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Disaggregation of official demographic projections in sub-groups by education level: the neglected “composition effect” in the future path of life expectancy

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Abstract

We developed an innovative method to break down official population forecasts by educational level. The mortality rates of the high education group and low education group were projected using an iterative procedure, whose starting point was the life tables by education level for Italy, based on the year 2012. We provide a set of different scenarios on the convergence/divergence of the mortality differential between the high and low education groups. In each scenario, the demographic size and the life expectancy of the two sub-groups were projected annually over the period 2018–2065. We compared the life expectancy paths in the whole population and in the sub-groups. We found that in all of our projections, population life expectancy converges to the life expectancy of the high education group. We call this feature of our outcomes the “composition effect”, and we show how highly persistent it is, even in scenarios where the mortality differential between social groups is assumed to decrease over time. In a midway scenario, where the mortality differential is assumed to follow an intermediate path between complete disappearance in year 2065 and stability at the 2012 level, and in all the scenarios with a milder convergence hypothesis, our “composition effect” prevails over the effect of convergence for men and women. For instance, assuming stability in the mortality differential, we estimated a life expectancy increase at age 65 of 2.9 and 2.6 years for men, and 3.2 and 3.1 for women, in the low and high education groups, respectively, over the whole projection period. Over the same period, Italian official projections estimate an increase of 3.7 years in life expectancy at age 65 for the whole population. Our results have relevant implications for retirement and ageing policies, in particular for those European countries that have linked statutory retirement age to variations in population life expectancies. In all the scenarios where the composition effect is not offset by a strong convergence of mortality differentials, we show that the statutory retirement age increases faster than the group-specific life expectancies, and this finding implies that the expected time spent in retirement will shrink for the whole population. This potential future outcome seems to be an unintended consequence of the indexation rule.

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Introduction

The ageing of the European population and the resulting risk of financial crises in public pension systems is a major political challenge in all European countries. This challenge showcases the long-lasting attention paid by the European Commission to the elaboration of long-run projections of pension expenditures and their ratios to GDP (European Commission (DG ECFIN), 2009, 2012, 2015, and 2018). These projections draw heavily on demographic parameters, which are a basic instrument for social science scholars and policymakers and are produced by national and international public bodies (EUROSTAT, 2017; ISTAT, 2017a; United Nations, Department of Economic and Social Affairs, Population Division, 2017).

Population projections show a high and useful variability of results both between and within the exercises carried out by different bodies. The differences depend on the hypotheses regarding fertility rates, life expectancy, and immigration. However, official demographic projections usually do not provide any disaggregation by socioeconomic sub-groups, and this aspect represents a major drawback in the context of ageing and retirement planning for two main reasons. First, health status and life expectancy have a strong socioeconomic gradient (Dowd et al., 2011; Mackenbach & Valverde, 2018; Majer, Nusselder, Mackenbach, & Kunst, 2011; Office for National Statistics, 2012; Stringhini et al., 2017), even in old age (Enroth, Raitanen, Hervonen, & Jylhä, 2013; Hoffmann, 2008, 2011; Zarulli, Domantas, & Jdanov, 2012), the future evolution of which is highly debated (Bosworth & Zhang, 2015; Currie & Schwandt, 2016). The transparency and soundness of the hypotheses that support any population projection would increase considerably if they were disaggregated by socioeconomic sub-groups. Second, social differentiation of longevity increases the risk of financial imbalances for public pension systems, given that greater longevity is concentrated among pensioners who receive richer annuities (Organization for Economic Co-operation and Development, 2016). Furthermore, societal changes in economic structures over time can lead to changes in the distributions of socioeconomic indicators among populations, and, ultimately, in their correlation with mortality (Chen, Beckfield, Waterman, & Krieger, 2012). Taking into account those future, potential changes in population structure improves the soundness of both demographic projections and financial sustainability evaluations.

Actually, in the last decade, the importance of including education in population projection has been recognized and has led to a growing body of research and literature on this topic (See among others: KC et al., 2010; Lutz, Butz, & KC, 2014; Martins, Rodrigues, & Rodrigues, 2014; National Academies of Sciences, Engineering, and Medicine, 2015).

Our main research purpose in this paper is to project the demographic size of different social groups consistently with official projections of the whole population. We put forward a new computational procedure that allows us to break down official demographic projections by the socioeconomic status of population. Our starting point is the

most updated evidence on differences in mortality by level of education, and our research result is the disaggregation of the future projected population into two groups: one with low levels of education, corresponding to levels 0–2 of ISCED-2011 scale (UNESCO, 2012), and the other with high levels of education, corresponding to levels 3–8. Our definition of the two groups is the most meaningful for the Italian educational system because it distinguishes between those who achieved, at best, compulsory education, and the rest of the population.

To this purpose, we had to address a challenging research question about the future evolution of mortality differentials by level of education. That question has two very distinct aspects, which ask for specific resolution: on the one hand, we have to consider the prospective change of education levels in the population, and on the other hand, we have to consider the eventual developments of mortality differentials by education level. The first issue is beyond the scope of our research, and we simply assume that future demographic cohorts will show the same probability of reaching a high level of education as the youngest cohorts in the data presently available. This assumption implies that the share of those with low education in the total population is decreasing over time. The second issue, in contrast, is at the core of our research, and we need to explore the consequences of different potential paths of mortality differentials. Therefore, we start from the hypothesis that mortality differentials will keep stable in the time to come, and we next compute a set of projections, some of them based on some degree of convergence in mortality rates and others based on different degrees of further divergence.

Hence, our research outcome is a set of projected demographic scenarios, where each of them defines a distinct prospective path of life expectancy for the social group with low education and for the social group with high education. Our multiplicity and variety of results suggested we investigate the relationships among the path of life expectancy in the total population, coming from official demographic projections, and the same paths in each of these two social groups. Given our assumption that the share of those with low education on total population is decreasing over time, in any of our population projections, overall life expectancy converges to the life expectancy in the high education group. We call this feature of our outcomes the “composition effect”, and it is strictly related to the research findings on historical data by Costa et al. (2017), Costa (2018) and Luy et al. (2019). Using very different data sets, they show that the increase in life expectancy for the whole population was partially driven by the change in the education level. As a consequence, the increase in life expectancy for each social group was smaller than the increase for the whole population.

However, in our projections, the composition effect overlaps with the path of mortality differentials specific to each scenario, and this raises a couple of further and final research questions, never addressed in the literature until now: first, we explore how strong the convergence in life expectancy between groups needs to be in order to offset the composition effect. When the composition effect is actually offset, one of the groups should show prospective gains in life expectancy, which are larger than the ones projected for the total population. Second, since the composition effect brings about an increasing gap between the life expectancy of the population and that of the most disadvantaged group, we study how strong the convergence in life expectancy has to be in order to have a gap that is stable or decreasing over time.

The context of increasing life expectancy at later ages and a rigorous indexation rule of the legal age at retirement¹ represents the major rationale of our choice to test our innovative method primarily on Italian data. The second justification for focusing on Italy is the paucity of available data on mortality differentials. We took advantage of that constraint by developing a method that is parsimonious in terms of data requirements and therefore can be easily applied to other countries whose data availability is comparable to that of Italy.

Given the availability of data in Italy, we used the level of education as a proxy for socioeconomic status. We divided the population into two groups by level of education: at most lower secondary education (low education, ISCED-2011 levels 0–2) and at least upper secondary education (high education, ISCED-2011 levels 3–8). The statistical distribution of population by age, sex, and education was derived from the last available “Work and Study Trajectories of Graduates” survey by ISTAT (2017b). The probability of becoming a member of the high education group was kept constant over the projection period (2018–2066) for the sake of simplicity².

Our projection procedure mirrors the one used by Italian National Institute of Statistics (ISTAT 2018, years 2018–2065) and is based on a discrete-time Markov chain process, where the population vector is the distribution of the Italian population by age and sex on the 1st of January for each year of projection. The transition matrix is based on a cohort-component methodology, and it is composed of the probabilities by age and sex to survive until the next year (prospective probabilities) and by specific fertility rates. Conversely, immigrations and emigrations are estimated as influx and outflow vectors of the population, distributed by sex and age. ISTAT predicted the prospective probabilities, fertility rates, and migration flows using an expert-based probabilistic model, and we adopted the ISTAT projection parameters in the Median Scenario³. We expanded both the vectors and the transition matrices to obtain the distribution by age, sex, and education of the Italian population for each year of the projection, starting in 2018, when we used data derived from the “Labour Force Survey” by ISTAT (2018).

The mortality rates of the sub-groups were projected using an iterative procedure, whose starting point was the estimate of the life tables by education level made by ISTAT, which are based on the year 2012. First, we estimated the Brass logit relation between the survival curves at high and low education levels in 2012. Second, we projected the survival relationship into the future, either keeping it stable or simulating different paths of convergence/divergence, and simultaneously considered the mortality rates of the sub-groups as components of a weighted average, which was forced to be equal to the Italian mortality rates officially projected by ISTAT.

In the following sections, we stress the economic and political relevance of disaggregating official demographic projections by socioeconomic sub-groups (section “Inequality in ageing and its financial and economic impacts”), and we summarize the most

¹Since 2012, in Italy, age and seniority prerequisites for retirement have been linked to variations in population life expectancy.

²Assuming a different hypothesis would not significantly change our results, since the cohorts that will contribute to defining the life expectancy at 65 years of age over the projection period (i.e. Italians born between 1953 and 2000) will presumably show a composition effect in terms of education level largely similar to the one observed by the ISTAT survey.

³We also tested our method on alternative ISTAT scenarios, resulting in substantially identical outcomes. The results are available in the supplementary materials.

recent evidence on differential mortality by socioeconomic status in Italy (section “Differential longevity by educational level in Italy”). In section “Projections of populations for sub-groups and related literature”, we briefly discuss the current methods in the literature to project a population by sub-groups, and in section “[Methods](#)”, we present our method.

In section “[Results](#)”, we summarize the outcomes of our projections, which confirm the validity of our method, by disaggregating the official demographic projections with a good degree of approximation (maximum error equal to 0.02‰); they also show that the “composition effect” is highly persistent, even in scenarios where the mortality differential between social groups is assumed to decrease over time. Our threshold convergence scenario envisages that the mortality differential follows a midway path between complete disappearance in the year 2065 and stability at the 2012 level. In the threshold scenario, and in all the scenarios with a milder convergence hypothesis, the “composition effect” prevails over the effect of convergence for both men and women. This model has two main effects: first, prospective gains in life expectancy of the population are larger than the ones projected for the sub-groups, and second, the mortality gap between those with low education and the whole population increases over the projection period. This result has relevant implications for retirement and ageing policies, which are discussed with the limitations of the study in section “[Discussion](#)”. Finally, we present our conclusions in section “[Conclusions](#)”.

Inequality in ageing and its financial and economic impacts

In Europe, the ageing of the population is a major challenge for the decades ahead. The European Commission highlighted the need for pension reforms in member countries in order to deliver adequate and sustainable retirement incomes (European Commission, [2010](#), [2012](#)). At the same time, those policy documents clearly show the lack of attention paid to unequal ageing: they do not mention this issue and completely overlook the possibility of differentiating policies according to work position, type of job, and/or health status. As a consequence, these policies do not consider that the adoption of identical policies for individuals experiencing different ageing processes might have relevant economic, financial, and welfare impacts or that poverty and social exclusion could be perpetuated by those policies. The European Commission’s lack of attention to heterogeneity in ageing is reflected both in its reports that monitor the long-run impact of ageing on public budgets of member states and evaluate to which degree member states follow the Commission’s recommendations (European Commission (DG ECFIN), [2009](#), [2012](#), [2015](#), [2018](#)) and in its reports on the adequacy of current and future old-age incomes (European Commission (DG EMPL), [2012](#), [2015](#), [2018](#)).

Our research aims to develop a procedure that includes longevity inequalities in official demographic projections at the national and European levels and yields approximate coherence between official demographic projections and projected populations in two groups: those with low levels of education, and those with high levels of education. This approach represents a major innovation with respect to the present state of the art (Eurostat, [2017](#); European Commission (DG ECFIN), [2017](#)). Our innovative method could be the first step towards projection models drawing on the assumption of socially differentiated longevity, productivity, and health status.

Differential longevity by educational level in Italy

Socioeconomic status is usually defined by a set of proxy variables, such as education level, income, house conditions, and job position, which allow us to define a social hierarchy (Galobardes, Shaw, Lawlor, Lynch, & Davey, 2006a, 2006b). The essential role of the socioeconomic determinants of health and mortality in explaining the observed heterogeneity in the life span of individuals is a “solid fact” (Marmot & Wilkinson, 2006; Wilkinson & Marmot, 2003), which has been recognized by the World Health Organization (World Health Organization, Regional office for Europe, 2012). Many studies using survey or administrative data have provided evidence in support of a strong correlation (and, in some cases, causality) between socioeconomic position, health status, and mortality (e.g. Hoffmann, 2008; Majer et al., 2011; Marmot & Siegrist, 2006). The social gradient involves both young and old ages as well as workers and retired individuals. On the other hand, the future evolution of such a gradient is highly debated. Some studies found a deepening gap between opposite socioeconomic positions (Bosworth & Zhang, 2015), whereas others found a narrowing gap (Currie & Schwandt, 2016).

In the case of Italy, estimates of socioeconomic differences in mortality are limited in number and often methodologically inconsistent over time. We used education as a proxy for socioeconomic status because ISTAT recently provided life tables until age 90 differentiated by gender and by four educational levels: none or primary, lower secondary, upper secondary, and tertiary or more. These tables come from a linkage between death certificates and Italian census data in 2012 (ISTAT, 2016). According to ISTAT estimates, the difference in life expectancy at birth between extreme educational levels amounts to 5.2 years for men and 2.7 years for women. At 65 years of age, the differences in life expectancy are 2.2 and 1.3 years for men and women, respectively.

Before the 2016 study, two other reports had been published (ISTAT, 1990, 2001) based on census data in 1981 and 1991 and on the linkage with death certificates during the first 6 months after the census. Unfortunately, the results of the three studies on census data are not easily comparable. The response rate of Italian municipalities was very unstable over time; furthermore, the age classes were modified in the 2016 analysis. In ISTAT (2001), index numbers of mortality rates in 1982 and 1992 were computed, and an increase in mortality differences by educational level was observed for both men and women, with older women being the only exception. Following the ISTAT methodology, we first computed comparable index numbers for 1982, 1992, and 2012. Then, as explained in the “Methods” section, we summarized the differences in mortality over time by using the parameters of a Brass logit relation.

Recently, an article by Luy et al. (2019), using official data on differential mortality by education level, investigated the relation between the structure of the population by level of education and the population life expectancy. The authors used the “replacement decomposition technique” (Andreev, Shkolnikov, & Begun, 2002; Shkolnikov et al., 2006) to measure the impact of increasing education levels on the rising path of life expectancy in Italy, Denmark, and the USA between 1990 and 2010. They pointed out that a consistent part (approximately 20% for Italy) of improvement in longevity can be attributed to the changing structure of the population by level of education.

There are alternative estimates of life expectancy differentials by social status indicators. Maccheroni (2008) worked on 2001 census data and death certificates but lacked information on mortality after age 75. Lallo and Raitano (2018) used a longitudinal dataset and found a difference of about 5 years in life expectancies at 60 years of age across working status conditions (see also Luy, Di Giulio, & Caselli, 2011). Costa et al. (2017) reported that in Turin, the difference in life expectancy at age 35 between an individual with a university degree and one with primary education was 5 years for men and 4 years for women. When socioeconomic status was measured by social class, Costa, Zengarini, Demaria, D'Errico, and Leombruni (2013) showed that in Turin, male and female managers at age 65 had life expectancies 3 years and 1 year higher, respectively, than unskilled manual workers. Stringhini et al. (2015) found that absolute educational inequality in mortality strongly declined over 40 years in Turin. Relative differences were stable among men and tended to narrow among women.

Alternative data sources have been used to estimate the socioeconomic gradient in mortality. Belloni, Alessie, Kalwij, and Marinacci (2013), d'Errico et al. (2005), and Leombruni, Richiardi, Demaria, and Costa (2010) used the pension and social contribution archive managed by the national social security body. Marinacci et al. (2013) and Piccinelli et al. (2018) worked on a national longitudinal study based on a health interview survey carried out in 1999–2000 by the Italian Statistical Institute. A longitudinal study specifically focused on ageing and carried out in 1992–1993 was used by Amaducci et al. (1998) and by Minicuci et al. (2005). None of those studies estimated life expectancy differentials.

Projections of populations for sub-groups and related literature

Projecting dimensions beyond age and sex is one of the recent developments in population projection methodology (Willekens, 2006; Wilson & Rees, 2005)⁴. For example, the base population can be disaggregated by region of residence, ethnicity, health, and occupational or educational status. The disaggregation by social sub-group of the population and its evolution over time can be achieved using two different methodologies: multistate modelling and microsimulations.

Microsimulation models are built on individual-level determinants of events, offering the possibility to consider a large number of different sub-groups and to estimate the potential interactions among several dimensions. In microsimulation, however, outcomes are subject to random variation, which makes the method subject to “specification randomness”; the degree of random variation affecting the output of the model increases with the number of explanatory variables included in the model (Van Imhoff & Post, 1998).

Conversely, the approach of multistate modelling is macro since the average outcome is modelled and the determinants are external to the model. This attribute makes the method unmanageable when too many additional dimensions are considered because the arrays capturing the interaction between variables become very large and the transition probabilities cannot be estimated reliably. However, modelling the average outcome allows better control of the results and ensures consistency between the base population and sub-group forecasts (Booth, 2006; Rogers, 1995a).

⁴Multidimensional projections started with Keyfitz and Rogers in 1980s.

Since the main goal of the present study is to provide a method to compute disaggregated projections approximately consistent with base population projections published by official bodies, multistate modelling seems to be the more suitable methodology for our purposes. Multistate modelling is the dynamic multidimensional extension of the cohort-component model (Caswell, 2001; Lutz, Goujon, & Doblhammer-Reiter, 1999; Rogers, 1995a; Schoen, 2010). The age and sex dimensions are expanded to additional sources of differentiation, such as educational or occupational status. This implies the need to model transition probabilities among states (sub-groups) and the interactions of various states with the vital rates (mortality, fertility and migration). Furthermore, the transition probabilities can be kept constant over the simulation period or can be changed according to appropriate assumptions and extrapolations of past evidence.

Recent works on multistate projections by level of education are based on the methodology developed by the IIASA (KC et al., 2010; Lutz et al., 2014; Lutz & Goujon, 2001; Lutz, Goujon, KC, Stonawski, & Stilianakis, 2018). Martins et al. (2014) produced a demographic projection for the Portuguese population by sex, age group, and level of educational attainment for the period 2011–2031, whereas Lutz et al. (2014) produced demographic projections by educational attainment of the world population until 2100, and for 150 countries until 2050 (KC et al., 2010).

The methodology suggested by Lutz et al. (2014) is the closest to ours. Their multistate projections focus on the differentiation of vital rates, mainly fertility, by education level and its impact on population size. They briefly address the evolution and estimate of mortality differentials and mainly refer to the work of KC et al. (2010) and Lutz, Goujon, KC, and Sanderson (2007). They adapt a Gompertz relational model (Booth, 1984; Brass, 1971) and estimate the age pattern of mortality by education on the basis of the projected life expectancy at age 15 by education and the mortality schedule of the whole population.

The IIASA approach has several remarkable advantages: it produces projections that cause implicit assumptions on social differentials in demographic variables to emerge, it allows the examination of unique and useful scenarios, and it improves both the transparency and the accuracy of population projections. Nevertheless, IIASA-disaggregated projections may not be consistent with the aggregated ones provided by official bodies⁵. Moreover, the adapted Gompertz relational model makes it difficult to consider differences by educational level in the evolution of the mortality schedules.

Ultimately, for our purposes, multistate modelling is the best choice; however, we need a method to project mortality rates by education (rather than fertility rates as in Lutz et al., 2014). Furthermore, our vital rates must be consistent with the rates projected by official bodies for the whole population.

Recent studies on forecasting life expectancy by sub-groups (Danesi, Haberman, & Millosovich, 2015; Oeppen, 2008; Van Baal, Peters, Mackenbach, & Nusselder, 2016) use some extensions of the Lee-Carter model (Lee & Carter, 1992; Li & Lee, 2005), which is currently the most popular model for forecasting mortality rates in a single population (Booth, 2006; Booth & Tickle, 2008). Li and Lee (2005) proposed a method to forecast two or more populations simultaneously, allowing each population to have

⁵The main purpose of most multistate projections is to provide different and more “realistic” aggregated results with respect to simpler models (Rogers, 1995b).

its own age pattern and level of mortality but imposing shared rates of change by age in order to obtain non-divergent forecasts. They labelled this forecast as “coherent”, but the definition of coherence has been recently debated. Whereas Li and Lee (2005) considered “coherent” a non-divergent forecast, Hyndman and Ullah (2007) proposed a different approach, labelling mortality forecasts as “coherent” when the forecasted age-specific ratios of death rates for any two subpopulations converge to a set of appropriate constants. A methodological application of this definition is the product-ratio method with functional time series (Hyndman, Heather, & Farah, 2012).

However, all the methods mentioned above require a long time series of age-specific mortality rates for each subpopulation. In contrast, we need a method that is parsimonious in terms of data requirements in order for the model to be useful when there is a paucity of official data, as in the case of Italy, where data on mortality differentials are very poor and official estimates of mortality by educational status are available just in three single points in time (1982, 1992, and 2012). These data are based on the census and are not easily comparable with one another. In addition, both Li and Lee (2005) and Hyndman and Ullah (2007) focus on the internal coherence of projections, that is, on the property of non-divergence in the forecasts of mortality rates for a set of subgroups within the same population. For our purposes, this is not enough. Our concept of “coherence” is external as well as internal, since we need to model and parameterize the future evolution of mortality differentials under the constraint that the total sum of population in all the sub-groups approximately adds up to the projection for the whole population provided by some external official body. To fulfil all our needs, we developed a new method by taking advantage of what Rogers (1995a) suggests in the case of multiregional projections, which is to parameterize the model schedules of demographic rates of the base population and then derive the projections of sub-group populations on specific estimates of the same functional representation. In contrast to Rogers, instead of the mortality of a single population, we parameterize the “relation” between the mortality rates in different groups and then project such a relation under the constraint of reproducing the mortality rates of the whole population provided by some official body. The relational model of mortality (Brass, 1971), which linearly relates the logit transformations of two survival curves using only two parameters and at least one complete survival curve, seems to fit our needs appropriately. Moreover, the Brass model has been largely used for indirect mortality estimates and forecasts (Keyfitz, 1991; Pollard, 1987).

In the “[Methods](#)” section below, we will show how we used the Brass method to obtain a projection of the Italian population by educational status that is “coherent” with the official statistics produced by the Italian National Statistics Institute. The flexibility, comparability, and applicability of our methodology to contexts with poor or non-homogeneous official statistics make it a valuable instrument for policymakers.

Methods

Our projection method mirrors the discrete-time Markov chain model to forecast the Italian population in ISTAT (2017a), where migrations are taken into account by adding and subtracting exogenously determined vectors. In our approach, we first expanded both the transition matrices and the population vectors to obtain the distribution of age, sex, and education of the Italian population for each year of the projection. We divided

the Italian population into two groups: low education (at most lower secondary education, ISCED-2011 levels 0–2) and high education (at least upper secondary education, ISCED-2011 levels 3–8)⁶. Then, after defining the life cycle and specifying both the transition matrices and the population vectors, we projected the transition probabilities. Particular attention was given to the computation of survival probabilities by education level, which are the key point of our work and show the property of “coherence”, as defined in section “Differential longevity by educational level in Italy”, with ISTAT projections for the whole population. Their computation is based on the estimate of the Brass logit relation between the survival curves in the high and low education groups in 2012 and on a set of alternative assumptions on the potential paths of mortality differentials in the future.

We first keep constant the Brass parameters estimated in 2012 over the projection period, hypothesizing a stable mortality differential by educational level. Subsequently, we set up 20 different paths for the mortality differential. We defined two opposite, extreme hypotheses: on the one hand, we assume a complete disappearance of mortality differences by 2065, forcing the alpha and beta Brass parameters to reach gradually the values of 0 and 1 in 2065, respectively. On the other hand, we assume a further divergence of mortality differences, projecting into the future the Brass parameter trends estimated using past data. Given the two scenarios of full convergence and full divergence, the residual 18 scenarios are computed by gradually loosening the extreme convergence/divergence hypothesis. Namely, each of them is based on an assumption on the Brass parameters, which is 10% weaker than the one used in the preceding scenario.

Therefore, we have a set of 21 potential, future paths of survival differentials, and for each of them, by solving a system of equations, we considered the mortality rates of the sub-groups as components of a weighted average that was forced to be approximately equal to the Italian mortality rates, as officially projected by ISTAT in the Median Scenario.

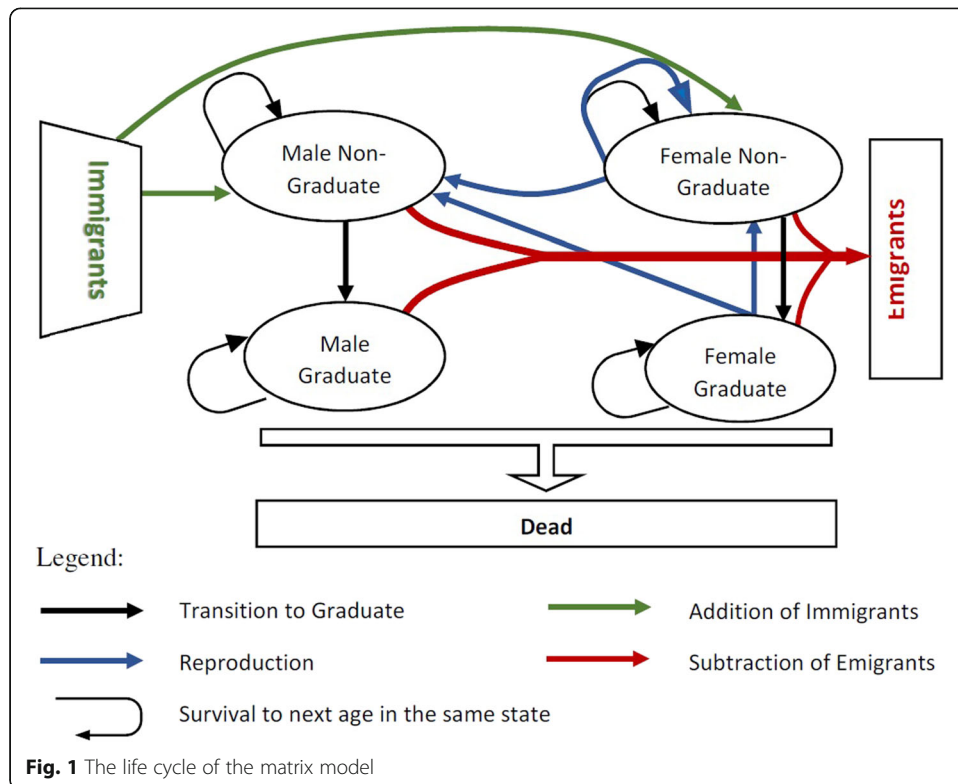
We primarily use the Median Scenario of ISTAT demographic projections, and we present our results based on this scenario, but we have also tested our method on two opposite scenarios for Italian mortality, still projected by ISTAT, and substantially identical results were obtained⁷. Below, we provide an outline of our methodology in three sub-sections: in 5.1, we define our Markov chain model; in 5.2, we present the estimation of the Brass relation, which captures the survival differences between the high and low education groups in 2012 using official ISTAT data; and in 5.3, we present our iterative process to compute the survival probabilities by education level, consistent with ISTAT official projections. A more detailed presentation of the model, along with some examples, is available in the [supplementary material](#), sections A and B.

The Markov chain model

First, we defined our life cycle (Caswell, 2001), adapting the ISTAT projection methodology to our purposes (Fig. 1).

⁶See: UNESCO, 2012.

⁷Results on alternative scenarios are available in [Supplementary materials](#), section D.



Choosing a projection interval of 1 year, we define 4 possible transient states, i.e. high level of education and low level of education by sex, and two absorbing states, i.e. emigrated and dead. By “high level of education”, we mean people with at least an upper secondary level, which is level 3 or more on the ISCED scale (UNESCO, 2012). As in ISTAT projections, immigrants are a flux of new individuals, which are exogenously forecasted. We assume all immigrants to be in the low education group.

All states and the flux of immigrants are internally divided into 121 states, one for each possible age from 0 to 120. After age 120, we assume no survival. Following the ISTAT methodology, we consider migration movements and mortality as mutually exclusive events. Finally, we assume that an individual first survives in the initial state and then has the possibility to pass to another state.

Specifically, defining $\mathbf{p}_{(t+1)}$ as the population vector at time $t+1$, the model can be represented by the following equations:

$$\begin{cases} \mathbf{p}_{(t+1)} = [\Psi_{(t)} * \mathbf{p}_{(t)}] - \mathbf{r}_{(t)} + \mathbf{g}_{(t)} + \mathbf{b}_{(t)} \\ \mathbf{b}_{(t)} = \Phi_{(t)} * \bar{\mathbf{p}}_{(t,t+1)} \end{cases}$$

where

- $\Psi_{(t)}$ is the transition matrix at time t ;
- $\Phi_{(t)}$ is the fertility matrix, generating the new-borns (surviving) at time t ;
- $\mathbf{r}_{(t)}$ is the emigrant vector;
- $\mathbf{g}_{(t)}$ is the immigrant vector;
- $\mathbf{b}_{(t)}$ is the new-borns vector; and

$\bar{p}_{(t,t+1)}$ is the population vector of the average number of people living in the country between time t and time $t + 1$, after migration.

The fertility matrix uses the specific fertility rates in ISTAT (2018) for each year of the projection⁸. Similarly, the immigrant and emigrant vectors are taken from ISTAT (2017a). The transition matrix $\Psi_{(t)}$ is a combination of survival probabilities by educational level, whose computation is presented in the following sub-sections, and conditional transition probabilities to a higher level of education, which are derived from the last available surveys (ISTAT, 2017a, 2018) and are kept constant over the projection period.

The estimate of the Brass relation between survival probabilities by education level

The starting point of our method is the ISTAT estimate of differential life tables by education level and sex, consistent with the survival curve of the whole Italian population, based on data referring to 2012 (ISTAT, 2016). From those life tables, we extract the values of the survival curve, by sex, of those with low levels of education (defined as people with at most a lower secondary education, ISCED-2011 levels 0–2) and those with high levels of education (defined as people with at least an upper secondary education, ISCED-2011 levels 3–8). Then, we use a Brass logit relational model to transform the relation between the survival curves of the low and high education groups in 2012 in a mathematical function. The Brass logit relational model is based on the assumption that two distinct age patterns of mortality can be related to each other by a linear relationship between the logits of their respective survivorship probabilities (Brass, 1971). Following Brass' suggestion, our logit transformation is

$$Y^{LO}_x = \frac{1}{2} \times \ln \left[\frac{l^{LO}(x)}{1 - l^{LO}(x)} \right]; Y^G_x = \frac{1}{2} \times \ln \left[\frac{l^{HI}(x)}{1 - l^{HI}(x)} \right] \quad (1)$$

where $l^{LO}_{(x)}$ are the values at age x of the low education group survival curve, and $l^{HI}_{(x)}$ are the values at age x of the high education group survival curve. The model then supposes a linear relationship between the logit of the two survival curves, as expressed below:

$$Y^{LO}_{(x)} = \alpha + \beta \times Y^{HI}_{(x)} \quad (2)$$

where $Y^{LO}_{(x)}$ are the logits of the low education group survival curve, $Y^{HI}_{(x)}$ are the logits of the high education group survival curve, and α and β are the parameters of the linear regression that must be estimated. We test and do not reject the assumption of linearity; then, we estimate the parameter values $\hat{\alpha}$ and $\hat{\beta}$ using an OLS method.

Once the Brass model is estimated on most updated data, some assumptions must be made on the evolution of the two parameters α and β , first over the period 2012–2018 and second over the projection period 2018–2065. The simplest way to do this is by

⁸Since we are more interested in projecting differential mortality, for the sake of simplicity, we do not assume a differential fertility. Nevertheless, our projection model could easily include differential fertility, similar to the work by Lutz et al., 2014, without dropping its "coherence" property. However, for the purpose of the present study, the total number of the estimated new-born vector must be equal to that estimated by ISTAT for the whole population. This makes it less relevant to distinguish the contribution of each group of females to the new-born vector.

keeping the two parameters constant over both periods. Furthermore, we set up a scenario analysis where different future paths of convergence/divergence between the survival curves in the two groups were assumed. The structure of our scenario analysis is presented in the next section, but, preliminarily, the presence of a past temporal trend in mortality differences has to be investigated by taking into consideration the two previous reports by ISTAT on mortality and education level, based on data from the Italian census in 1981 and 1991 (ISTAT, 1990, 2001). We computed comparable life tables for the high and low education groups in each of the three ISTAT studies and derived the related survival curves for 1982, 1992, and 2012. Then, we assessed the presence of a temporal trend by comparing the Brass parameters estimated in each of the years. We found a clear temporal trend between the years 1982–1992–2012 in the case of men. The data on women do not show any trend when the whole period is considered. However, a trend can be detected and estimated when the analysis is limited to the last 2 years, 1992 and 2012. Those trends were used in order to set up the scenario analysis that is presented in the next section. Methods, results, and validations are available in the [supplementary material](#), section C.

In summary, in our demographic projection, we can keep the parameters of the Brass relation stable, or we can use a scenario analysis, where each scenario is identified by a rule that determines the evolution of Brass parameters first over the period 2012–2018 and then over the projection period 2018–2065. For example, we can set time-dependent values, $\hat{\alpha}_t$ and $\hat{\beta}_t$, by simply extending into the future the trend observed in the estimated values of $\hat{\alpha}_t$ and $\hat{\beta}_t$ or forcing the parameters to linearly converge to 0 and 1, for alpha and beta, respectively.

The iterative procedure to project survival differences consistently with official forecasts

As mentioned above, we have a two-fold purpose. The first is to project the survival probabilities of the low and high education groups by making use of the estimated Brass relation; the second is to make the projections for the size of the two sub-groups approximately coherent with official projections for the whole population.

The “coherence” between sub-groups and the whole population is reached by assuming the officially projected mortality of the whole population at specific time “ t ” and age “ x ” to be equal to the weighted sum of mortalities in the two sub-groups, that is,

$$m_{x,t}^{\text{ITALY}} = \frac{m_{x,t}^{\text{LO}} + (m_{x,t}^{\text{HI}} * w_{x,t}^{\text{HI}})}{1 + w_{x,t}^{\text{HI}}} \quad (3)$$

where

$m_{x,t}^{\text{ITALY}}$ = specific mortality rate at time “ t ” of the Italian population, as estimated by ISTAT;

$m_{x,t}^{\text{LO}}$ = specific mortality rate at time “ t ” and age “ x ” of the low education group;

$m_{x,t}^{\text{HI}}$ = specific mortality rate at time “ t ” and age “ x ” of the high education group;

$w_{x,t}^{\text{HI}}$ = relative weight at age “ x ” and time “ t ” of the high education population on the low education population.

Both the specific mortality rates of the whole Italian population and the sizes of the high education/low education sub-groups are taken as given and known: the Italian-

specific mortality rates are extracted from the official ISTAT forecasts, and the sizes of the high and low education sub-groups come from the population vector of the Markov chain model. The specific mortality rates at time “ t ” of the low and high education sub-groups are unknown. That is, in our iterative procedure at any time “ t ”, we base the computation of sub-group mortality rates on the size of the two sub-groups, which derive from the application of the sub-group mortality rates at time “ $t - 1$ ”.

To find the two unknowns, we use the relation existing between the values of the two survival curves at any specific age and time, as described above in Eqs. (1) and (2), which can be written as

$$\frac{1}{2} \ln \left[\frac{l^{LO}(x)}{1 - l^{LO}(x)} \right] = \alpha + \beta \times \frac{1}{2} \ln \left[\frac{l^{HI}(x)}{1 - l^{HI}(x)} \right] \tag{4}$$

At this point, we need to rewrite this in terms of mortality rates instead of survival probabilities. Recalling some useful identities and relations between mortality and survival in continuous time (Caselli, Vallin, & Wunsch, 2001; Keyfitz & Caswell, 2005), we can rewrite the identity in (4) as

$$\frac{1}{2} \ln \left[\frac{\exp[-\sum_0^x m_a^{LO}]}{1 - \exp[-\sum_0^x m_a^{LO}]} \right] \cong \alpha + \beta \times \frac{1}{2} \ln \left[\frac{\exp[-\sum_0^x m_a^{HI}]}{1 - \exp[-\sum_0^x m_a^{HI}]} \right] \tag{5}$$

Having rewritten the Brass linear relation between the low and high education groups in terms of mortality rates (5) and simultaneously considering Eq. (3), we can combine them in a system of equations as follows:

$$\underline{F}_t(m^{LO}, m^{HI}) = (F_{1,t}(m^{LO}, m^{HI}), \dots, F_{\omega-1,t}(m^{LO}, m^{HI}))^T = \underline{0} \tag{6}$$

where \underline{F}_t is a vector of functions $F_{x,t}$ depending on age “ x ” and time “ t ”, $\underline{0}$ is a vector of zeros, and

$$F_{x,t}(m^{LO}, m^{HI}) = \begin{cases} \frac{m_{x,t}^{LO} + (m_{x,t}^{HI} * w_{x,t}^{HI})}{1 + w_{x,t}^{HI}} - m_{x,t}^{ITALY} = 0 \\ \hat{\alpha}_t + \hat{\beta}_t * \frac{1}{2} \ln \left[\frac{\exp[-\sum_0^x m_{a,t}^{HI}]}{1 - \exp[-\sum_0^x m_{a,t}^{HI}]} \right] - \frac{1}{2} \ln \left[\frac{\exp[-\sum_0^x m_{a,t}^{LO}]}{1 - \exp[-\sum_0^x m_{a,t}^{LO}]} \right] = 0 \end{cases} \quad x = 0, 1, 2, \dots, \omega - 1 \tag{7}$$

with $\omega - 1$ equal to the last age.

At any time “ t ”, we know the values $m_{x,t}^{ITALY}$, $w_{x,t}^{HI}$, $\hat{\alpha}_t$ and $\hat{\beta}_t$. Solving the system for $m_{x,t}^{LO}$ and $m_{x,t}^{HI}$, we obtain mortality functions of the two sub-groups that are approximately coherent with the Italian mortality function.

From the mortality rate, we derive the probability of death by applying the following approximation:

$$lq_x \cong 1 - \exp[-m_{x,x+1}] \tag{8}$$

Now, we can estimate a life table for the high and low education groups and the prospective probabilities of survival. Those are used, along with migrations, birth rates and probabilities to graduate, in the Markov chain to project the population vector to the next year. The procedure is repeated until the end of the projection period is reached.

Results

We first present the projection where the Brass parameters estimated on the 2012 dataset are kept constant, and we then show how the share of population with low levels of education on total population is decreasing over time and how population life expectancy converges to the life expectancy in the high education group. This result, which we named the “composition effect”, comes from the maintained assumption that the rate of a high level of education in future generations will be equal to the rate shown by the youngest cohort whose education choices have been recorded at present.

Subsequently, we present the results of a scenario analysis, where we investigate the consequences of opposite assumptions on the future potential evolution of mortality differentials by level of education.

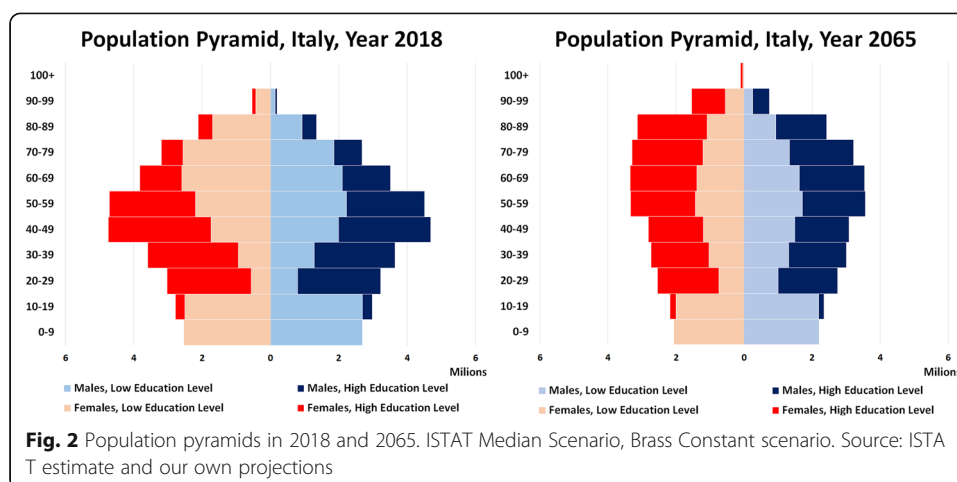
All the projections we present are based on the Median Scenario of ISTAT official projections for the Italian population, but we also tested our model on alternative ISTAT scenarios, and very similar results were obtained. These projections are available in [supplementary material](#), section D.

Projection at constant Brass parameters

As repeatedly mentioned, the objective of our innovative procedure is the approximate replication of an “official” demographic projection, and its disaggregation for socioeconomic sub-groups. Therefore, the first model validation is the comparison of the total amount of the population projected by our model, named “RetSimM”, and by our “official” benchmark, which is the “Median Scenario” of the ISTAT demographic forecast on the Italian population (ISTAT 2018). This is a crucial test, since our first aim is to obtain “coherent” projections by educational level. In fact, the errors in the total amount of the population are negligible, in the order of thousands, and less than 0.2‰ in proportion. This confirms the validity of our methodology and signals the achievement of our first and preliminary goal. (The time profile of projection errors can be found in the [supplementary material](#), section E.)

The main result of our procedure is the disaggregation of “official” demographic projections by educational level for each sex, each age, and each year within the projection period. The population pyramids of the Italian population differentiated by education level in 2018 and 2065, respectively, are an adequate representation of the outcome of our model (Fig. 2).

The comparison between the two pyramids shows the increasing share of older ages in the whole population. The value added by our projection procedure amounts to the evaluation of the weight of the high education group in the population. In 2018, older generations are characterized by a low level of education for both men and women, as is evident in the upper part of the population pyramid in 2018. At the same time, younger generations, i.e. the people aged 30–59, show a higher percentage of people with a high level of education in 2018. These last generations have, for the most, already completed their studies and are thus not affected by our maintained hypothesis of constant transition probabilities to higher level of education. Hence, the simple projection of the ageing of such generations results in a radical change in the composition of older people by education level in 2065.



Between 2018 and 2065, the share of population aged 60 or more with a high level of education will increase from 29 to 61%. This last result has relevant consequences on the future longevity of the whole population. Even though no group increased its longevity, the weighted average between the mortality of the two groups would result in an increase in longevity of the whole population. In other words, future population longevity will be affected by a substantial “composition effect” related to the improved education level of individuals.

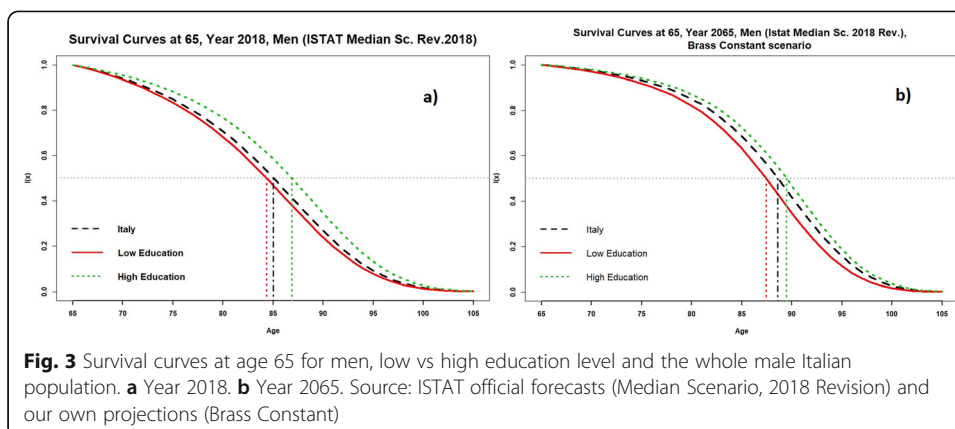
This composition effect is completely hidden in the official demographic projections that represent the benchmark of our innovative procedure.

The relevance of the composition effect on population longevity is made clear by the survival curves and the life expectancies implicit in the population pyramids previously presented. We show survival curves at age 65 for men (Fig. 3) and women (Fig. 4), in 2018 and 2065.

The comparison of survival curves in 2018 and 2065 reveals a rightward shift of all curves, consistent with official demographic projections. The stable gap in survival between the high and low education groups directly derives from the assumed constancy of the Brass approximation of mortality differentials. There is, however, a further feature of our sub-group survival curves that casts new light on the nature of the survival curve of the whole population, as projected by ISTAT: the increasing gap between the survival of the low education group and that of the whole population. This feature is confirmed in the cases of both women and men, and it is still confirmed using very different ISTAT scenarios of demographic projection, both in the “low” scenario with minimal or no increase in Italian life expectancy and in the “high” scenario with a higher increase in life expectancy (see [supplementary material](#), section D).

The root cause of this change lies in the modification of demographic structure by education level: because of the previously mentioned composition effect, the survival of the population increases its distance from the survival of the most disadvantaged social group. The relevance of this result is further substantiated by the analysis of life expectancies associated with the previous survival curves.

According to ISTAT projections, between 2018 and 2065, the increase in population life expectancy at age 65 will amount to 3.7 years (Table 1, columns 2, 5; Table 2, rows 1, 2, 7, 8). The rise will be larger in the case of women, 3.8 years,



than in the case of men, 3.4 years, which will bring the gap in life expectancy to 3.7 years. Our projections allow us to break down ISTAT values for education level: in the constant scenario, life expectancy will increase by 2.9 years for men with low levels of education, and by 2.6 years for men with high levels of education; at the same time, life expectancy will increase by 3.2 years for women with low levels of education and by 3.1 years for men with high levels of education. Therefore, in the constant scenario, the projected increase of life expectancy at age 65, 3.7 years, is larger than the projected rise in any of the four social groups considered. The relative size of the extra increase of population life expectancy goes from 15% in the case of women with low levels of education to 42% in the case of men with high levels of education.

Within that framework the most disadvantaged social group appears to be the one whose members are men with a low level of education. Their life expectancy at 65 is significantly lower than that of those in the high education group and is significantly lower than the life expectancy at 65 of the whole population. Furthermore, the gap between the life expectancy of men with low education and that of the whole population shows a large increase, from - 2.2 in 2018 to - 3 in 2065.

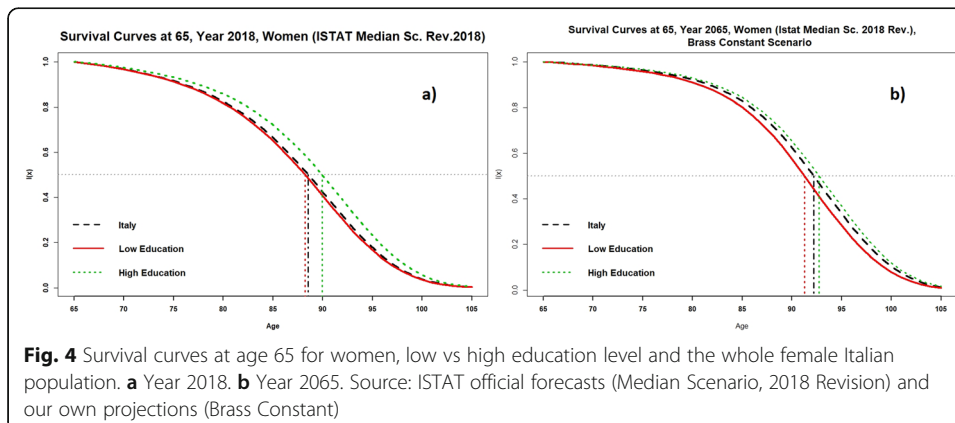


Table 1 Life expectancies at age 65 in 2018 and 2065, by sex and education level

Year	2018	2065	RetSimM estimates				
	ISTAT official estimate (median scenario)	ISTAT official estimate	Convergence scenario	50% conv. scenario	Constant scenario	50% trend scenario	Trend scenario
Population	20.9	24.6	24.6	24.6	24.6	24.6	24.6
Men	19.4	22.7	22.7	22.7	22.7	22.7	22.7
<i>Low education</i>	18.7		22.7	22.2	21.6	21.1	20.6
<i>High education</i>	21.0		22.7	23.2	23.6	23.9	24.3
Women	22.6	26.4	26.4	26.4	26.4	26.4	26.4
<i>Low education</i>	22.3		26.4	25.9	25.5	25.0	24.5
<i>High education</i>	23.9		26.4	26.6	26.9	27.2	27.5

Estimates in 2018 for the low and high education groups refer to the hypothesis of constant Brass parameters
 Source: ISTAT Median Scenario and our own estimates based on the RetSimM model

Scenario analysis: future potential evolutions of mortality differentials

To investigate the potential future path of social differences in mortality, we have to explore how the composition effect we presented in the previous section will overlap with the future path of mortality differential by education level. To address that question, we present a set of 20 different projections, where each of them is identified by a specific assumption on the future Brass parameters. We define two opposite, extreme

Table 2 Projected increases in life expectancy at age 65, 2018–2065

	Official ISTAT projection	RetSimM estimates		Official ISTAT projection	RetSimM estimates
Population	3.7		Population	3.7	
Men	3.4		Women	3.8	
Convergence scenario			Convergence scenario		
Low education		3.9	Low education		4.1
High education		2.0	High education		2.7
50% convergence scenario			50% convergence scenario		
Low education		3.4	Low education		3.6
High education		2.3	High education		2.9
Constant scenario			Constant scenario		
Low education		2.9	Low education		3.2
High education		2.6	High education		3.1
50% trend scenario			50% trend scenario		
Low education		2.4	Low education		2.7
High education		2.9	High education		3.3
Trend scenario			Trend scenario		
Low education		2.0	Low education		2.3
High education		3.1	High education		3.5

Source: ISTAT Median Scenario and our own estimates based on the RetSimM model

hypotheses: in the full convergence scenario, the mortality differential by education level gradually decreases from year 2012 to 2018, and disappears in 2065. At the opposite extreme, the full divergence scenario is identified by the time trends in Brass parameters, which we estimated from the years 1982–1992–2012 in the case of men, and between 1992 and 2012 in the case of women. The slopes of the estimated trends were applied to the values of the Brass parameters estimated on 2012 data, and prospective values from 2013 to 2065 were computed.

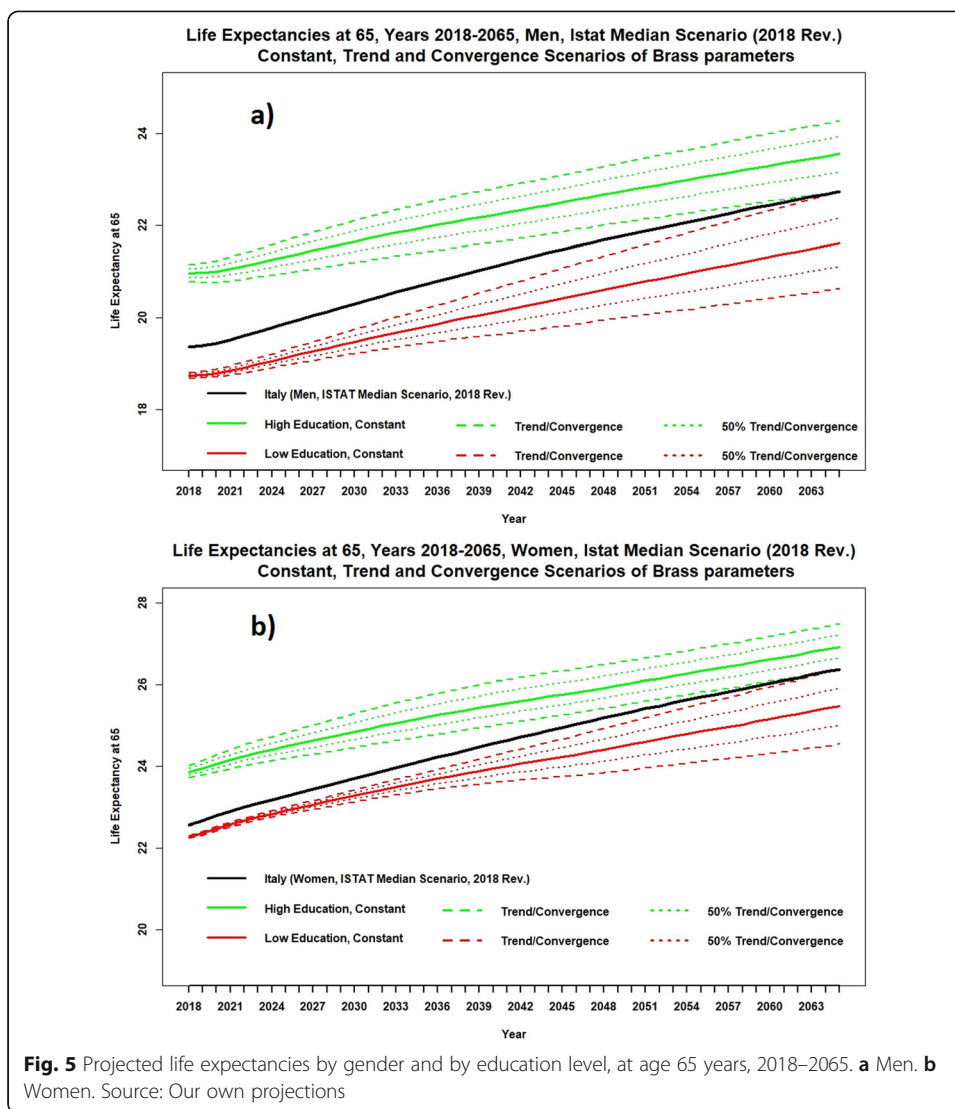
Given the two scenarios of full convergence and full divergence, the residual 18 scenarios are computed by gradually loosening the extreme convergence/divergence hypothesis. Namely, each of them is based on an assumption on the Brass parameters, which is 10% weaker than the one used in the preceding scenario. We present both convergence and divergence scenarios for the sake of completeness; however, the latter ones do not truly add very much to what we presented above, since the outcomes of the “composition effect” are simply magnified in divergence scenarios. In convergence scenarios, on the contrary, the composition effect is counteracted by the drift of mortality rates in the two social groups towards the population mortality rate, and we are interested in exploring how strong the convergence in mortality rates between groups needs to be in order to offset the composition effect. When the offsetting occurs, one of the groups should show prospective gains in life expectancy that are larger than the ones projected for the total population; furthermore, the gap between the life expectancy of the population and that of the most disadvantaged group should be stable or decreasing over time.

To keep tables and graphs simple, we present our projection results on life expectancy at age 65 in the two extreme scenarios and in the two scenarios that are midway between full convergence/divergence and stability of Brass parameters⁹. The midway convergence scenario is our threshold. The increments of life expectancy for the whole population between 2018 and 2065 are larger than the sub-group increments in all scenarios except those with a convergence hypothesis are stronger than the one in the threshold (Tables 1 and 2 and Fig. 5). This result is verified in the “high” and “low” ISTAT scenarios (see [supplementary material](#), section D).

In Fig. 5, the extra annual increase in population life expectancy is evidenced by the difference between the slope of population projections (steeper) and the slopes of sub-groups (flatter). To cast light on that slope differential, in Figs. 6 and 7 the annual increases in life expectancy in all four sub-groups and in all our 21 projection scenarios are presented. The inspection of those graphs reveals that, at the beginning of projection period, ISTAT annual population increases in life expectancy at age 65 exceed the corresponding increases in most of our scenarios. In the case of women, until 2040, even in the case of full convergence, the annual increase in life expectancy in the female population is much larger than the corresponding increase for women with high levels of education, and it is just equal to the increase for women with low levels of education. In the case of men, the convergence effect offsets the composition effect more quickly.

However, until 2041, in all scenarios where convergence of the Brass parameters is 50% weaker than in the case of full convergence (threshold scenario), the annual

⁹Complete results of all simulated scenarios are available in [supplementary material](#), section D.

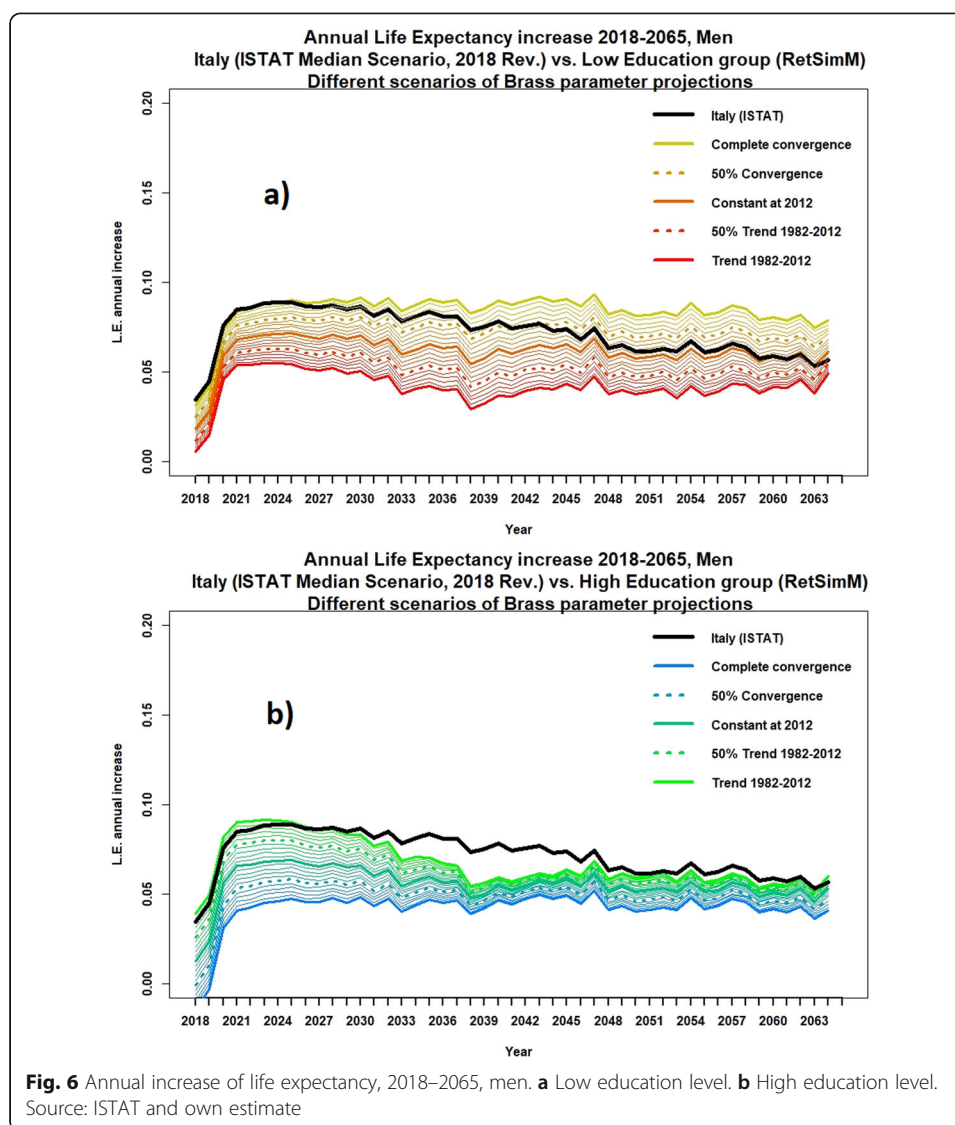


increase in life expectancy in the male population is still larger than that of men with low levels of education.

Moreover, only in the cases where the convergence is full, or close to it, does the gap in life expectancy between the whole population and the men in the low education group show a reduction over the projection period.

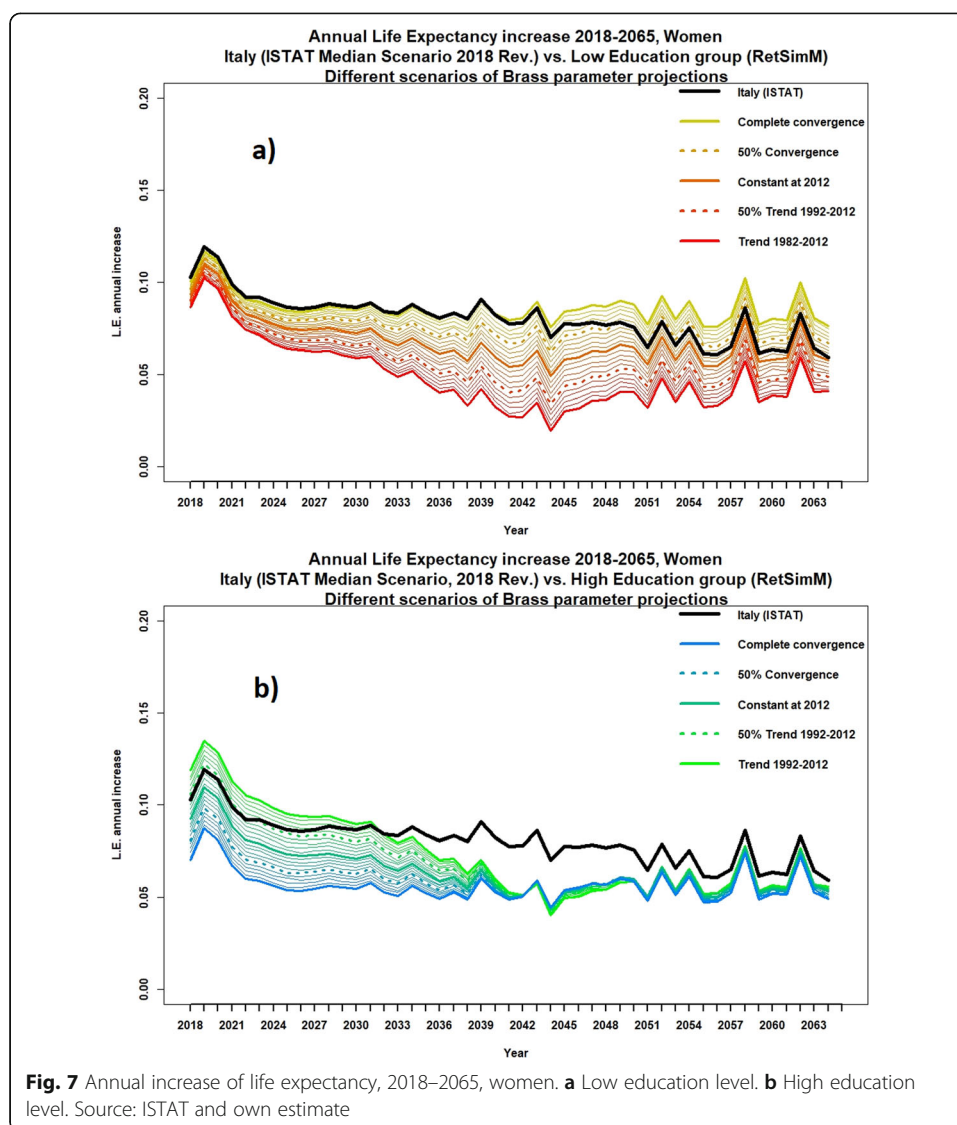
Discussion

Our work contributes to the growing field of scientific literature that aims to integrate additional dimensions into demographic population projections. It represents a novel approach because it develops a flexible and simple method to break down official projections by education level, and it creates the opportunity for a new generation of projection models on social security expenditures and financial, economic, and welfare impacts. In particular, the new generation of models could cast new light on the financial risks associated with inequality in longevity, given that higher longevity is concentrated among pensioners who receive richer annuities, and the annuity market is



affected by anti-selection (Organization for Economic Co-operation and Development, 2016, 2017). Furthermore, such models will make it possible to estimate the distribution of public expenditures among social groups and verify whether social public programmes “will unexpectedly come to deliver disproportionately larger lifetime benefits to higher-income people, who, on average, will increasingly collect those benefits over more years than those with lower incomes” (National Academies of Sciences, Engineering, and Medicine, 2015). Finally, these models will allow the chance to evaluate the financial and economic impacts of policy reforms based on “proportional universalism”, that is, on policies that “are universal but with attention and intensity that is proportionate to need” (World Health Organization, Regional office for Europe, 2012).

Apart from the innovative nature of our method, our results shed new light on some aspects of Italian and European pension policies that have not drawn much attention until now. Following the recommendations of the European Commission (European Commission, 2010, 2012), Italy—similar to many other European countries¹⁰—links



retirement age to variations in life expectancy. The indexation rule establishes that any variation in population life expectancy at age 65 must be mirrored in an identical variation in the legal retirement age. This rule is highly rigorous, since it is automatic, applies to all retirement requisites, and reflects the full amount of the population life expectancy's variation. ISTAT predicts an increase of 4 years in population life expectancy at age 65 in the period 2018–2065 (Table 2). What our results interestingly show is that a fraction of the future increase in the population life expectancy at age 65 will be due to the gradual substitution of older cohorts, predominantly with a low level of education, by new cohorts characterized by higher levels of education. We labelled that as the “composition effect”. Similar results were found by Luy et al. (2019), who operated a decomposition analysis of life expectancy increase by educational level in Italy, Denmark, and the USA between 1990 and 2010, and by Costa et al. (2017) and Costa (2018), who computed the variations in life expectancy by education level in the city of

¹⁰See Table II.1.2 in European Commission (DG ECFIN) (2018).

Turin in the period 1971–2011. Luy et al. (2019) aimed to estimate to what extent the gains in life expectancy at age 30 were related to structural changes in the population, which were due to increasing education levels (“structure” effect), and to what extent they were related to reductions in mortality inside the groups (“mortality” effect). The authors showed that the “structure” contribution to the increase in total life expectancy ranged from approximately 15% for men in the USA to approximately 40% for women in Denmark (21% and 20% in Italy, for men and women, respectively). Costa et al. (2017) and Costa (2018) found that the average life expectancy at age 35 for men increased faster than that of every single group of citizens by education level. At the same time, the low education group experienced an increase in its distance from the population average.

Our scenario analysis shows that the composition effect will overlap with the future path of mortality differentials by educational level. In the case of stability, or even an increase in the differentials, the rigorous Italian indexation rule implies that people from both high and low education groups will have to postpone their retirement age to a larger extent than the increase in their life expectancy. The same applies in those scenarios where the composition effect prevails over the effect of convergence.

In other words, over the next 50 years, life expectancy computed at the statutory retirement age, which is the expected time spent in retirement, could shrink for everybody. This potential future outcome seems to be an unintended consequence of the indexation rule, and it plausibly goes beyond the European recommendations, which were aimed at stabilizing “the balance between working years and years in retirement” (European Commission, 2012; p. 10)

There is a second aspect of Italian and European pension policy that our results allow us to explore. In Europe, many countries¹¹ have adopted pension schemes, where entitlements are actuarially linked either to social contributions paid, as in the case of notional defined contribution schemes, or to some average of earnings and to the age at retirement, as in the case of point systems. In all those countries, the actuarial balance mechanism is based on one common and universal parameter for all retirees: population life expectancies at the ages that are eligible for retirement. The choice of the same parameter for the whole population implies a redistribution of welfare among different groups of retirees, namely, from men to women and from the ones with low levels of education to those with high levels. Women’s advantages in the computation of retirement entitlements are not the focus of the present analysis; however, it can be considered a compensation of the gender gap in wages. Furthermore, in the presence of survival schemes, as in Italy, women’s advantage substantially disappears when the distribution of pension benefits is computed with respect to families and not individuals. Regarding educational inequalities, our projections show that, in all the scenarios where the composition effect is not offset by the effect of convergence, the most disadvantaged group, men with low levels of education, will bear an increasing burden during the next 50 years. Currently, the life expectancy at age 65 is already 2.2 years lower for men in the low education group than for the whole population. In the future, in our “constant” scenario, people in this group will see their gap increase from – 2.2 years in 2018 to – 3 in 2065.

¹¹See Table II.1.1 in European Commission (DG ECFIN) (2018)

Regarding the weaknesses of our analysis, we point out that the validity of education as an appropriate indicator of future socioeconomic risks and inequalities was recently questioned (Albertini, 2013; Ballarino, Bernardi, Requenn, & Schadee, 2009). Following the authors' line of reasoning, the predictive power of education level with respect to mortality differences could decline in the future. However, our analysis of mortality rates between 1982 and 2012 does not support the hypothesis of a decreasing relevance of education in explaining longevity differentials. Furthermore, educational level could still be considered a good proxy of future socioeconomic risks and inequalities if a "horizontal" dimension is added to its "vertical" dimension (Albertini, 2013). This means that the different typologies of upper secondary and university degree education levels should be taken into account. We will try to take advantage of that suggestion in future developments of our research.

Conclusions

Our innovative method shows that official demographic projections can be broken down by educational level and that inequalities in ageing, implicit in those projections, might be disclosed. Moreover, our results cast new light on the social consequences of indexing pension parameters to life expectancy. We focused on the Italian social security system, but our results could be extended to other European countries whose social security systems share similar features.

We believe that our method might be further developed to break down projections on future social expenditures by socioeconomic status. To our knowledge, at present, nothing similar exists in any European country, despite the relevance of social inequalities in ageing and their potential future increase. Exploring the intragenerational transfers of resources implicitly caused by present social policies can help to better focus these policies on groups that appear to be the more disadvantaged and the most in need of the social security net.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s41118-020-00113-3>.

Additional file 1. Supplementary material.

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Authors' contributions

The authors SG and CL contributed equally to the article, designing the study's analytic strategy, performing the statistical analysis, and commenting the results. The author(s) read and approved the final manuscript.

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Availability of data and materials

The data that support the findings of this study are available from ISTAT but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of ISTAT.

Competing interests

The authors declare that they have no conflict of interest.

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