Demographic Literacy:

Conceptual Foundations and Empirical Evidence on Aging

1. Introduction

Over recent decades, rapid demographic change has transformed fertility, mortality, and migration patterns, creating profound implications for welfare systems, labour markets, and family structures in post-transitional societies (Billari, 2022; Prskawetz et al., 2008; Strozza et al., 2024). More specifically, these shifts challenge traditional societal frameworks by altering the balance between working-age and dependent populations, reshaping care demands, and redefining the socioeconomic roles of individuals across the life course. In particular, the rising prevalence of ageing societies intensifies pressure on pension systems, health and long-term care infrastructures, and heightens concerns regarding the sustainability of intergenerational support mechanisms (for a discussion see Kravdal, 2025).

Beyond their structural and economic consequences, these demographic dynamics have deep and direct effects on individual and collective well-being, shaping people's life opportunities, expectations, and sense of security across the life course (e.g., Levy et al., 2020).

In a context of rapidly ageing societies, understanding demographic dynamics become a crucial capability—a form of knowledge that allows individuals to make informed decisions about family, work, and retirement, and to adapt to demographic realities that influence everyday life. For instance, limited awareness of demographic trends—such as population ageing and rising life expectancy - can leave individuals ill-prepared for longer life spans and the related economic and social implications (e.g., Arpino et al., 2018). Studies show that when individuals are informed about projected increases in the older population, they tend to adjust their anticipated retirement age accordingly (Radl & Fernández, 2022). Conversely, lacking such knowledge may result in unrealistic life-course planning, insufficient savings, and reduced preparedness for old age, ultimately affecting both financial and subjective well-being (Gan et al., 2015). In this sense, demographic awareness is not only a foundation for effective policy design but also a condition for resilient and future-oriented citizenship.

Recognizing the connection between demographic knowledge and well-being, international organizations such as the OECD have increasingly emphasized demographic awareness within broader agendas on social sustainability and lifelong learning (André et al., 2024). Many countries have developed public initiatives to enhance citizens' understanding of population issues, often through national statistical offices or European institutions such as the European Centre for Development of Vocational Training (CEDEFOP), Eurofound and EIGE (CEDEFOP, 2012; EU-OSHA, CEDEFOP, Eurofound & EIGE, 2017). However, research consistently reveals a persistent knowledge gap between institutional discourse and public awareness (van Loo et al., 2011; Dorbritz, 2008; Radl & Fernández, 2022). This lack of understanding undermines people's ability to anticipate demographic change, prepare for its social and economic implications, and maintain well-being in ageing societies.

Thus, in line with research on financial, digital, and health literacies as determinants of well-being (Lusardi & Mitchell, 2014; van Dijk, 2020), we claim that individuals with higher demographic literacy are better equipped to anticipate change, adapt behaviour, and participate meaningfully in societal decisions that affect their quality of life. In line with research on financial, digital, and health literacies as determinants of well-being (Lusardi & Mitchell, 2014; van Dijk, 2020), we propose demographic literacy as the ability to understand and critically interpret demographic information and trends, and to apply this understanding in everyday choices and policy engagement. Individuals with higher demographic literacy are better equipped to anticipate change, adapt behaviour, and participate meaningfully in societal decisions that affect their quality of life.

The contribution of our work is both theoretical and empirical. Theoretically, this study offers a first theorization of demographic literacy. Empirically, we provide an original operationalization of one of its processes, that is demographic knowledge related to population ageing. We operationalize demographic knowledge about population ageing through a composite indicator that captures correct understanding of both the increase in the elderly population and the decline in younger cohorts. We consider this knowledge as representing a minimum threshold of demographic awareness in ageing societies.

To illustrate our conceptual framework, we conduct an empirical analysis using data from an original survey on a nationally representative sample of 1,575 Italian adults aged 20–69. By combining responses to two factual questions on the knowledge of longevity and dejuvination trends, we derive a composite indicator that captures a basic level of demographic knowledge about population ageing. The analysis then explores how this knowledge varies across social groups, assessing the role of education, income, age, gender, and regional context. We make use of Random Forest, a machine-learning approach well suited to detecting complex and non-linear relationships between socio-demographic factors and levels of demographic knowledge.

The remainder of the paper is organized as follows. First, we present the theoretical framework, introducing the concept of demographic literacy and situating it within the broader context of rapid population change. Second, we discuss the potential indicators and data sources that can be used to operationalize this concept, emphasizing the multidimensional nature of demographic literacy and the challenges associated with its measurement. Third, we apply the proposed framework in an empirical analysis that employs machine learning models to examine individuals' demographic knowledge about the ageing process based on a set of socio-demographic characteristics. Finally, we conclude by summarizing the main findings and discussing their theoretical and policy implications.

2. Conceptualization of demographic literacy

Figure 1 illustrates a comprehensive conceptual approach to *demographic literacy*, designed to capture the key components and developmental stages of this construct, as well as its antecedents and both individual and societal outcomes.

Drawing on the conceptual framing of other emerging literacies (UNESCO, 2025), we define demographic literacy as the ability of individuals - embedded within diverse social and personal contexts ('Antecedents') - to acquire demographic knowledge ('Process') and apply it ('Application') in order to make informed decisions ('Micro-level outcomes') and to foster active engagement in public debates and policy processes related to population change ('Macro-level impacts').

The acquisition of demographic literacy is first shaped by both personal characteristics and environmental contexts ('Antecedents'). 'Personal characteristics' refer to factors such as education, socioeconomic status, cognitive skills, values, attitudes, and general literacy levels. 'Contextual factors', in turn, encompass the societal and educational frameworks that enable or constrain individuals' capacity to develop demographic understanding—for instance, the inclusion of demographic education within curricula in the educational system, the visibility of population issues in media and political agendas, and the broader cultural relevance attributed to demographic debates.

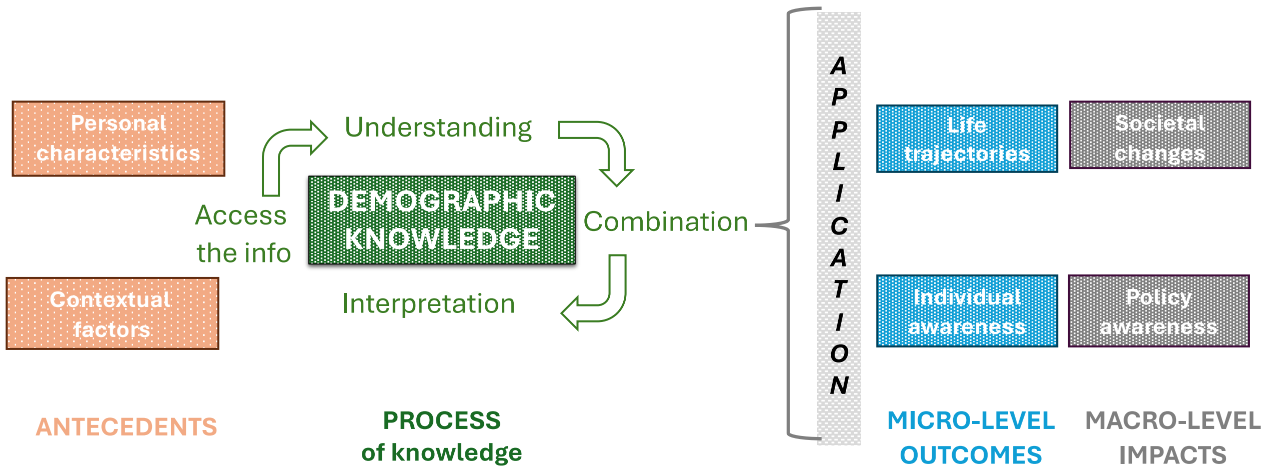
At the core of the framework lies the processual nature of demographic knowledge ('Process of knowledge'), which is conceptualized as a dynamic and cumulative competence that develops through successive stages. Echoing elements of the DIKW model (Ackoff, 1994; Rowley, 2007), our framework posits that the development of demographic knowledge begins with individuals' ability to 'Access information' on demographic facts—via formal education, media, institutional sources, or life-long learning. However, merely possessing information is not enough. It must also be understood ('Understanding'), meaning that individuals should be able to interpret data, grasp basic demographic concepts and place them in meaningful context. Yet, demographic knowledge goes beyond. The next stage in its development involves an integrated approach and the combination of multiple sources of information ("Combination"). At this stage, individuals connect demographic data from different domains, linking one piece of information to another to construct a more comprehensive view of population dynamics. In this sense, demographic literacy transcends the mere recognition of isolated trends—such as declining fertility or increasing longevity—by encompassing the ability to relate these processes to each other and to understand their cumulative effects on demographic change. For example, understanding the concept of an aging society requires considering multiple demographic processes simultaneously—at least, the increase in the proportion of older adults and the decline in the share of younger cohorts within the population. Only by relating these trends can one fully grasp the structural nature of population aging and its implications for social and economic systems. This, in turn, fosters a deeper and more critical understanding of demographic processes overall ('Interpretation').

Once individuals have internalized and critically assessed demographic data, the application of demographic knowledge becomes an enabling resource for informed decision-making at the individual level, and reflective participation at the societal level ('Application').

In other words, demographic literacy is fully achieved through the process of application, when demographic knowledge is translated into informed reasoning and action. In this sense, demographic knowledge empowers individuals to make more informed life decisions and thus their wellbeing. For example, in ageing societies, awareness that life expectancy is rising and that morbidity is increasingly concentrated in the latest stages of life may encourage individuals to adopt lifestyle and health behaviours that promote wellbeing throughout the life course. Such understanding can foster greater investment in preventive health practices—such as regular physical activity, healthy nutrition, and medical screening—while discouraging harmful behaviours earlier in life. But demographic knowledge can also strengthen collective wellbeing and social cohesion. The active use of demographic knowledge contributes to policy awareness and societal change. Greater demographic literacy within the population can enhance public understanding of population-related policies — such as those concerning ageing, fertility, or migration — and foster more informed opinions and expectations toward policy interventions, improving individual agency. Over time, this shared awareness can promote societal change, encouraging collective reflection on demographic shifts and supporting the development of more evidence-informed policy responses. For instance, in the context of population ageing, accurate knowledge of the demographic processes underpinning these shifts may strengthen civic engagement and intergenerational solidarity, as individuals become more aware of ageing as a shared societal responsibility. Higher levels of demographic understanding can translate into stronger support for inclusive and forward-looking policies, greater empathy across generational groups, and increased participation in community and volunteering activities that contribute to collective wellbeing.

In sum, this conceptual framework positions demographic literacy as both a personal competence and a social resource, whose development is contingent upon access to knowledge, shaped by personal and contextual factors, and whose outcomes extend from individual empowerment to collective well-being.

Fig. 1 Conceptual model of demographic literacy



This raises a central question for both theory and measurement: what types of demographic information constitute the core content of demographic literacy, and how are these elements addressed in existing empirical research?

To explore this, we review studies that have attempted to measure demographic knowledge. As we will show, these studies offer valuable insights; however, they often capture only selected dimensions of the construct and tend to do so in isolation. This fragmented approach reflects a broader tendency in the literature to focus on individuals' acquisition of factual knowledge about isolated demographic phenomena, without adequately considering the need for an integrated understanding of demographic knowledge and the applicative dimension emphasized in our framework.

3. Data and indicators about demographic knowledge

Since *demographic literacy* is a recently introduced notion with limited theoretical development (Kulcsár et al., 2009; Arie, 2018; Apicella et al., 2024), existing studies remain fragmented but offer a useful starting point for developing appropriate indicators. To date, no standardized measure has been designed to assess individuals' demographic literacy in a comprehensive way. In this study, we focus specifically on *demographic literacy about ageing*, understood as individuals' knowledge and understanding of the demographic processes underlying population ageing.

The ageing process is driven by three major demographic dynamics: increasing longevity (people live longer than in the past), declining fertility (birth rates have been falling for decades), and migration patterns (immigration flows are often insufficient to offset population losses at younger ages). Although research on individuals' knowledge of these areas offers valuable starting points, existing studies are few and typically rely on isolated indicators and small-scale datasets. As a result, they provide only partial insights yet can contribute to the development of more comprehensive measurement tools in the future.

The domain that has received the greatest empirical attention is *longevity literacy*. Most of the available indicators derive from psychology, gerontology, and health research (e.g., Northcott, 1994), where the Palmore Facts on Aging Quiz (1977, 1981) and its derivatives (Palmore, 1988; Breytspraak & Badura, 2015; Seufert, 2002) are the most widely used instruments. The Palmore test, a 25-item True/False quiz, evaluates knowledge about the biological, social, and demographic aspects of older age. Although not originally designed for comparative demographic monitoring, several of its items directly assess factual knowledge related to population ageing and demographic trends. Consistently across hundreds of studies, results show that factual knowledge about ageing remains extremely low, often barely above chance levels. These findings confirm that misperceptions of longevity are widespread and highlight the lack of demographic awareness even in advanced societies.

In addition, some research in economics and social policy indirectly addresses longevity literacy by examining how individuals' understanding of increased life expectancy affects financial and retirement planning (e.g., Lusardi & Mitchell 2007; Radl & Fernández, 2022; Fernandez et al., 2023). In particular, some studies refer to survival literacy in terms of the educational content of demographic survival probabilities (e.g., Billari et al., 2023). Individual age related perceptions, stereotypes and prejudices are then potentially investigated through the topic of *ageism* (e.g., Ayalon et al., 2019), to which specific items of fourth wave of the European Social Survey (2008–2009) are devoted. In these cases, proxies such as expectations of life span or projected retirement age can be interpreted as behavioral indicators of longevity knowledge and adaptation.

Evidence on *fertility literacy* is even more limited. A few public opinion surveys, most notably those conducted by INED in France, have collected data on population awareness of fertility trends. Barrusse (2020) uses INED's series of opinion polls from the 1970s and 1980s to show that French citizens were relatively aware of the decline in births during that period. More recently, the POP-AWARE Survey (Barrusse et al., 2019) conducted by INED provided an updated snapshot of fertility knowledge among the French population. Respondents were asked to identify European countries with the highest fertility levels and to estimate national birth rates. Results revealed significant inaccuracies, including overestimation of fertility in low-fertility contexts such as Italy and Spain. In the United States, the American Family Survey (Institute for Family Studies, 2019) has included similar questions, showing that most Americans believe fertility and teenage pregnancy are increasing, while in reality both are declining (for a micro-level approach see Martins et al., 2024; Blockeel et al., 2025). Such evidence points to widespread misunderstanding of dejuvenation processes and persistent gaps between demographic reality and public perception (Catalbiano & Rosina, 2018; Kulic et al., 2025).

Migration literacy has been investigated mostly through perception-based studies rather than standardized indicators. A robust interdisciplinary literature—drawing on sociology, political science, and migration studies—shows that individuals consistently overestimate the size of immigrant populations and misperceive their socio-economic characteristics (Alba et al., 2005; Kunovich, 2017; Gorodzeisky & Semyonov, 2020). Although these findings rely on diverse national surveys rather than harmonized instruments, the gap between perceived and actual migration levels functions as a de facto indicator of migration knowledge. The magnitude of this misperception has been linked to negative attitudes toward immigration and lower social cohesion (Alesina & Tabellini, 2024; Grigorieff et al., 2020). Hence, the difference between perceived and factual demographic proportions offers a simple but powerful quantitative indicator of migration literacy.

Overall, the empirical landscape indicates that demographic literacy is still measured indirectly through scattered proxies—each addressing a narrow aspect of demographic knowledge. Existing instruments such as the Palmore Facts on Aging Quiz, fertility awareness surveys (e.g., POP-AWARE, American Family Survey), and perception-based measures of migration and family change constitute valuable but uncoordinated building blocks. Moving forward, these tools could inform the construction of more coherent and comparable social indicators of demographic literacy, capable of integrating multiple domains—longevity, fertility, migration—within a single, multidimensional measurement framework.

To situate demographic literacy within the broader landscape of adult competences, we further reviewed established frameworks and measurement strategies developed in adjacent literacy domains, including statistical, digital, and general adult skills (see Appendix B). This overview shows that large-scale initiatives - such as PIAAC for adult skills, Eurostat's data literacy monitoring tools, and UNESCO's

SDG4-based literacy indicators - offer valuable methodological guidance for the measurement of emerging literacies. However, none of these instruments explicitly assess adults' ability to understand demographic trends or population ageing. This gap reinforces the relevance of the present study and highlights the need for the development of standardized measures capable of capturing demographic literacy as a distinct and policy-relevant dimension.

4. Socio-demographic determinants of demographic knowledge on population aging

This section provides a first empirical application of the proposed framework, focusing on the dimension of demographic knowledge. As outlined in the theoretical section, knowledge represents a necessary condition for the development of demographic literacy.

Italy provides an appropriate context for this analysis, as it combines one of the world's oldest population structures with persistent economic disparities (e.g., Rosina & Impicciatore, 2023).

The analysis explores whether individuals possess factual understanding of population ageing, with specific attention to two fundamental components—longevity and dejuvination—that jointly shape the ageing process.[1] To the best of our knowledge, no existing survey has simultaneously examined these interrelated dimensions of demographic knowledge together with socio-economic characteristics. For this reason, we commissioned an original survey specifically designed to investigate demographic knowledge on aging process within the Italian population. The data were collected by Ipsos for Osservatorio Senior and Astra Ricerche between 29 November and 14 December 2023, using the Ipsos probabilistic panel and the CAWI technique.

The survey is based on a random stratified sample of N = 1,575 individuals aged 20–69 years. The collected data were weighted to ensure representativeness of the Italian adult population. Post-stratification weights were applied based on benchmarks from the 2022 Labour Force Survey and

[1] While migration also contributes to population ageing, it is not considered here, as the focus is on the internal demographic mechanisms of fertility and longevity.

the most recent ISTAT population statistics (2023). The following variables were used in the weighting procedure: gender by employment status (employed vs. not employed); educational attainment (college degree vs. no degree) by age group (20–29, 30–39, 40–49, 50–59, 60–69); geographic region (North-West, North-East, Centre, South and Islands). A trimmed weighting approach was applied, whereby extreme weights were capped to reduce the potential influence of outliers and stabilize estimates.

The two questions on demographic knowledge about aging in Italy are as follows:

"According to you, [the elderly population] [the young population] in Italy: (1) is increasing; (2) is stable; (3) is decreasing; (4) I do not know.

Answers to the two questions have been treated to have one single outcome indicator related to the knowledge about the ageing process, which takes value 1 when the individual correctly answers to both questions (i.e., elderly population is increasing – ageing from the top - and young population is decreasing – ageing from the bottom), 0 otherwise. This reflects the idea, that a meaningful understanding of current demographic dynamics requires awareness of both trends simultaneously. Knowing only one of the two trends—either population aging or the decline in younger cohorts—is not sufficient to capture the full picture. Therefore, we consider correct answers to both questions as the minimum threshold for identifying individuals with basic demographic knowledge of population ageing. As discussed in the theoretical section, demographic knowledge entails not only access to and understanding of information, but also the ability to integrate multiple pieces of information into a coherent interpretation.

Building on this operational definition, the next step is to examine how demographic knowledge varies across the population. In line with the theoretical framework, this analysis focuses on the role of individual and contextual antecedents—such as education, income, gender, age and area of living—that shape opportunities to access, understand, combine and interpret demographic information. Identifying these social and economic determinants allows us to explore which factors foster or constrain individuals' demographic knowledge and, ultimately, to sustain its application at the macro and micro level.

Given the potential for complex, non-linear relationships between socio-economic conditions and demographic knowledge, we employ a Random Forest approach to identify the most influential predictors of demographic knowledge on aging.

Methods

We employ Random Forest (RF), a machine learning approach selected for its ability to capture complex and non-linear relationships between socio-demographic characteristics and levels of demographic knowledge. RF belongs to the broader class of supervised machine learning (SML) methods, which are designed to learn predictive patterns from labeled data (i.e., observations for which the outcome variable is known) without the need to predefine the functional relationships among variables (Breiman, 2001). In our setting, RF uses labeled data to identify how different predictors relate to individuals' knowledge of population age structure. Unlike traditional statistical methods, RF accurately maps inputs to outputs without assuming a specific data-generating process (Berk 2016), learning patterns from labelled data through an ensemble of classification trees built on bootstrap samples and random subsets of variables. The final prediction is obtained by aggregating the results of all trees through majority voting. Our analysis focuses on identifying which variables most contribute to the model's predictive accuracy for demographic knowledge on aging. Despite their potential to capture complex patterns in a data-driven way, the adoption of ensemble methods as Random Forests is still relatively uncommon in this field (e.g., Bitew et al., 2020; Arpino et al., 2021; Stulp et al., 2023).

To understand the influence of each predictor on the model's accuracy, RF provide a variable importance measure known as Mean Decrease in Accuracy (MDA). This metric is calculated by permuting the values of a predictor in out-of-bag (OOB) samples—observations not used to train the tree—and measuring how much the model's prediction accuracy decreases. Formally, the MDA for variable X_j is

$$MDA\ (X_j = \frac{1}{T}\sum_{t=1}^{T}(Accuracy_t\text{-}Accuracy_t^{perm(X_j)})$$

Where T is the total number of trees, $Accuracy_t$ is the accuracy of tree on its out-of-bag (OOB) sample, and $Accuracy_t^{perm(X_j)}$ is the accuracy after permuting X_j. A larger MDA indicates that the variable plays a crucial role in the model's predictions, as randomizing its values—while keeping the rest of the data unchanged—substantially reduces prediction accuracy on OOB observations. This allows ranking predictors according to their predictive relevance for demographic knowledge.

The predictors used in the RF model capture a wide range of socio-demographic characteristics, including gender (male, female), age group (20–29, 30–39, 40–49, 50–59, 60–69), geographic area of residence (North-West, North-East, Centre, South, Islands), and educational attainment (low: ISCED 0–2; medium: ISCED 3–4; high: ISCED 5–6). Household income is represented through deciles (from the 1st to the 10th), with two additional categories: "do not know" and "prefer not to answer." Urbanization level is based on the population size of the respondent's municipality, divided into six categories: fewer than 10,000 inhabitants; 10,000–30,000; 30,000–100,000; 100,000–250,000; more than 250,000 inhabitants; and a "no answer" category. All predictors were coded as binary (dummy) variables. Descriptive statistics are reported in Appendix Table A1.

Applying the Generalized Variance Inflation Factor (GVIF) to diagnose multicollinearity between predictors (Fox and Monette, 1992), we find negligible levels, unlikely to bias coefficients or their interpretation (see Table A2).[2]

Results

[2] We treat predictors as categorical (factor) variables rather than as a full set of dummies to avoid perfect multicollinearity.

Descriptive results

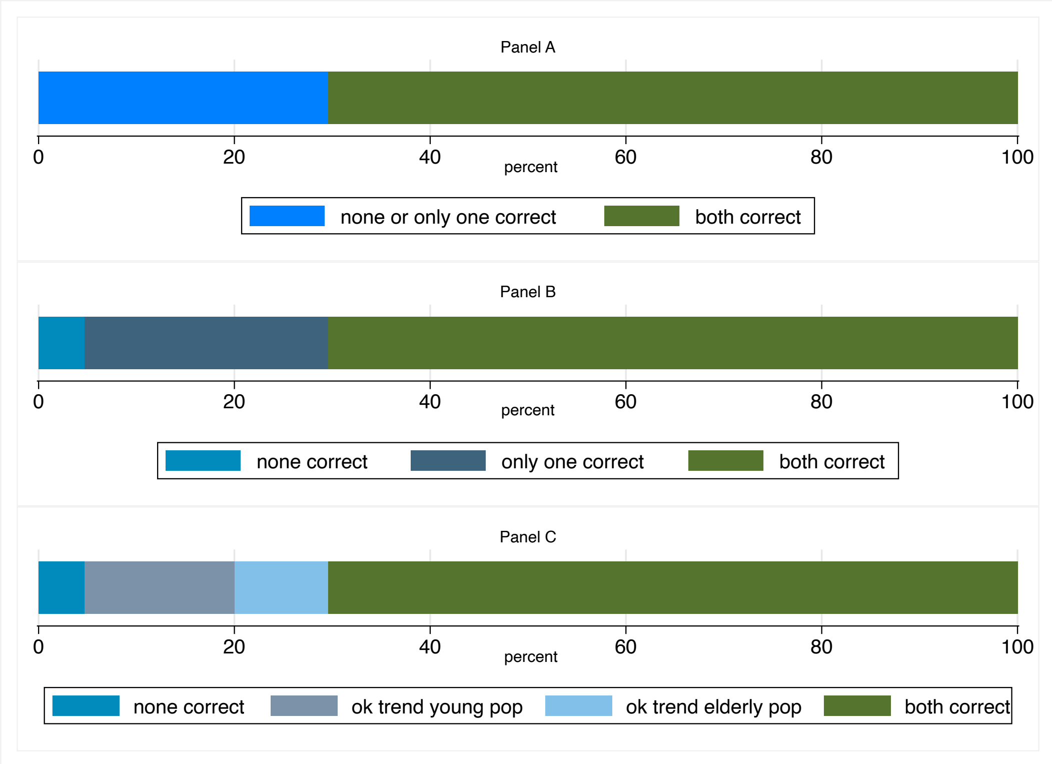
Figure 2 reports the prevalence of demographic literacy, defined as correctly answering both items on population trends: the long-term increase in the elderly population and the long-term decrease in the young population of respondent's country (Italy). We can observe from Panel A that individuals without knowledge of the population ageing account for about 30% of the total sample. This means that nearly one in three people in Italy fails to meet even the first requirement of demographic literacy on aging that is basic knowledge on population trends - as already explained in our definition of demographic literacy.

Panel B and Panel C of Figure 2 report summary measure that capture whether individuals simultaneously recognize the ageing trend and the dejuvenation process, or instead an isolated knowledge of one single fact. In particular, among those that report wrong answer(s), about 7% provided a wrong answer on both the items, about 13% on the question on dejuvenation, and about 10% on trend of elderly population.

To better understand the individual characteristics associated with this knowledge gap, we now turn to a predictive analysis.

[Figure 2 here]

Figure 2: Distribution of Demographic Knowledge on Aging



Empirical Assessment of the Algorithm

Prior to fitting the Random Forest, we performed a calibration procedure aimed at determining the optimal parameter configuration governing model complexity and predictive performance. Specifically, we tuned the minimum node size and the number of predictors sampled at each split.

Following the general strategy proposed by Breiman (2001), the model was repeatedly trained using different combinations of the minimum number of cases in terminal nodes and the number of variables randomly selected at each split. For each combination, predictive performance was evaluated through the out-of-bag (OOB) error rate, an internal measure of prediction accuracy.

Figure A.2 shows how the OOB error varies across parameter values. Lighter areas correspond to lower error rates, and the black cross marks the combination that minimizes the OOB error, representing the optimal balance between model complexity and predictive accuracy. The irregular shape of the tuning surface reflects the adaptive nature of the search grid, which focuses on the most informative regions of the parameter space. The black cross in Figure A.2 identifies the parameter configuration that yields the lowest out-of-bag (OOB) error rate, and this corresponds when the size of terminal nodes was set to 1 and the number of variables randomly selected at each split was 13. For what regards and the number of trees to be grown in the forest, Figure A.3 shows that the out-of-bag (OOB) error rate stabilizes after approximately 500 trees – in this case the OOB error rate stabilized around 29%. To ensure fully stable predictions and reproducible estimates of variable importance, the final model was trained with 1,000 trees, which yielded a final OOB error rate of about 28%. Increasing the number of trees beyond this point does not lead to overfitting but only increases computation time (Breiman, 2001).

Random forests

Random forests

Figure 3 shows the standardized variable-importance measures with respect to predictive accuracy. Variables with positive importance values (highlighted in blue) contribute positively to the model's predictive power, while those with negative values (shown in red) have less or even negative influence. Key predictors with strong positive importance include all levels of education, having a very low income (first decile of the distribution), but also being in the middle age and living in a small urbanization.

Figure 3: Variable importance (VIMP) measures for all 33 independent variables included as predictors in the Random Forests

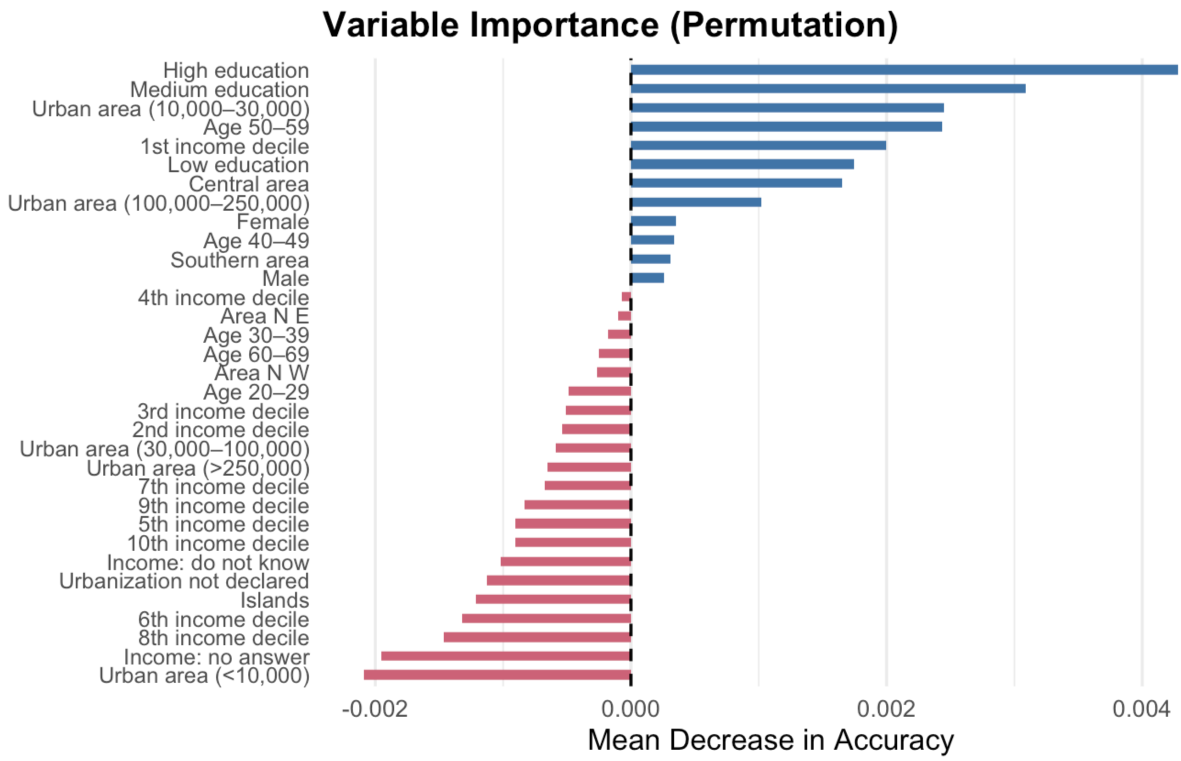
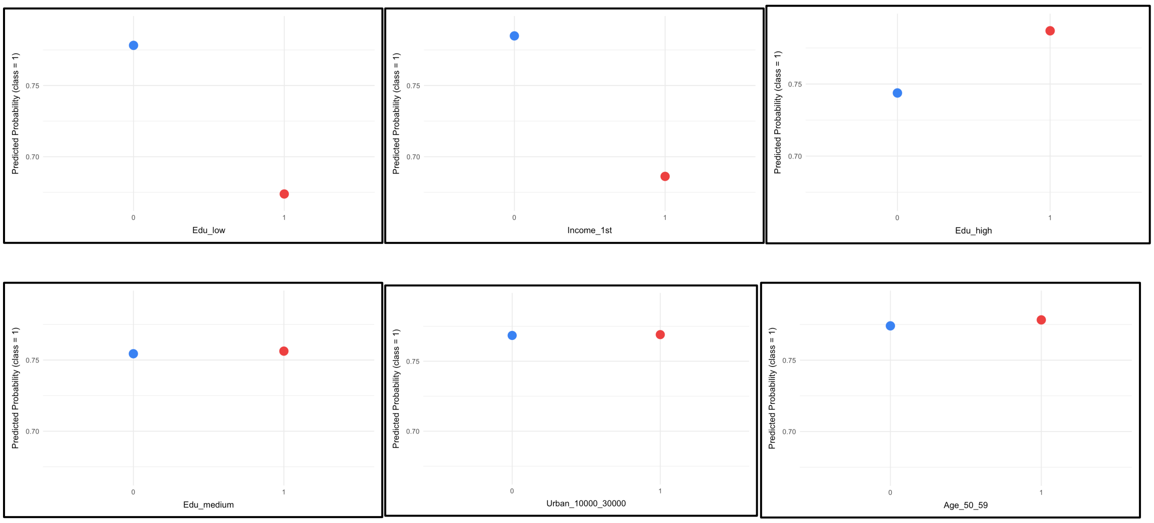


Figure 4 presents the predicted probabilities of the outcome across the categories of the most influential variables, illustrating the model's ability to capture nuanced, non-linear effects without requiring prior variable grouping. Individuals with lower levels of education tend to exhibit, on average, smaller predicted probabilities of belonging to class 1 (i.e., possessing demographic knowledge on ageing), whereas those with a high educational attainment show a significantly higher likelihood of doing so. A comparable pattern is observed for income, as respondents in the lowest decile demonstrate considerably lower predicted probabilities of demographic knowledge.

In contrast, the effects associated with being aged 50–59, residing in a small urban area, or having a medium level of education appear less robust, as the corresponding predicted probabilities indicate weaker or more uncertain associations with the outcome.[3]

[3] It is also important to note that, in Random Forest models, some variables may exert their influence primarily through interactions with other predictors rather than through isolated main effects. Consequently, while PDPs are useful for visualizing average marginal relationships, they may only partially reflect the complex dependencies captured by the model.

Figure 4: Partial Dependence Plots of most predictive independent variables.



Note: The y axis of each plot reports the predicted probability of having demographic knowledge associated with each value of the most important predictor (x axis) - based on VIMP.

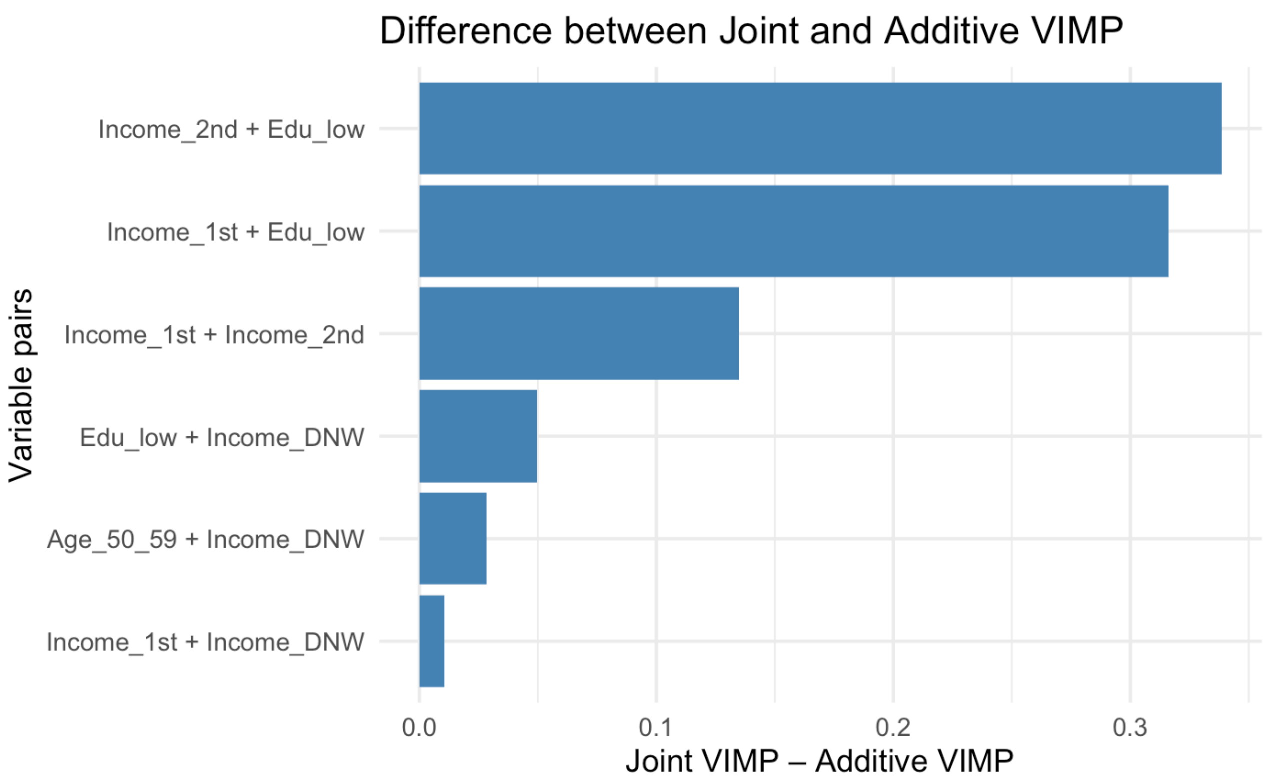
To explore whether certain predictors interact in shaping demographic knowledge, we examined joint variable importance (VIMP) scores for selected pairs of variables. Starting from the four most influential predictors reported in Figure 3, we compared their combined contribution to the sum of their individual effects (see Table A.1 in the Appendix).

As shown in Figure 5, the most substantial interaction was found between low education and low income (first and second deciles), where the joint importance clearly exceeded the additive effect, suggesting that socioeconomic disadvantage is particularly impactful when these two factors co-occur.

Other interactions, even if weaker, also emerged—such as between low education and income non-response, and between age (50–59) and income non-response—potentially pointing to more nuanced patterns worth further investigation. We know that when respondents do not report their income this is related to poor economic conditions.

Overall, these findings indicate while education and income levels emerged as the most influential predictors in the permutation-based Variable Importance, the joint–additive comparison reveals that other variables also contribute through interaction effects. In particular, pairs such as (Income_2nd + Edu_low) or (Edu_low + Income_DNW) show higher joint VIMP values than expected from their additive contributions, indicating that part of their predictive power arises from interaction patterns rather than purely independent effects.

Figure 5: Difference between Joint and Additive VIMP



Similar conclusions are offered by the Joint VIMP Heat Maps (Figure A3), that illustrates the joint VIMP values derived from the random forest model for selected pairs of predictor variables. The brightest cells in the heatmap are concentrated among combinations involving low education and various forms of economic disadvantage. Particularly strong joint importance is observed between low education and both the first- and second-income deciles, as well as between the first and second income deciles themselves. Another notable interaction is found between low education and individuals who did not report their income. These results are consistent with those from the joint–additive VIMP difference analysis and suggest that the combined influence of low educational attainment and low-income status plays a particularly important role in shaping literacy outcomes.

From a theoretical perspective, the findings imply that economic and educational disadvantages do not function independently but instead reinforce one another. The joint effects observed in the model indicate that individuals who experience both low income and low education are substantially more likely to exhibit lower knowledge than would be predicted by considering each factor in isolation. These results underscore the necessity of adopting a multidimensional approach when addressing educational inequalities, as interventions targeting a single domain may fail to account for the compounded impact of overlapping disadvantages.

Overall, the empirical results reveal that demographic literacy is unevenly distributed across the population and closely intertwined with broader socio-economic inequalities. Individuals with higher education, stronger economic security, and greater access to information are significantly more likely to demonstrate an accurate understanding of demographic ageing. Conversely, demographic illiteracy tends to cluster among those facing cumulative disadvantages, suggesting that the ability to interpret demographic change is itself socially stratified.

These patterns empirically confirm the conceptual expectation that demographic literacy, even at its basic knowledge level, is shaped by intersecting social inequalities. This reinforces the interpretation of demographic literacy as both a cognitive resource and a social indicator of inclusion.

These findings have implications that extend beyond cognitive knowledge: they point to inequalities in well-being and life preparedness. Individuals who lack basic demographic understanding may be less equipped to anticipate future challenges, plan for ageing, or engage meaningfully in social and policy debates that affect their lives. Strengthening demographic literacy, therefore, is not only a matter of informational accuracy but a way to enhance citizens' capacity for informed choice, resilience, and subjective well-being in ageing societies.

6. Conclusions

This study underscores the importance of demographic literacy as an emergent competence for individuals navigating rapid demographic change in contemporary societies. Building on a novel conceptual framework, we argue that demographic literacy extends beyond the simple retention of facts. By analogy with other literacies - such as financial, health, or digital literacy - it encompasses the capacity to access, understand, and integrate information on population dynamics, and to apply this knowledge in personal decisions and civic engagement.

Through an empirical application focused on Italy - one of the most rapidly ageing countries worldwide - we provide an original operationalization of demographic literacy using integrated indicators of demographic knowledge related to population ageing. Our findings show that accurate understanding of basic ageing processes is far from universal, with almost one-third of adults unable to correctly identify both the rise of the older population and the decline of younger cohorts. Inequalities in demographic literacy are patterned along key socioeconomic lines: individuals with higher levels of education and income are significantly more likely to possess this knowledge, while cumulative disadvantage amplifies the likelihood of knowledge gaps.

From a theoretical perspective, the findings underscore the importance of moving beyond fragmented approaches to demographic knowledge, typically focused on isolated components such as fertility, mortality. We further argue that these results illustrate that demographic literacy functions as a social resource, with possible personal and policy implications. Individuals who lack fundamental demographic knowledge may be less equipped to anticipate extended lifespans, prepare financially and socially for later life, or understand the demographic foundations of policies that affect pensions, care systems, and intergenerational relations.

Several limitations should be acknowledged.

First, the empirical analysis relies on a restricted set of indicators focused primarily on population ageing; therefore, it captures only a partial dimension of demographic knowledge – even though maybe the most relevant in contemporary post-transitional societies.

Second, the indicators used assess knowledge but do not capture its applicative dimension, which is what transforms knowledge into literacy. In other words, the indicators do not account individuals' ability to use demographic information in practice, thus overlooking the behavioural components that are central to a full understanding of literacy and to its translation into informed reasoning and action. In this sense, demographic literacy has the potential to become a key social indicator for understanding how societies perceive, interpret, and adapt to demographic change.

Third, data constraints prevent cross-national comparisons and longitudinal analyses, which would be necessary to evaluate the consistency of demographic literacy across contexts and over time.

Finally, while the current operationalization provides an initial measurement, future refinements should include stronger psychometric validation and the integration of subjective and functional dimensions.

Thus, future research should move toward the development of standardized indicators of demographic literacy, capable of capturing not only factual knowledge but also interpretative abilities and practical application.

Advancing this line of inquiry also requires a stronger integration with other literacies—such as financial, health, and digital literacy—to understand how these forms of competence interact to shape individual decision-making and civic participation. Moreover, future work should investigate the policy relevance of demographic literacy as an emerging indicator of civic capability and social inclusion, identifying how it can inform interventions aimed at reducing informational inequalities.

Finally, comparative and cross-national perspectives are needed to explore how institutional, cultural, and informational contexts influence the development of demographic literacy and condition its impact on social cohesion and well-being.

Such extensions would allow demographic literacy to evolve from an emerging theoretical construct into a robust empirical indicator of how individuals and societies understand and respond to population change.

References

Ackoff, R. L. (1994). Systems thinking and thinking systems. *System dynamics review*, *10*(2-3), 175-188. https://doi.org/10.1002/sdr.4260100206

Alba, R., Rumbaut, R. G., & Marotz, K. (2005). A distorted nation: Perceptions of racial/ethnic group sizes and attitudes toward immigrants and other minorities. *Social forces*, *84*(2), 901-919. https://doi.org/10.1353/sof.2006.0002

Alesina, A., & Tabellini, M. (2024). The political effects of immigration: Culture or economics?. *Journal of Economic Literature*, *62*(1), 5-46. https://doi.org/10.1257/jel.20221643

André, C., P. Gal, and M. Schief. 2024. "Enhancing Productivity and Growth in an Ageing Society: Key Mechanisms and Policy Options." *OECD Economics Department Working Papers* No. 1807. Paris, France. OECD Publishing.

Apicella, G., De Giorgi, E., Di Lorenzo, E., & Sibillo, M. (2024). Gender-inclusive financial and demographic literacy: Monetizing the gender mortality gap. *Applied Stochastic Models In Business and Industry*, *40*(4), 1082-1104

Arie, H. (2018). Improving Productivity Through Demographic Literacy. In *Handbook of Bureaucracy* (pp. 373-384). Routledge

Arpino, B., Bordone, V., & Scherbov, S. (2018). Smoking, education and the ability to predict own survival probabilities. *Advances in Life Course Research*, *37*, 23-30.

Arpino, B., Le Moglie, M., & Mencarini, L. (2022). What tears couples apart: A machine learning analysis of union dissolution in Germany. *Demography*, *59*(1), 161-186.

Ayalon, L., Dolberg, P., Mikulionienė, S., Perek-Białas, J., Rapolienė, G., Stypinska, J., ... & de la Fuente-Núñez, V. (2019). A systematic review of existing ageism scales. *Ageing research reviews*, *54*, 100919.

Barrusse, V. D. L., Lefèvre, C., & Véron, J. (2019). What people in France know about population: Evidence from a recent survey. *Population & Societies*, *572*(11), 1-4.

Barrusse, V. D. L. (2020). Discussion on the return of "denatality" in France and its perception between 1974 and 1981. *Population and Economics*, *4*(3), 33-56.

Billari, F. C. (2022). Demography: Fast and slow. *Population and development review*, *48*(1), 9-30

Billari, F. C., Favero, C. A., & Saita, F. (2023). Online financial and demographic education for workers: Experimental evidence from an Italian Pension Fund. *Journal of Banking & Finance*, *151*, 106849

Bitew, F. H., Nyarko, S. H., Potter, L., & Sparks, C. S. (2020). Machine learning approach for predicting under-five mortality determinants in Ethiopia: evidence from the 2016 Ethiopian Demographic and Health Survey. *Genus*, *76*(1), 37.

Blockeel, C., Campbell, A., Coticchio, G., Garcia-Velasco, J. A., Pinborg, A., & Santulli, P. (2025). Educate. Empower. Reproduce. A call for action against the demographic winter. *Reproductive BioMedicine Online*, 105047.

Breiman, L. (2001). Random forests. *Machine learning*, *45*(1), 5-32.

Breytspraak L., Badura L. (2015). *Facts on Aging Quiz* [revised; based on Palmore (1977; 1981)]. http://info.umkc.edu/aging/quiz/

Caltabiano, M., & Rosina, A. (2018). The dejuvenation of the Italian population. *Journal of Modern Italian Studies*, *23*(1), 24-40.

Van Dijk, J. (2020). *The digital divide*. John Wiley & Sons.

Dorbritz, J. (2008). Demographic knowledge and evaluation of demographic trends. In *People, Population Change and Policies: Lessons from the Population Policy Acceptance Study Vol. 2: Demographic Knowledge–Gender–Ageing* (pp. 21-44). Dordrecht: Springer Netherlands.

European Centre for the Development of Vocational Training (Cedefop) (2012) *Working and Ageing: The Benefits of Investing in an Ageing Workforce*. Luxembourg: Cedefop.

EU-OSHA, Cedefop, Eurofound and EIGE (2017), Joint report on Towards age-friendly work in Europe: a life-course perspective on work and ageing from EU Agencies, *Publications Office of the European Union*, Luxembourg

Fernández, J. J., García-Albacete, G., Jaime-Castillo, A. M., & Radl, J. (2023). Priming or learning? The influence of pension policy information on individual preferences in Germany, Spain and the United States. *Journal of European Social Policy*, *33*(3), 337-352.

Fox, J., & Monette, G. (1992). Generalized collinearity diagnostics. *Journal of the American Statistical Association*, *87*(417), 178-183.

Gan, L., Gong, G., Hurd, M., & McFadden, D. (2015). Subjective mortality risk and bequests. *Journal of Econometrics*, *188*(2), 514-525

Gorodzeisky, A., & Semyonov, M. (2020). Perceptions and misperceptions: Actual size, perceived size and opposition to immigration in European societies. *Journal of Ethnic and Migration Studies*, *46*(3), 612-630.

Grigorieff, A., Roth, C., & Ubfal, D. (2020). Does information change attitudes toward immigrants?. *Demography*, *57*(3), 1117-1143.

Institute for Family Studies. (2019). The American Family Survey. https://csed.byu.edu/0000017e-2611-d5d4-a57f-277126ef0001/american-family-survey-2019-report-pdf/

Kravdal, Ø. (2025). Should we be concerned about low fertility? A discussion of six possible arguments. *Demographic Research*, *53*, 373-418.

Kulcsár, L., & Brown, D. (2009). Public Perceptions of Population Changes in Hungary. *Eastern European Countryside*, *15*, 23.

Kulic, N., Griaznova, O., Clerici, E., Bellani, D., Mantovani, D., Vergolini, L., & Scervini, F. (2025). A comprehensive overview of a large-scale survey on inequality perceptions (IneqPer) in Italy. *Frontiers in sociology*, *10*, 1620096.

Kunovich, R. M. (2017). Perceptions of racial group size in a minority-majority area. *Sociological Perspectives*, *60*(3), 479-496

Levy, B. R., Slade, M. D., Chang, E., Kannoth, S., & Wang, S. Y. (2020). Ageism amplifies cost and prevalence of health conditions. *The Gerontologist*, *60*(1), 174-181.

van Loo, J., Lettmayr, C., & Launikari, M. (2011). Setting the scene: promoting an inclusive labour market for ageing workers. *Working and ageing*, 273.

Lusardi, A., & Mitchell, O. S. (2007). Baby boomer retirement security: The roles of planning, financial literacy, and housing wealth. *Journal of monetary Economics*, *54*(1), 205-224.

Lusardi, A., & Mitchell, O. S. (2014). The economic importance of financial literacy: Theory and evidence. *American Economic Journal: Journal of Economic Literature*, *52*(1), 5-44.

Martins, M. V., Koert, E., Sylvest, R., Maeda, E., Moura-Ramos, M., Hammarberg, K., & Harper, J. (2024). Fertility education: recommendations for developing and implementing tools to improve fertility literacy. *Human Reproduction*, *39*(2), 293-302.

Northcott, H. C. (1994). Public perceptions of the population aging'crisis'. *Canadian Public Policy/Analyse de Politiques*, 66-77.

OECD (2020). *International Survey of Adult Financial Literacy*. 2020

Osservatorio Senior (2023). https://osservatoriosenior.it/le-nuove-sfide-dei-senior/

Palmore, E. (1977). Facts on aging: A short quiz. *The gerontologist*, *17*(4), 315-320.

Palmore, E. (1981). More on Palmore's facts on aging quiz. *The Gerontologist*, *21*(2), 115-116.

Palmore, E. B. (1988). *The facts on aging quiz: A handbook of uses and results*. Springer Publishing Company.

Population Connection (2025) *Population Connection survey: How much do Americans know and worry about population trends?* https://populationconnection.org/blog/survey-americans-population-trends/ Visited on 27th October 2025.

Prskawetz, A., Fent, T., & Guest, R. (2008). Workforce aging and labor productivity: The role of supply and demand for labor in the G7 countries. *Population and Development Review*, *34*, 298-323.

Radl, J., & Fernández, J. J. (2022). Pension policy literacy and retirement expectations: A cross-country survey experiment. *The Journals of Gerontology: Series B*, *77*(4), 739-749.

Rosina, A., & Impicciatore, R. (2023). The end of a growing Italy. What are the conditions for well-being and development in an aging population?. *Rivista Italiana Di Economia, Demografia E Statistica*, *77*(3), 5-17.

Rowley, J. (2007). The wisdom hierarchy: representations of the DIKW hierarchy. *Journal of information science*, *33*(2), 163-180.

Seufert, R. L., & Carrozza, M. A. (2002). A test of Palmore's Facts on Aging Quizzes as alternate measures. *Journal of Aging Studies*, *16*(3), 279-294.

Strozza, C., Bergeron-Boucher, M. P., Callaway, J., & Drefahl, S. (2024). Forecasting inequalities in survival to retirement age by socioeconomic status in Denmark and Sweden. *European Journal of Population*, *40*(1), 17.

Stulp, G., Top, L., Xu, X., & Sivak, E. (2023). A data-driven approach shows that individuals' characteristics are more important than their networks in predicting fertility preferences. *Royal Society Open Science*, *10*(12), 230988.

Appendix A

Table A1. **Descriptive Statistics**

Variable	N	%
Male	867	55.2
Female	705	44.8
Age 20-29	98	6.2
Age 30-39	237	15.1
Age 40-49	370	23.5
Age 50-59	441	28.1
Age 60-69	426	27.1
Area North-West	470	29.9
Area North-East	283	18.0
Area Centre	339	21.6
Area South	324	20.6
Area Islands	156	9.9
Low education	120	7.6
Medium education	673	42.8
High education	779	49.6
Income 1st decile	47	3.0

Variable	N	%
Income 2nd decile	66	4.2
Income 3rd decile	92	5.9
Income 4th decile	91	5.8
Income 5th decile	138	8.8
Income 6th decile	125	8.0
Income 7th decile	197	12.5
Income 8th decile	174	11.1
Income 9th decile	138	8.8
Income 10th decile	150	9.5
Income Don’t know	65	4.1
Income Don’t want to say	289	18.4
Degree of Urbanization <10,000 inhabitants	141	9.0
Degree of Urbanization >10,000 & <30000 inhabitants	440	28.0
Degree of Urbanization >30,000 & <100,000 inhabitants	331	21.1
Degree of Urbanization >100,000 & <250,000 inhabitants	138	8.8

Variable	N	%
Degree of Urbanization >250,000 inhabitants	347	22.1
Degree of Urbanization no answer	175	11.1

Table A2. **Generalized Variance Inflation Factors (GVIF)**

Variable	GVIF	Df	GVIF_adj
Gender	1.07	1	1.03
Age	1.13	4	1.02
Area of living	1.28	4	1.03
Educational level	1.23	2	1.05
Income	1.36	11	1.01
Level of Urbanization	1.25	5	1.02

Figure A1. **OOB error for nodsize and mtry**

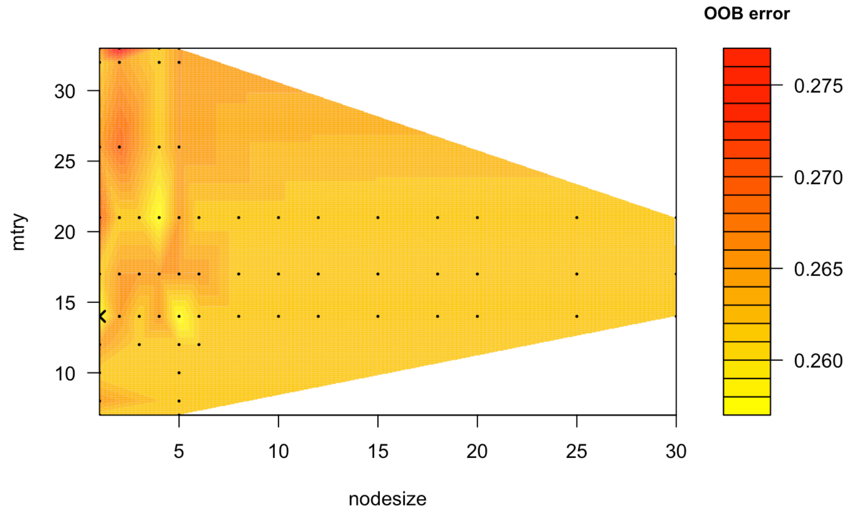


Figure A2 **OOB Error Rate vs Number of Trees**

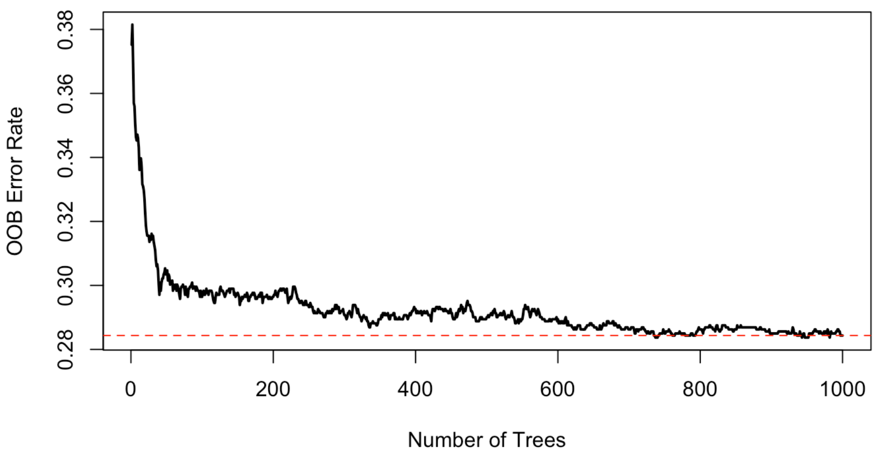
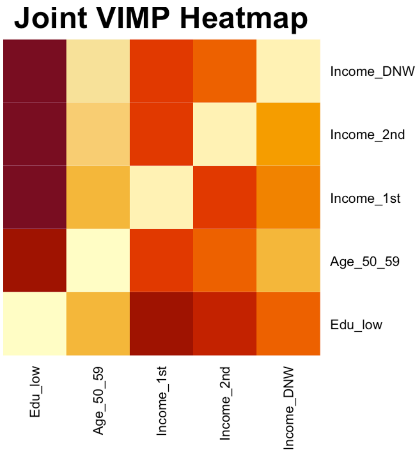


Figure A3. **Joint VIMP Heatmap**



Appendix B

Measurement of other forms of literacy

In this section, we review existing programs and frameworks designed to assess adults' skills and knowledge in various domains of literacy. Our aim is to provide an overview of established practices, resources, and measurement tools that have traditionally been used to operationalize and evaluate different forms of literacy. We argue that these experiences offer a valuable foundation for advancing discussions within demography on the development of comparable instruments to measure demographic literacy.

1. Large-scale international assessments of adult skills

A valuable reference point is the Survey of Adult Skills conducted within the Programme for the International Assessment of Adult Competencies (PIAAC) by the OECD. This large-scale initiative assesses the proficiency of adults (aged 16-65) in core information-processing skills - literacy, numeracy, and problem solving - and collects detailed information on the use of these skills in everyday life and at work. The first cycle (2011-2018) involved 39 countries and over 245,000 respondents, while the second cycle (2022-2023) currently covers 31 countries, with initial results released in 2024[4].

Although PIAAC does not yet include specific measures of demographic or ageing literacy, its design provides a robust model for how adult literacies can be operationalised, monitored over time, and compared internationally. This approach could inform the development of future indicators of demographic literacy.

2. Statistical and data literacy initiatives

As societies become increasingly data-driven, the ability to understand and critically evaluate quantitative information has gained central importance.

At the European level, Eurostat promotes statistical literacy through education initiatives such as the *European Statistics Competition* and web-based resources designed to enhance citizens' familiarity with

[4] https://www.oecd.org/content/dam/oecd/en/publications/reports/2025/08/survey-of-adult-skills-2023-technical-report_92061789/80d9f692-en.pdf

data. It also monitors data and digital literacy using the Digital Skills Indicator (DSI) 2.0[5]. At the national level, ISTAT (Italy) delivers accessible materials - such as *Dati alla mano*[6], animations, and data-focused games - to facilitate the interpretation of statistical information. It also organises national competitions like the *Olympics of Statistics* to foster early statistical reasoning.

Collectively, these initiatives show how statistical offices can engage the public and produce indicators to track literacy in society over time.

3. Literacy as a global capability and policy objective

The United Nations, particularly through UNESCO, recognises literacy as a foundation of Sustainable Development Goal 4 (SDG 4)[7], emphasising lifelong opportunities for literacy and numeracy regardless of age or gender.

The UNESCO Institute for Statistics (UIS) collects internationally comparable indicators - including adult and youth literacy rates and literacy among older adults - drawing on a wide array of data sources such as censuses, household surveys, and learning assessments[8].

Additionally, initiatives like the UN World Data Forum[9] highlight the relevance of data innovation and cross-sector partnerships in strengthening statistical capabilities and informed citizenship worldwide.

4. Experiences supporting knowledge of population issues

Some initiatives explicitly link adult learning to the challenges posed by demographic change. Within the European Union, CEDEFOP has examined the implications of population ageing for labour markets, lifelong learning, and active ageing (CEDEFOP, 2011).

A coordinated action by EU-OSHA, Cedefop, Eurofound and EIGE (2017) further identified promising practices to sustain labour-market participation in ageing societies.

Population research networks - such as the Association of Population Centers (APC) - and data

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[5] https://digital-skills-jobs.europa.eu/en/inspiration/resources/digital-skills-indicator-20-measuring-digital-skills-across-eu
[6] https://www.istat.it/statistiche-per-temi/focus/dati-alla-mano/
[7] https://sdgs.un.org/goals/goal4
[8] https://databrowser.uis.unesco.org/browser/EDUCATION/UIS-SDG4Monitoring
[9] https://unstats.un.org/unsd/undataforum/about/

infrastructures (e.g., ICPSR) also contribute by promoting data literacy and access to demographic information.

While these experiences remain fragmented, they underline growing institutional attention to public understanding of population issues.

5. Implications for measuring demographic literacy

Taken together, existing frameworks show the maturity of measurement strategies for several adult literacies. However, standardised tools to assess demographic literacy are still largely missing. Current approaches focus on adjacent domains - statistical, digital, or health literacy - without directly evaluating knowledge, perceptions, or awareness of demographic ageing or citizens' capability to interpret demographic change as a shared societal challenge.

This gap presents clear opportunities for innovation. The indicators fielded in our Ipsos–Osservatorio Senior–Astra survey provide an initial example of how basic demographic knowledge on ageing can be quantified and monitored, offering a testing ground for the future development of more comprehensive measures of demographic literacy.

References Appedix B

Cedefop (2011), Working and Ageing: Guidance and Counselling for Mature Learners, Publications Office of the European Union, Luxembourg (https://euroguidance.eu/images/publications/Working-and-ageing-Guidance-and-counselling-for-mature-learning/index.html#p=1).

EU-OSHA, Cedefop, Eurofound and EIGE (2017), Joint report on Towards age-friendly work in Europe: a life-course perspective on work and ageing from EU Agencies, Publications Office of the European Union, Luxembourg.

UIS (UNESCO Institute of Statistics), World Education Statistics, Montreal, Canada, 2024, ISBN:978-92-9189-332-4.