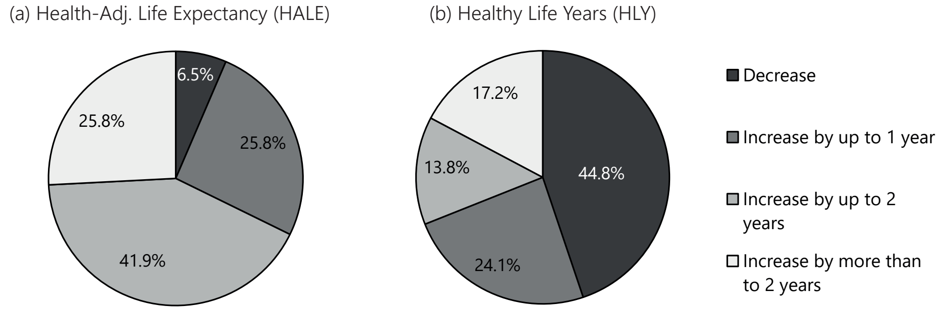
This editorial proceeds as follows. In Section 2, we use the above mentioned EIP-AHA objective of increasing the average healthy lifespan in the EU by two years between 2010 and 2020 to demonstrate the significant impact that the characteristics of the underlying health data and the selection of a health indicator can have on the estimated number of life years spent in good health, as well as on the level, differences, and trends. Section 3 adds the "compression version expansion of morbidity" debate – i.e., the discussion around the question whether the life years gained by rising LE are primarily spent in good health or with health impairments – as a second example. These illustrations are followed by a summary of the work and findings of the LETHE project with regard to the sensitivity of the HE indicator (Section 4) and the presentation of the articles included in this special issue (Section 5). The editorial ends by drawing together the most important conclusions derived from the LETHE project (Section 6).

2 Sensitivity of HE indicators: the EU's EIP-AHA goal

The structural indicator selected by the EU for assessing its strategic goals regarding population health is the average remaining years of life spent free from activity limitations, referred to as "Healthy Life Years" (*Lagiewka* 2012). Healthy Life Years (HLY) are computed based on the "Global Activity Limitation Indicator" (GALI), that is, people's self-ratings of long-term activity limitations due to health problems which are collected annually in EU-SILC. The GALI consists of the single-item question "For at least the past six months, to what extent have you been limited because of a health problem in activities people usually do?" with the three possible answers: severely limited, limited but not severely, and not limited at all. The latter defines the "healthy" status as the basis for determining HLY (*Berger et al.* 2015).

In the early 2010s, the trend in HLY suggested that the EIP-AHA target of increasing the healthy life span in the EU by two years by 2020 could not be achieved. However, if the EU had chosen the World Health Organization's "Health-Adjusted Life Expectancy" (HALE) as its health indicator, the development of population health would have appeared more optimistic (for the derivation of HALE, see, e.g., *Mathers et al.* 2001). Figure 2 illustrates the different conclusions provided by the two HE indicators – HLY and HALE – by grouping the populations of the EU into

Fig. 2: Proportion of European countries by change in the healthy lifespan (at birth) between 2010 and 2013 on the basis of different indicators for Health Expectancy, men

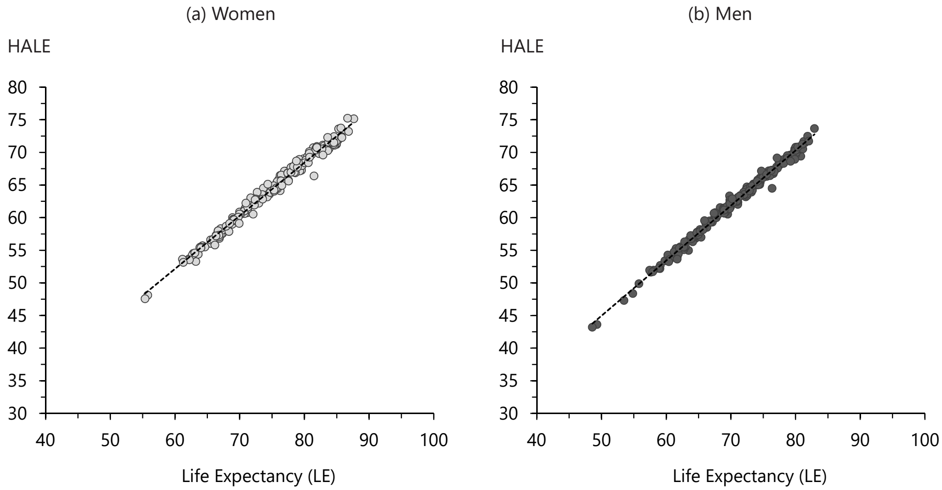


Source: own calculations with data from *EUROSTAT* and *IHME*.

those where the healthy lifespan decreased between 2010 and 2013, those that experienced an increase of up to one year, those where the healthy lifespan increased between one and two years, and those that already had reached the EU objective with an increase of two years or more. According to the HLY, almost half of the populations experienced decreases in the healthy lifespan between 2010 and 2013, including countries as diverse as Latvia, Slovakia, Germany, Greece, Denmark, and the UK. According to the HALE indicator, however, almost 95 percent of European populations experienced an increase in healthy lifespan during these same years, with approximately 25 percent having already exceeded the targeted increase of two healthy life years.

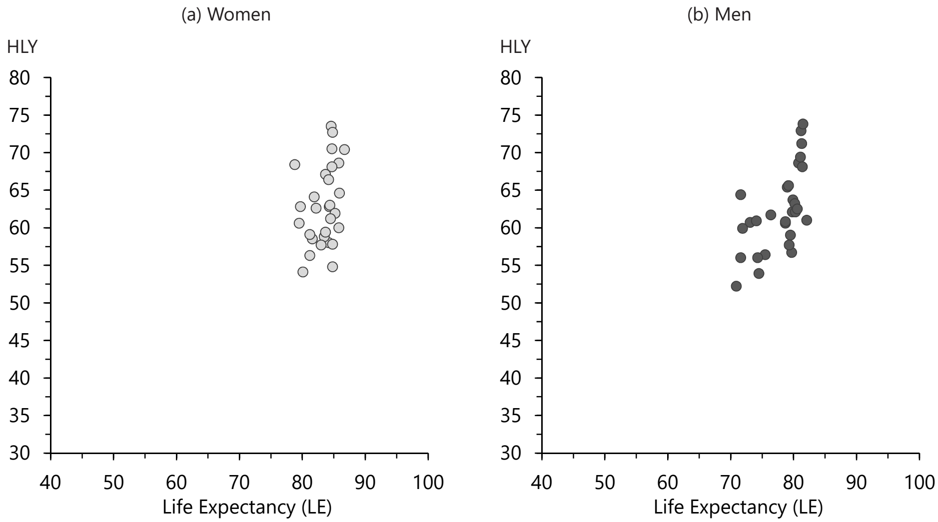
These differences between HLY and HALE raise the question of which HE indicator is better suited to describe population health. GALI, which serves as the foundation for the HLY indicator, is based on individuals' self-assessments of their level of perceived activity limitation. By contrast, HALE is based on the "Global Burden of Disease" (GBD) which quantifies the comparative magnitude of health loss due to approximately 300 diseases, injuries, sequelae (consequences of diseases and injuries), and risk factors in a summary measure for population health. The GBD utilizes more than 100,000 different data sources, such as hospital discharge data, disease registries, and household surveys, and uses numerical weights ranging from 0 (perfect health) to 1 (death) to combine all health issues into a single indicator (for details, see *IHME* 2013). At first glance, this approach may seem to be the ultimate solution by not only taking the multidimensional nature of health into account, but also by serving as a measure free of subjective decisions regarding the type of health indicator and the grouping of its outcome categories. However, the GBD methodology necessarily gives the highest weights to the most severe health problems. Since these are also associated with the highest risk of dying, the HALE indicator correlates strongly with LE. This correlation becomes apparent in Figures 3a and 3b, which contrast the HALE values for over 200 countries on the x-axis with the respective LE at birth values on the y-axis for women and men, respectively.

Fig. 3: Association between health-adjusted life expectancy (HALE) and life expectancy at birth (LE) for 204 countries by sex, 2019



Source: own calculations with data from *IHME*.

Fig. 4: Association between healthy life years (HLY) and life expectancy at birth (LE) for 29 European countries by sex, 2019



Source: own calculations with data from *EUROSTAT*.

The correlation between the two indicators is so strong that HALE does not provide insights into differences between countries beyond LE. This is not the case for the HLY, which is significantly less correlated with populations' LE (see Fig. 4a and 4b). This illustrates that the choice of health indicator is crucial. Thus, it is important to consider carefully which health dimension should be reflected in the HE indicator used to answer a particular research question or policy goal.

Despite the decline in HLY in the first years after the launch of the EU 2020 strategy, the ambitious EIP-AHA goal was eventually achieved: HLY increased in the EU-27 countries by 2.2 years between 2010 and 2020 (EUROSTAT database).[1] This appears to be a great success of EU's development programme, especially if we imagine this improvement as a steady trend. However, a closer look at the data reveals that the increase in HLY was not gradual. Between 2010 and 2013, HLY had declined by -0.8 years. The decisive trend change occurred in 2015 and 2016, when HLY increased by 1.5 and 1.2 years, respectively (see the solid black line in Fig. 5). As a result, HLY at this point has increased by 2.2 years compared to 2010. HLY then remained essentially unchanged through 2020.[2]

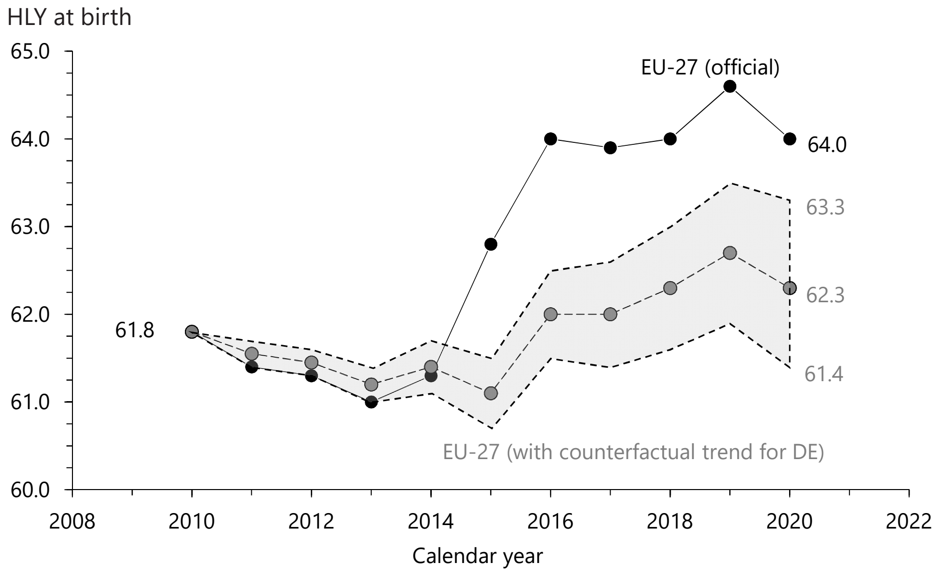
To understand to what extent these increases in HLY reflect a joint success of the European population, we decomposed the changes in HLY between 2014 and 2015 and between 2015 and 2016 into the individual contributions of each country. Therefore, we reconstructed the HLY for EU-27 for each calendar year from the weighted average of member states' HLY, with the weights being the countries' relative populations sizes. The results of the decomposition reveal that the strong increase in HLY between 2014 and 2016 was caused almost exclusively by two countries: Germany, which was solely responsible for the increase in 2015, and Italy, which accounted for more than half of the increase in HLY in 2016 (see Table 1). Changes in HLY in these two countries have a particularly strong weight for the development of HLY of the entire EU-27 population due to their population size.

Table 1 also shows the decomposition of the change in HLY between 2010 and 2016, i.e., between the starting point of the Europe 2020 strategy and the year when the EIP-AHA target was reached. It becomes apparent that more than half of the overall increase is due to the contribution of Germany, where HLY increased by ten years between 2014 and 2015. This enormous gain in life years spent free from activity limitations did not result from an improvement in population health, however. Rather, it can be attributed to a change of the GALI question in the German SILC survey from the standard single question to a routed three-question version. Since 2015, participants in the German SILC are asked "Are you permanently limited by a health problem in activities of normal daily living?" with the two answer options "Yes" and "No". Only respondents who answer "Yes" are then directed to the two additional questions "To what extent are you limited in activities of normal daily

1 The figures described in the remainder of the section refer to the entire populations, i.e., women and men taken together. However, the trends and conclusions described apply equally to both genders.

2 The only exception was a further increase in HLY in 2019, but this gain was lost a year later due to the decline in LE in the first year of the Covid-19 pandemic.

Fig. 5: Trend in Healthy Life Years at birth in the EU-27 population from 2010 to 2020, official data from Eurostat versus counterfactual trend with 95 % confidence interval



Notes: DE = Germany, counterfactual trend estimated by generalized additive models (GAM) with restricted maximum likelihood for optimal estimates and smoothing.
Source: *EUROSTAT*; authors' own calculations.

living?" (strongly limited/moderately limited) and "How long have your restrictions lasted?" (less than six months/six months or longer).[3] Although the three-question version covers the same aspects as the original single question, the results for the GALI since 2015 are clearly not comparable to the results from previous waves of the German SILC survey (see also *von der Lippe et al.* 2017).

To simulate how HLY in the EU-27 could have evolved without the change in the German GALI question, we estimated a counterfactual trend of HLY in Germany from 2010 to 2020 with 95 % confidence intervals based on the actual trend from 2005-14 by generalized additive modelling (GAM). We then substituted the actual HLY values for Germany with our counterfactual estimates in the reconstructed HLY trend for the EU-27 population. The resulting simulated trend for EU-27 shows that the headline target of EIP-AHA would most likely have been missed without the modification of the GALI question in the German SILC (see the dashed line in Fig. 5). According to this estimate, the HLY would be 1.7 years lower than the official value in 2020, and thus only 0.5 years higher than in 2010, 1.5 healthy years short of the target. Even using the value for the upper 95 % confidence interval for the counterfactual HLY

3 Own translation of the authors of the German SILC questionnaire.

Tab. 1: Country-specific contributions to changes in Healthy Life Years at birth in the EU-27 population from 2014-15, 2015-16, and 2010-16

	2014-15		2015-16		2010-16	
	in years	in percent	in years	in percent	in years	in percent
Germany	+1.82	+121.49	+0.00	+0.00	+1.14	+52.01
Italy	+0.03	+1.84	+0.65	+54.09	+0.46	+20.77
Poland	+0.03	+1.73	+0.11	+9.16	+0.16	+7.38
Spain	-0.11	-7.04	+0.23	+18.96	+0.16	+7.22
Sweden	-0.00	-0.30	+0.01	+0.91	+0.12	+5.42
France	-0.03	-2.01	-0.03	-2.49	+0.09	+4.16
Romania	+0.01	+0.60	+0.01	+0.73	+0.07	+3.05
Slovakia	-0.00	-0.16	+0.02	+1.79	+0.04	+1.87
Hungary	-0.02	-1.18	+0.02	+1.28	+0.04	+1.76
Ireland	+0.00	+0.22	+0.01	+1.18	+0.02	+0.80
Slovenia	-0.00	-0.20	+0.00	+0.08	+0.02	+0.76
Portugal	-0.01	-0.62	+0.05	+4.00	+0.01	+0.48
Bulgaria	-0.01	-0.86	+0.04	+3.31	+0.01	+0.39
Belgium	+0.00	+0.17	-0.01	-1.04	+0.01	+0.35
Cyprus	-0.01	-0.36	+0.01	+0.81	+0.01	+0.24
Estonia	-0.00	-0.04	+0.01	+0.45	+0.00	+0.06
Malta	+0.00	+0.01	-0.00	-0.16	+0.00	+0.03
Czechia	-0.03	-1.77	+0.01	+0.60	+0.00	+0.00
Finland	-0.00	-0.32	+0.00	+0.30	-0.00	-0.04
Latvia	-0.00	-0.11	+0.00	+0.20	-0.00	-0.17
Luxembourg	-0.00	-0.11	-0.00	-0.17	-0.00	-0.18
Croatia	-0.03	-2.15	+0.02	+1.34	-0.01	-0.34
Lithuania	-0.02	-1.50	+0.01	+0.65	-0.01	-0.42
Netherlands	-0.08	-5.35	+0.05	+3.78	-0.01	-0.53
Denmark	-0.02	-1.57	+0.02	+1.29	-0.02	-0.77
Austria	+0.01	+0.38	-0.02	-1.66	-0.05	-2.15
Greece	-0.01	-0.80	+0.01	+0.60	-0.05	-2.17
EU-27	+1.50	100.0	+1.20	100.0	+2.20	100.0

Notes: countries are ordered by contribution in period 2010-16.

Source: *EUROSTAT*; authors' own calculations

trend in Germany, the EIP-AHA target would have been missed by half a year, with a value of 63.3 years in 2020. The strong HLY increase in Italy in 2016 also coincided with a technical variation in Italy's SILC, when the survey technique was changed from CAPI (Computer-Assisted Personal Interviewing) to CATI (Computer-Assisted Telephone Interviewing).

Regarding EU's HLY we can conclude that – with its current implementation – it cannot fulfil its important task as a structural indicator. Its value does not reflect the actual health of the population. Instead, it is decisively influenced by technical aspects related to the collection of GALI. Although this situation is unsatisfactory for everyone using and relying on the HLY indicator, it gives us the opportunity to rethink the concept's definition and estimation. Two immediate recommendations emerge from the lessons learned from the first years using HLY as a structural indicator (see also *Solé-Auró et al.* 2025). First, the survey question must be uniform, clear, and simple to minimize the impact of semantic differences between languages (see *Luy et al.* 2023). There is empirical evidence that the complication of the GALI question does not necessarily make the result more precise (*Cambois et al.* 2016). Second, the question should only have Yes and No options. These suggestions could lead to a very simple new GALI question, such as "Does your health limit you in your daily activities?" (Yes/No). The hesitation against a change of the health definition behind the structural health indicator might be reduced by the fact that several countries have already changed the GALI question in a similar manner as Germany did, including Sweden in 2014 and Slovenia in 2019. Given the great effect of this modification, it is likely that other countries will follow. Thus, the change of the GALI question is already ongoing, though with variation in the exact survey module, the time of implementation, and with no proper evaluation of its impact on estimating HLY trends. In our opinion, the advantage of reducing the existing bias and the possibility for manipulation notably outweighs the disadvantage of having a discontinued time series. This would probably be a significant step towards having a health indicator that allows for tracking trends across countries and evaluating the populations' progress toward the goals of public health programmes such as the EIP-AHA target.

3 Sensitivity of HE indicators: the "compression versus expansion of morbidity" debate

The comparison of HLY and HALE in the previous section illustrates how relevant the choice of health indicator is for one of the most important questions in health research, namely whether the life years gained through increasing LE are predominantly spent in good or poor health. Three theoretical models have been proposed in the literature:

1. longer lives are associated with more years spent in poor health, or the "expansion of morbidity hypothesis" (*Gruenberg* 1977),
2. longer lives are associated with a delay in the onset of health problems, or the "compression of morbidity hypothesis" (*Fries* 1980), and
3. there is a balanced relationship between health and longevity, or the "dynamic equilibrium hypothesis" (*Manton* 1982).

All three theories are based on the concept of HE and constitute the so-called "compression versus expansion of morbidity" debate (see e.g. *Jagger* 2000; *Payne* 2022). Empirical evidence supports each of these approaches, depending on the specific health domain considered (*Christensen et al.* 2009). In particular, existing research suggests a postponement or stagnation of functional limitations and disabilities (*Bardenheier et al.* 2016; *Crimmins* 2015; *Freedman et al.* 2016; *Payne* 2022; *Shen/Payne* 2023), but an increase in morbidity defined by the presence of several biomarkers or physician-assessed health conditions and chronic diseases

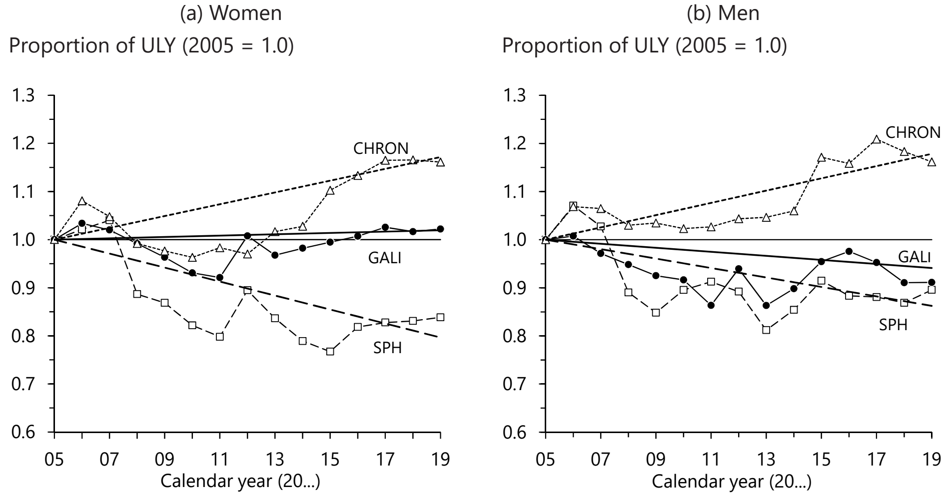
(*Beltrán-Sánchez et al.* 2016; *Crimmins* 2015; *Crimmins/Beltrán-Sánchez* 2011; *Crimmins et al.* 2019; *Payne* 2022; *Shen/Payne* 2023). These trends were confirmed in our investigation of trends in HE in Germany from 2005 to 2019 (*Luy* 2022, 2024b). We used the three health indictors of the "Minimum European Health Module" (MEHM) included in annual SILC: self-perceived general health, chronic morbidity, and activity limitations. General health reflects the self-assessment of a person's overall health based on the question "How do you rate your health in general?" (Very good/Good/Fair/Bad/Very bad), and chronic morbidity is defined as the presence of longstanding health problems based on the question "Do you have any longstanding illness or health problem?" (Yes/No). Activity limitations are assessed with the GALI as described in Section 2.

For the German SILC, the data from 2008 onwards is considered fully comparable (*Statistisches Bundesamt* 2019). Nonetheless, the comparability of the MEHM health indicators is in some cases significantly restricted because of changes in the questions and answer options (see *Luy* 2022). The question on general health was surveyed most homogeneously over the entire period 2015-2019, and thus provides the time series least distorted due to changes in question wording. In contrast, there were several changes to the question on chronic morbidity, which also lead to noticeable jumps in the indicator's value over time. The most significant changes occurred in the question on activity limitations, particularly the change to the GALI question in 2015, which was discussed in more detail in the previous section. For the illustration of trends in this section, we eliminated the break in the time series of activity limitations between 2014 and 2015 by adjusting all values from 2015 onwards to the jump between 2014 and the average value for 2015/16.

To assign the trends in HE (from age 16) to the three theoretical trend scenarios of the "compression versus expansion of morbidity" debate, we focus on the life years spent with health impairment, i.e., using the "unhealthy life years" (ULY) as the HE indicator. Therefore, we calculated the proportion of life years spent in poor or very poor general health, with chronic morbidity, and with activity limitations that are classified as "severe". The results are shown in Figures 6a and 6b for women and men, whereby the trends in ULY are normalized to the respective baseline value for 2005 for better comparability. Consequently, all trends start with the value 1.0 and show how the proportion of life years spent with impaired health has changed in relation to the baseline year over time. The annual values for chronic morbidity (CHRON) are shown in white triangles connected by dotted lines, those for self-perceived general health (SPH) in white squares connected by dashed lines and those for activity limitations (GALI) in black circles connected by solid lines. In addition, the respective trends are illustrated by simple linear regression lines, which are shown in bolder print in the respective line type.

Figures 6a and 6b show that the trends in ULY point in different directions for both women and men. ULY for general health show a reduction in the proportion of impaired life years, i.e., a compression of morbidity, whereas an expansion of morbidity can be seen in the case of chronic morbidity. The trend in life years spent with severe activity limitation is not clear and corresponds most closely to the dynamic equilibrium scenario, as the trend between 2005 and 2019 is close to

Fig. 6: Trends in the proportion of unhealthy life years (ULY) from age 16 in Germany, 2005-19, annual values and linear trend lines



Notes: CHRON = chronic morbidity, GALI = global activity limitations indicator, SPH = self-perceived health.

Source: *Luy* (2024b).

the 1.0 baseline, especially for women. For men, the trend points more towards the compression scenario, albeit to a lesser extent than for general health. In summary, it can be concluded that each of the MEHM health indicators provides a different answer to the compression-expansion question for the German population.

This raises the question of why different health indicators lead to different conclusions. A key difference between the three health dimensions of the MEHM lies in the severity of disease progression, which is reflected in their association with the risk of dying. Analyses using longitudinal data for Germany have shown that the risk of dying is significantly higher among people with poor general health and severe activity limitations than among people who report suffering from one or more chronic diseases (*Luy* 2021). Consequently, the different trends in ULY make sense. The increase in LE, i.e., in the total number of life years, must originate from the reduction in diseases with high mortality, which can explain the compression effect in poor and very poor general health. Chronic diseases, on the other hand, lead to death less frequently or later in life. Moreover, the likelihood of suffering from a chronic disease increases with age. It can therefore be concluded that the compression of morbidity in general health is a cause of the increase in LE, while the expansion of morbidity in chronic diseases is a consequence of the increase in LE (see also *Luy* 2022).

4 The ERC project LETHE

The examples presented in the previous two sections illustrate that HE indicators cannot be seen as simple extensions of conventional LE. HE indicators include a variety of sensitivities which can affect their values and thus have the potential to bias both the conclusions drawn from them as well as the policy recommendations and assessments that often follow. The main objective of the LETHE project was therefore to test and assess the HE indicators' sensitivity to several technical issues. These can be roughly divided into two areas:

1. Conceptual issues, i.e., aspects of health measurement, and
2. Technical issues, i.e., the methodological aspects of HE estimation.

The conceptual domain includes, above all, the definition of health. Health is multidimensional and difficult to quantify. Unlike LE, where there is only one variant of mortality (and moreover, individuals only die once), there are as many different variants of HE as there are health indicators. We demonstrated that the choice of health indicator has a significant impact on, e.g., the analysis of levels and trends in life years spent in good or poor health (*Di Lego* 2021; *Luy* 2024b), differences between women and men (*Di Lego et al.* 2020; *Luy* 2024a; *Nepomuceno et al.* 2021; *Schmitz/Lazarevič* 2020), and the health consequences of informal care (*Kaschowitz/Lazarevič* 2020). For most of these estimates of HE, the health status of individuals is measured by self-assessments based on specific questions in survey questionnaires. Therefore, the choice of survey has a strong impact on estimating HE on the one hand, but on the other hand, the reporting behaviour of the survey participants and their understanding of health and health problems also determines outcomes (*Lazarevič/Brandt* 2020; *Lazarevič/Quesnel-Vallée* 2023; *Luy et al.* 2023). In addition, the chosen definition of "good health" has an influence, as most survey questions on people's health status are not dichotomous and therefore can have different thresholds between good and poor health. These effects have been shown, e.g., by *Beller et al.* (2022). Particularly in the case of non-dichotomous health indicators, it makes a difference whether one studies trends or differences between populations in the healthy life expectancy or the unhealthy life expectancy.

The technical area of HE estimation includes, for example, the choice of the underlying life table (period table, cohort table, or a "mixed form," such as the "Cross-sectional Average Length of Healthy Life" discussed in the next paragraph), the handling of missing responses in surveys ("missing cases"), the procedure for smoothing the age-specific proportions of health status or the use of unsmoothed values, and the size of the age groups used. Moreover, the start of the upper open age interval (e.g., 75+, 80+, 90+) and the methodological combination of mortality and health based on prevalence values (Sullivan method based on cross-sectional data) or incidence values (multi-state method based on longitudinal data) can also influence HE estimates. Although the multi-state method is the conceptually superior approach, most studies use HE values derived from the method developed by *Sullivan* (1971), mainly due to data availability. To use the Sullivan method, a cross-sectional survey of health status and a period life table are sufficient, whereas the multi-state method requires several longitudinal observations of the health status and information on the mortality of the survey participants. The research team of the LETHE project examined in detail various aspects of these technical sensitivities. For instance, we showed that HLY estimates using EU-SILC data are not significantly biased by health-related attrition across samples, but sample attrition increases the uncertainty in the measurement of individual countries. Consequently, health-related attrition should be taken into account in cross-sectional estimates of HLY based on longitudinal samples of EU-SILC (*Muszyńska-Spielauer/Spielauer* 2023). We also found that attrition from longitudinal SHARE samples impacts cross-sectional data, yielding estimates of population health that are over-optimistic (*Muszyńska-Spielauer/Spielauer* 2022).

In addition to these tests and assessments of HE's estimation and measurement sensitivities, the project team developed three new health indicators with the aim of overcoming some of the limitations of the commonly used HE measures: "Cross-sectional Average Length of Healthy Life" (HCAL; *Sauerberg et al.* 2020), "Well-Being Adjusted Health Expectancy" (WAHE; *Muszyńska-Spielauer/Luy* 2022), and "DIF-adjusted HLY" (*Luy et al.* 2023). HCAL modifies the Sullivan method and combines the health prevalence data with the "Cross-Sectional Average Length of Life" (CAL), which was introduced by *Brouard* (1986) and *Guillot* (2003), instead of the classic period LE. In this sense, it captures historical mortality and health, in contrast to only a snapshot of time as reflected in period LE. HCAL is therefore a more refined indicator, and we suggest using it in addition to the conventionally estimated HE when data is available, since it allows for a broader spectrum of empirical analyses. We additionally introduced a method for decomposing differences in HCAL, which sheds new light on the interaction between mortality and health (*Sauerberg/Canudas-Romo* 2022). WAHE combines health and mortality information into a single indicator with weights that quantify the reduction in well-being associated with decreased health. The advantage of this indicator in comparison to others is its ability to differentiate between the consequences of health limitations at various levels of severity and its transparent, simple valuation function. DIF-adjusted HLY is an indicator that adjusts for the effect of a possible bias due to interpersonal reporting heterogeneity across populations. For this, we used anchoring vignettes (see *Luy et al.* 2023 for details). In a further article, we extended the state of the art by combining the three MEHM indicators, i.e., GALI, self-perceived health (SPH), and chronic health problems, into a single measure of generic health (*Lazarevič* 2023). We demonstrated the utility of this indicator by showing that it significantly reduced age-specific reporting behaviour and some non-health biases present in the classic indicators such as SPH. Furthermore, this approach can be flexibly extended to additional indicators of health, if available. We concluded that using the MEHM to measure generic (physical) health is a promising approach for a wide array of applications and is worth further exploitation. Most recently, we contributed to the development of a double-accounting approach to increment-decrement life table methods to intuitively derive a multi-state health distribution over age and cumulative duration spent in each state (*Riffe et al.* 2024).

5 Contributions of this special issue

The special issue "Levels and Trends of Health Expectancy: Understanding its Measurement and Estimation Sensitivity" marks the completion of the ERC project LETHE. It contains five articles, each dealing with a specific aspect of HE computation or a concrete empirical application on the basis of HE indicators.

The article "The Sensitivity of the Healthy Life Years Indicator: Approaches for Dealing with Age-Specific Prevalence Data" by *Vanessa Di Lego* and *Markus Sauerberg* (2023) deals with the issue that the characteristics of the age-specific prevalence distribution are still rarely accounted for, although patterns of prevalence often fluctuate considerably by age. Moreover, assumptions on health prevalence at very young ages are necessary for the estimation of HLY at birth because data on health below age 16 is not available in SILC data. The authors also assess whether smoothing the age-specific prevalence distributions by different methods, extrapolating to older ages, and changing assumptions at younger ages affect HLY estimates. They show that assumptions made before age 15 are most important and affect women and men differently, thus affecting HLY at birth for some countries. Estimates at age 65 are only slightly impacted, however. The authors argue that generalized additive models (GAMs) are promising for harmonizing and extrapolating health prevalence values to older ages, while using polynomials or aggregating into 5-year age groups seem more appropriate for younger ages. The authors conclude that – as most EU policies use HLY at birth and by sex for developing and monitoring health policies – caution is advised when estimating HLY for the total lifespan from birth until the highest ages. Another important contribution of the article is a "best-practice" guideline that researchers can use when their goal is to smooth health prevalence or graduate age patterns of health.

The article "Biases in Assertions of Self-Rated Health: Exploring the Role of the Respondent, Country of Residence, and Interviewer" by *Patrick Lazarevič* (2023) challenges the assumption that SPH is a universally valid and comparable measure of general health. The author uncovers significant non-health influences that bias respondents' assessments. Using data from more than 16,000 participants across five countries in the SHARE study, the author disentangles objective "latent health" and subjective "reporting behaviour," showing that factors such as the respondent's life satisfaction, the characteristics of the interviewer, and national context shape SPH responses. These non-health influences explained about 7 percent of SPH's variance, a notable figure considering that latent health accounts for about half. Crucially, individual respondent characteristics emerge as the strongest biasing factor. These findings underscore the need for researchers to account for these biases, particularly across gender, age, and countries, and suggest that supplementing SPH with more factual health questions in surveys could improve validity in cross-national comparisons.

The article "Healthy Lifespan Statistics Derived from Cross-Sectional Prevalence Data Using the Sullivan Method are Informative Summary Measures of Population Health" by *Magdalena Muszyńska-Spielauer, Tim Riffe,* and *Martin Spielauer* (2024) expands the application of the widely used Sullivan method for calculating HE by showing its ability to estimate broader healthy lifespan distribution statistics. By interpreting the Sullivan method through the lens of the stationary population model, the authors show that, for chronic conditions without recovery, it is possible to derive detailed healthy survival distributions using only cross-sectional prevalence data and life tables. Their empirical analysis, based on SHARE data from 2017 and EUROSTAT life tables, reveals important differences between conditional and unconditional HE, with conditional HE potentially providing new insights for health policy. Notably, they find that while higher LE is typically linked to lower lifespan inequality, higher HE can correspond to greater inequality in healthy years when measured conditionally. This work highlights the value of refining traditional methods to produce more nuanced measures of population health, offering fresh perspectives for comparative research and policymaking.

The article "Mismatches in Health: A Global Analysis of Discrepancies Between Self-Reported and Tested Mobility and Cognition" by *Vanessa di Lego, Sonja Spitzer* and *Patrick Lazarevič* (2024) highlights critical concerns about the reliability of self-reported health data, especially in global comparisons across diverse economic and cultural contexts. Analysing harmonized data from 25 countries, the authors reveal significant discrepancies between self-reported and objectively tested measures of mobility and cognition, with inconsistencies being most pronounced in lower-income countries. The study shows that these discrepancies correlate with the Human Development Index, as less developed nations exhibit greater mismatches. Moreover, while objective health declines clearly with age, self-reports often fail to capture this trend, particularly for memory. These findings cast doubt on the validity of using self-reports in cross-national health assessments and underscore the need for caution when comparing health data across regions with varying levels of development.

Finally, the article "Cross-Sectional Association Between Life Expectancy and Unhealthy Life Years: Proof of Concept Tests of the CroHaM Hypothesis" by *Marc Luy* (2024c) builds on the recently presented "CroHaM hypothesis," which proposes (1) that longitudinal health domain-specific expansion and compression effects depend primarily on the health domains' mortality risk and (2) that these effects exist equivalently in the cross-sectional context, affecting differences in HE between populations and subpopulations with different levels of LE (*Luy* 2021). Luy tests this hypothesis by analysing the association between LE and ULY at age 50 for a large number of subpopulations. The analyses are carried out for the three MEHM health domains which relate to mortality in different ways: poor self-perceived health and strong activity limitation with comparatively high mortality, and chronic morbidity with comparatively low risk of dying (see also Section 3). The results from the decomposition of differences in ULY between each subpopulation and the total population and between women and men for each subpopulation into the effects caused by differences in health ("health effect") and mortality ("mortality effect") support the CroHaM hypothesis. A positive relationship between LE and ULY can be found only for chronic morbidity, whereas this relationship is negative for poor self-perceived health and strong activity limitation. However, when the mortality effect is controlled for, there is a negative relationship between LE and ULY for all three health domains. The practical relevance of these findings is discussed using the example of the so-called "gender paradox" in health and mortality. The author concludes that the CroHaM hypothesis may describe an important determinant of life years spent with and without health impairment, and it may help us understand and interpret trends and differentials in healthy or unhealthy life years based on cross-sectional data.

6 Conclusions from the LETHE project

The examples presented and summarized in this editorial are not only an academic matter. They demonstrate that HE's measurement and estimation sensitivity can easily have severe consequences: mis- or over-interpretations can enter the political discussion and influence current and future public health programmes. The efforts that have been hitherto undertaken to improve the estimation of HE focused primarily on the measurement of health with surveys (see, e.g., *McDowell* 2006). However, the effect of the chosen HE indicator, data, and method have remained widely unexplored, and they are often overlooked even in the context of major research topics. In Sections 2 and 3, we have shown this in greater detail for trends in HE. The same sensitivity aspects affect research on other phenomena with high societal relevance, such as the significant differences in HE between European populations (see e.g. *Jagger et al.* 2008; *Jagger et al.* 2013) and between subgroups by socio-economic position (e.g. *Cambois et al.* 2011; *Crimmins/Saito* 2001; *Fouweather et al.* 2015; *Mäki et al.* 2013; *Matthews et al.* 2009; *Solé-Auró et al.* 2015), or the emergence of the so-called "gender and health paradox" (e.g. *Crimmins et al.* 2002; *Crimmins et al.* 2011; *Di Lego et al.* 2020; *Di Lego et al.* 2019; *Luy* 2024a; *Rieker/Bird* 2005).

The explanation for these shortcomings of the extant research on population health likely lies in the fact that the quantitative assessment of health is one of the youngest endeavours in population research. Naturally, the problems caused by the measurement of health are perceived at an early stage of research, while the HE indicators' measurement and estimation sensitivities are less obvious. However, the examples presented in Sections 2 and 3 have illustrated that the methodological sensitivity of HE is equally important for providing unbiased interpretations and for drawing fully appropriate conclusions. The efforts undertaken so far to investigate these issues do not include a systematic, comprehensive, and complementary analysis of the methodological features of HE estimation to explore their empirical impacts on answers to a specific research question (see, e.g., *Jagger et al.* 2020; *Murray et al.* 2002; *Robine et al.* 1992; *Robine et al.* 2003; *Robine et al.* 1993). Many, but not all methodological issues are mentioned in these books. However, these issues were elaborated independently by different authors who focused on very different theoretical and empirical aspects.

The central aim of the ERC project LETHE was to fill this gap and to assess the HE indicators' sensitivity to specific measurement (i.e., conceptual) features and specific estimation (i.e., technical) features, identify the most important sources of possible biases, and find options for overcoming these issues. During the project work, it turned out that the investigated estimation features do not lead to a significant bias in most of the tested empirical applications, especially for those aged over 65 years. In other words, HE indicators are rather robust regarding the technical aspects of their estimation. However, the opposite applies to the investigated measurement features. These have an enormous impact on the HE indicators and can lead to significant biases in empirical application, as shown by way of the examples of the EU's EIP-AHA goal to increase the number of healthy life years in its member states by two years between 2010 and 2020 in Section 2 and the "compression versus expansion of morbidity" debate in Section 3. The employed health dimension, choice of survey, and reporting heterogeneity across populations are some of the aspects that have proven to be more significant than different estimation techniques used to compute health prevalence. In some cases, the issue may even lie at the core of data collection, such as the gender bias in how health data is collected and what information is considered important.

These new insights into the understanding of HE values, trends, and differentials are highly relevant and valuable for all researchers, policy makers, and other stakeholders who are using these indicators to track levels and trends of population health. Above all, they help reduce the risks of misinterpretation and drawing potentially misleading conclusions. It is important to note, however, that we focused on prevalence-based methods, that is, using health stock information at a given period in time by age and sex across European countries. It is uncertain whether the estimation issues described above are of equal relevance for incidence-based HE measures, where the prevalence is derived from longitudinal transitions between health states observed during a study period (*Lièvre et al.* 2003). Nonetheless, because of the limited availability of longitudinal data, all EU-level policies are formulated using prevalence-based health information, and consequently, our research focused on this relevant practical application.

To conclude, the measurement and estimation sensitivities of the HE indicator are highly relevant for all researchers, policy makers, and other stakeholders who use this statistical parameter to track levels and trends of population health. Ever more systematic exploration of these measurement and estimation issues with direct empirical applications to concrete actual research questions is needed to provide new insights not only into the levels and trends of HE, but also into its main drivers and causal mechanisms. The research carried out within the ERC project LETHE, including the articles of this special issue, provides some insights into the HE indicators' sensitivity and hopefully helps raise awareness of these sensitivities to avoid the mis- or over-interpretations of HE statistics.

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