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"Broadening demographic horizons"

Guest Editors: Alexia Prskawetz, Sergei Scherbov and Warren Sanderson

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Vienna Institute of Demography
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Authors for this volume

Mohammad Jalal ABBASI-SHAVAZI, Department of Demography, Faculty of Social Sciences, Jalal Al Ahmad Avenue, University of Tehran, Tehran, Iran and Professorial Fellow, Melbourne School of Population and Global Health, Medicine, Dentistry and Health Sciences, The University of Melbourne, Australia

Nicholas BIDDLE, Centre for Aboriginal Economic Policy Research and ANU Centre for Social Research and Methods, Research School of Social Sciences, Australian National University, Australia

Helge BRUNBORG, Previously with Statistics Norway

William P. BUTZ, Senior Research Scholar, World Population Program, IIASA, Laxenburg, Austria

Graziella CASELLI, Sapienza University of Rome, Department of Statistical Sciences, Viale Regina Elena 295, 00161, Rome, Italy

Joel E. COHEN, Laboratory of Populations, The Rockefeller University and Columbia University, 1230 York Avenue, New York, NY 10065, USA
Additional affiliations: Earth Institute and Department of Statistics, Columbia University, USA; Department of Statistics, University of Chicago, USA

Nicholas GAILEY, Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW, WU), International Institute for Applied Systems Analysis, Schlossplatz 1, 2361 Laxenburg, Austria

Patrick GERLAND, United Nations Organization, Department of Economic and Social Affairs (DESA), Population Division, Two UN Plaza, Room DC2-1934, New York, NY 10017, USA

Bernhard HAMMER, Wittgenstein Centre for Demography and Global Human Capital, Vienna, Austria

Gavin W. JONES, Emeritus Professor, Australian National University, ACT, Canberra, Australia

Nico KEILMAN, Department of Economics, P.O. Box 1095 Blindern, N 0317 Oslo, Norway

Bernhard KÖPPEN, University of Koblenz-Landau, Universitätsstraße 1, 56070 Koblenz, Germany

Rosa Maria LIPSI, Italian National Institute of Statistics (ISTAT), Italy

Wolfgang LUTZ, Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW, WU), Vienna, Austria

Marc LUY, Vienna Institute of Demography of the Austrian Academy of Sciences, Welthandelsplatz 2/Level 2, 1020 Vienna, Austria

James O'DONNELL, School of Demography, Research School of Social Sciences, Australian National University, Australia

Alexia PRSKAWETZ, Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW,WU), Vienna Institute of Demography, Welthandelsplatz 2/Level 2, 1020 Vienna, Austria and TU Wien, Austria

Francesco RAMPAZZO, University of Southampton, UK

James RAYMER, School of Demography, Research School of Social Sciences, Australian National University, 9 Fellows Road, Acton ACT 2601, Australia

Philip REES, Professor Emeritus, School of Geography, University of Leeds, Leeds LS2 9JT, UK

Warren C. SANDERSON, Department of Economics, Stony Brook University, Stony Brook 11794-4384, New York, USA and Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW,WU), International Institute for Applied Systems Analysis, Schlossplatz 1, 2361 Laxenburg, Austria

Sergei SCHERBOV, Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW,WU), International Institute for Applied Systems Analysis, Schlossplatz 1, 2361 Laxenburg, Austria

Yanlin SHI, Department of Actuarial Studies and Business Analytics, Macquarie University, Australia

Maria Rita TESTA, Wittgenstein Centre (IIASA, VID/ÖAW, WU), Vienna Institute of Demography/Austrian Academy of Sciences, Welthandelsplatz 2, 1020 Vienna, Austria

Frans WILLEKENS, Netherlands Interdisciplinary Demographic Institute (NIDI), Lange Houtstraat 19, NL-2511 CV The Hague, The Netherlands

Meng XU, Department of Mathematics, Pace University, 41 Park Row, New York, NY 10038, USA

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Broadening demographic horizons: demographic studies beyond age and gender

Alexia Prskawetz, Warren C. Sanderson and Sergei Scherbov*

Demography is generally defined as the scientific study of changes in the size and the structure of populations. While the meaning of population size is relatively clear, there are many different population structures that can be analyzed. Demography conventionally focuses on age and sex structures, and many of our core models are defined in terms of age and sex. But there are other important dimensions that are the subject of demographic analysis and modelling, such as place of residence, ethnicity/race, marital status, educational attainment, labor force participation status, and health status. Explicitly addressing the changing structures of populations along these broader demographic dimensions make demography more relevant for the rest of the world. Moreover, as these dimensions often represent important sources of population heterogeneity, studying them can improve our understanding of population dynamics in itself. In recent years, there have been exciting developments that have broadened the demographic perspective along these lines of multi-dimensionality, and that have contributed new methods to the demographer's conventional tool kit.

This volume of the Yearbook presents a selected set of papers that in one way or another challenge conventional ideas about how demographic studies are conceived and carried out. These papers cover concepts and developments related to multiregional, multistate, and probabilistic population forecasts; population projections by education and labor force status; and causal models of migration.

* Alexia Prskawetz (corresponding author), Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW,WU), Vienna Institute of Demography, Welthandelsplatz 2/Level 2, 1020 Vienna, Austria and TU Wien, Austria
Email: afp@econ.tuwien.ac.at

Warren C. Sanderson, Department of Economics, Stony Brook University, Stony Brook 11794-4384, New York, USA and Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW,WU), International Institute for Applied Systems Analysis, Schlossplatz 1, 2361 Laxenburg, Austria

Sergei Scherbov, Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW,WU), International Institute for Applied Systems Analysis, Schlossplatz 1, 2361 Laxenburg, Austria

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The complexity of the demographic transition and its links with the educational transition and urbanization processes, and the need for a multidimensional context when analyzing the relationship between birth intentions and birth outcomes, are among the other topics discussed in the Yearbook. To further broaden our understanding of the consequences of demographic change, differentials in life expectancy and economic activities are discussed in light of pension reforms and projected economic dependency ratios.

The papers are organized into three sections: the first section is a set of four short non-referred discussions; The second section consists of seven research papers; while the third section includes two papers that focus on data issues. All of these contributions help to broaden the horizons of demographic research.

Demographic Debate

The paper by Butz asks an important question at the core of demographic studies: "Are there principles of demography that lend coherence to the field?" The question has two parts: (1) Are there principles of demography; and, (2) do they provide a coherent intellectual scaffolding upon which demographic studies can be built? The answers given by Butz provide us with a clearer understanding of what demography is, and of what it can become.

The paper by Cohen, Brunborg, and Xu tackles a difficult question that has bedeviled demographers for decades: How we can determine which multiregional population forecast is the most plausible? The paper shows how Taylor's Law could be used to choose the best among six forecasts of Norwegian county populations. Their method has wide applicability, and broadens our understanding of how forecasts will be assessed in the future.

The field of probabilistic population forecasting was first developed in 1949 by Finnish demographer L. Törnquist, but evolved slowly in the decades that followed. Keyfitz (1981) injected new momentum into this field by encouraging demographers to present forecasts in terms of ranges. The paper by Keilman presents general principles that can guide demographers in the production of probabilistic population forecasts, and stresses the need for the development of probabilistic forecasts of populations by level of education.

The paper by Rees reflects on the evolution of multi-dimensional demography through applications that explicitly incorporate education into more conventional models focused solely on age and gender. The author explores the advantages as well as the challenges associated with this approach, and provides a critical assessment of recent efforts to advance this research, as documented in the 1,000+-page Oxford University Press volume 'World Population and Human Capital in the 21st Century' (Lutz et al. 2014). In the paper, Rees attempts to summarize the massive amount of material covered in this volume in order to make it accessible to a broader readership, while also providing suggestions about how this approach could be updated and extended in the future.

Research Articles

The demographics of the Muslim population, which accounts for up to 24% of the world's population, are considered in the paper by Abbasi-Shavazi and Jones. Demographic trends in nine Muslim-majority countries (which cover 73% of the Muslim-majority population) are studied in detail. The authors explore the cultural and socioeconomic diversity of these Islamic countries, and its role in enabling these populations to reap the demographic dividend. The article notes that in recent years, fertility and mortality have been declining in the Muslim countries studied, except for Niger, Afghanistan, and Pakistan; and that literacy and mean years of schooling among women have been increasing, albeit at different levels and paces across countries. The authors also point out, however, that despite improvements in educational attainment among the younger female cohorts, female labor force participation continues to be lower in Muslim countries in Africa and the Middle East than in Asia. Low levels of gender equity and cultural objections to women's participation in the labor market are cited as possible explanations for these observed trends.

The paper by Caselli and Lipsi focuses on pension reforms in Italy and their differential impact by gender and educational group. The authors observe that since women and higher educated individuals have relatively long lives, and women retire relatively early, changes in the legislated conversion factor (LCF) and increases in the minimum retirement age may result in different effects across gender and education. They argue that by ignoring the differential life expectancy, the pension system – despite being based on actuarial fairness – implicitly redistributes from individuals with lower life expectancy to individuals with higher life expectancy. Specifically, their analysis shows that by assuming an average LCF, men and low educated individuals are penalized more by the pension reform than women and higher educated individuals. Caselli and Lipsi conclude by stating that the social inequalities certain groups have already experienced through their working lives and pension contributions should not be intensified by pension systems that ignore differential life expectancy in calculating the LCF.

The paper by Prskawetz and Hammer considers the role of changes in the educational composition on economic dependency ratios for Austria up to 2050. Two alternative dependency ratios are considered: the first is based on age-, gender-, and education-specific employment rates; and the second is based on age- and education-specific consumption and income from the National Transfers Accounts project (whereby the first indicator only considers the share of dependent people, while the second indicator also accounts for the degree of dependency). Higher educated individuals enter and exit the labor market at older ages and have higher incomes than lower educated individuals. By combining age-, gender-, and education-specific economic activities as of 2010 with simulated changes in age, gender, and educational compositions, the analysis indicates that economic dependency could be reduced through higher levels of educational attainment.

The paper by Raymer et al. analyzes a frequently ignored aspect of multistate population projections: namely, that the data used to define people's characteristics are often self-reported. In the case of Australia, which is the focus of the paper, the self-identification of the indigenous population in particular can cause data problems. The authors note that when indigenous people migrate to areas where the indigenous population is smaller, they sometimes change their self-identification, which can in turn affect the measurement of migration rates. By showing how changes in self-identification over time can impact population projections, Raymer et al. broadens our understanding of the role of self-reported data in population forecasting.

Most models of migration built into population forecasts are purely statistical. The paper by Willekens challenges this approach and recommends that demographers think about the causal mechanisms that underlie migration. By listing 12 detailed characteristics that a causal model of migration should have, the authors provide a roadmap for the development of future causal models of migration that takes us beyond our current horizons.

The paper by Testa and Rampazzo studies the relationships between birth intentions and outcomes in a multidimensional context. The authors point out that like in many other facets of life, the link between intentions and outcomes is not simple, as events involving partnership, housing, work, and education all interact with fertility intentions and outcomes. Using data from Generations and Gender Surveys to disentangle these complex interactions, the analysis provides us with a richer and a more nuanced understanding of the link between birth intentions and outcomes.

The Sanderson et al. paper uses the UN's machinery for making stochastic population forecasts, which produces probabilistic forecasts of population age structures and sizes, as well as consistent stochastic life tables. Based on their new measures and the UN probabilistic forecasts, Sanderson et al. show that in today's high- and middle-income countries, population aging is likely to come to an end well before the end of the century. This analysis goes beyond the current demographic horizons by showing that population aging is a transitory phenomenon.

Data & Trends

The paper by Gailey and Lutz summarizes the 2018 update of the 2014 demographic scenarios published in 'World Population and Human Capital in the 21st Century' (Lutz et al. 2014). This recent update was produced by CEPAM (Centre for Population and Migration), which is a collaboration between IIASA's World Population Program and the Joint Research Centres (JRC) of the European Commission (European Commission 2018). These new scenarios provide detail by level of education for 201 countries, and by labor force status for the EU countries. In addition to the fertility, mortality, and migration scenarios included in the earlier assessment, three migration scenarios are distinguished: no migration, a continuation of recent migration rates, and a doubling of recent migration rates.

The paper by Luy and Köppen introduces the new concept of 'express transitioning'. The countries that have experienced express transitioning are those that have passed through the demographic transition relatively quickly. Luy and Köppen show that these countries are systematically different from the countries that underwent slower demographic transitions, especially with regard to urbanization and education. The addition of the concept of express transitioning broadens our understanding of the dynamics of population change.

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DEMOGRAPHIC DEBATE

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Are there principles of demography? A search for unifying (and hegemonic) themes[1]

William P. Butz*

The principles underlying a field of study can provide both internal coherence and external influence. First, in our context of a scientific discipline, principles can lend coherence by explicating how the discipline's various aspects and pieces fit together, and how their total becomes greater than the sum of the parts. Second, a discipline's principles can suggest how its perspectives and findings might contribute to other disciplines, and, even more broadly, to policy analysis and civil discourse. The exporting of hegemony across scientific fields and beyond—a process that can be more aggressive and less friendly than the usual multidisciplinary pursuits—can awaken new passions in adjacent academic fields.

If there are principles of demography that already reflect and provide coherence within our field, is it then possible that the explicit elucidation or even the promotion of these principles abroad adds to the prominence of our science in the academic and policy communities, while enriching other approaches to studying human behavior? Anthropology, economics, geography, psychology, and sociology might be open to the hegemony of demographic perspectives, models, and tools, as unified under a set of principles.

The philosophy and methodology of science, in which my topic modestly sits, has interested Wolfgang Lutz throughout his career. Drawing on his strong academic grounding in history and philosophy, he has recently made the fruitful proposal of partitioning scientific disciplines into identity sciences and intervention sciences, and causality into strong causality and functional causality (Lutz et al. 2017, 17–19). The identity sciences, which are generally the humanities, ask 'Who are we?' and 'Where do we come from?' The intervention sciences ask 'How do the most important forces of change in a social system function, so as to predict the future evolution of the system?'

* William P. Butz, Senior Research Scholar, World Population Program, IIASA, Laxenburg, Austria
Email: william.butz@icloud.com

[1] This paper is the lightly edited text of an oral presentation delivered at the Wittgenstein Centre Conference, December 2016 in Vienna.

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While strong causality is possible in the natural sciences, functional causality in the social sciences must, following Lutz, establish causality through three essential criteria. First, there must be a strong empirically observed association between the factors studied. Second, there must be a plausible narrative—I might call this a theory—about the mechanism of influence. Third, the other competing mechanisms must fail.

Beyond offering these particular contributions of definition and differentiation, Lutz clearly has a more general fascination with the question of how the various social sciences approach the world. Having an economist next door to his office for three years gave him ample opportunity to elucidate and argue about these distinctions. Lutz's points were always well thought-out, and, against my counterarguments, often distressingly convincing.

Perhaps the search for the principles of demography that lie beneath the surface of what we do at our desks can enable us to usefully distinguish our science from other disciplines, while injecting our perspectives into other approaches to understanding human behavior.

So what is a principle? Here, based on web sources, are three definitions:

- A principle is a fundamental truth or proposition that serves as the foundation for a chain of reasoning.
- A principle is a general scientific statement or theorem that has numerous special applications across a wide field.
- A principle is a big idea that occurs throughout the subject.

The titles of many textbooks contain the word 'principles': Principles of Chemistry, Physics, Archaeology, Mathematics, Demography, Economics, and more. In demography, the titles of at least three textbooks include the word 'principles'. The textbook by Donald Bogue seems to be first (Bogue 1969).

When pulling books from diverse scientific fields from the library stacks, one searches in vain for any explicit principles in most of them. Instead, the authors apparently use the construction 'principles of' to mean 'introduction to'. In the writing of these textbooks, and possibly in the teaching based on these texts, these two constructions have little or nothing to do with each other. As we shall see, in at least one academic discipline most textbooks with titles that refer to 'principles' elaborate actual principles within their pages.

Whether explicitly stated or not, the content, approaches, and findings of some disciplines appear to be based on strong principles:

- In ethics, there appears to be a principle of respect for individuals, which asserts that individuals are to be treated as autonomous agents. To the extent that this principle is accepted, many relationships between individuals, as well as between individuals and the organizations and governments they interact with, are not considered acceptable.
- In science, independent verifiability and, where applicable, informed consent seem to be universal principles.

- In physics, Bernoulli's principle relating velocity with pressure in a stream of fluid is accepted as a principle.
- In sociology, the proposition that people behave differently in groups than they do as individuals seems to underlie much of the work in the field, distinguishing sociology from several other disciplinary approaches. Another powerful sociological principle appears to be that societies are organized into distinct social units that tell their members what the rules are. A third potential principle of sociology is that any given group of people has characteristics that a single member does not have.
- In statistics, there seems to be a principle that it is possible to know about the whole by examining a small part only.

I have chosen to elevate these general propositions to the high status of principles without having encountered most of them as such in the smatterings of disciplinary literatures I'm familiar with. Economics is the only field of inquiry I have come across that uses an explicit set of principles, and that directly refers to these principles in textbooks and, more generally, in teaching. Here are four prominent principles of economics:[2]

- Incentives matter. This principle states that across all aspects of human behavior behavioral response elasticities are not zero.
- Decision-making occurs at the margin. This principle animates traditional neoclassical price theory.
- Opportunity costs are the costs that matter in making decisions. Thus, for example, it is not the costs of concrete and steel that matter in deciding whether to build a new airport, but the potential payoff of the best available alternative investment, such as building a network of new primary schools.
- The future is discounted relative to the present. A payoff 50 years from now is worth less in making today's decision than the same payoff today.

Many people will ignore or dispute the relevance of these principles of economics. The first principle falls by the wayside whenever policy-makers design a public program expecting a level of effectiveness that ignores the tendency of people everywhere to turn a change in their environment to their own perceived benefit, often at the expense of the outcomes envisioned by the designers. On empirical grounds, some behavioral economists have called into question the middle two principles by arguing that this is not how people actually behave. Moreover, many environmentalists decry the last principle on ethical grounds.

Indeed, explicit disciplinary principles are explicit targets; a successful attack on a general principle does damage to countless propositions that depend on it. This is surely beneficial for the elucidation of general principles, if not for the academics who depend on them for their livelihood.

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2 For the elucidation of selected principles of economics, see, for example: Mankiw (2018); Frank et al. (2016); Case et al. (2016).

I would argue that these principles of economics have been singularly successful in both maintaining disciplinary coherence (not always a good thing) and exporting hegemony to other social sciences—notably, political science, sociology, and geography—and to civil discourse. To the extent that the effect of exporting hegemony has occurred, it may be due less to the stealthy march of economists into these other fields than to the general familiarity of social scientists with the principles of economics. Similarly, in the domain of civil discourse, it is likely that this effect is attributable less to the presence of economists among decision-makers than to the familiarity of policy-makers with economic principles. Indeed, I suspect that the person on the street, who is unlikely to have taken an economics course, is more familiar in a general sense with one or more of the principles of economics than with any of my examples of principles from other disciplines. Somehow, these economic principles have wormed their way into the public consciousness. Their explicit formulation in teaching and broader exposition may be a fundamental reason why.

Now what about demography? Are there principles of demography that lend coherence to the field? If stated, taught, and promulgated explicitly and proactively as unifying principles, might these propositions have some beneficial hegemonic power in other scientific fields and, more broadly, in civil discourse? Here is my affirmative answer in the form of five proffered principles of demography. There may well be others, but this list represents a start.

- *The balancing equation.* There are only four ways population size changes: birth, death, movement in, and movement out. From this principle arises the distinction between stocks and flows in dimensions more complex than the size of the population—levels of schooling, for example. This distinction between stocks and flows leads to the difference between ratios and rates, the corresponding epidemiological distinction between prevalence and incidence, and the difference between wealth and income in economics. These distinctions are often lost in confused media discussions of such diverse phenomena as migration, education, disease, economic well-being, and public opinion. They flow directly from the principle of the balancing equation.
- *Size, composition, and spatial distribution.* Ignoring any one of these three fundamental dimensions of any human population can lead to a misunderstanding of patterns over space or time, with undue influence attributed to the dimension(s) included.
- *Age, period, and cohort effects.* These three effects are closely related conceptually, and are systemically confounded in the real world. Wittgenstein Centre scientists have recently found through survey data that young people in Europe are more likely to identify with Europe than with their country of residence, whereas older people are more likely to identify with their home country than with Europe (Striessnig and Lutz 2016, 305–311). This finding is interesting in itself, and has critically important implications for Europe's future. Is this difference in the data an age effect, a period effect, or a cohort

effect? If it is an age effect, then the difference will disappear as young people age and become similar to older people today. If it is a period effect, then the difference is attributable to some peculiarity of the week, month, or year the survey was taken, and may disappear the next time the survey questions are asked. But if the difference is a cohort effect that arises from the socialization of people who are now young, then it is likely to persist as this young cohort ages. This means that when the young people of today grow older, they may continue to identify with Europe, and will therefore differ from the older people of today. The causal nature of this difference will matter for the future of Europe. Wittgenstein Centre research suggests that the cohort explanation is the most likely of the three.

More generally, this three-way distinction is a principle with broad applicability. The relationships between these effects are second-nature to demographers, but are, in my experience, difficult for many others to think clearly about. Economists, for example, might benefit from paying more attention to this principle.

- *Cohort progression.* The principle that important personal characteristics are cohort characteristics, and thus persist in people as they age, underlies much of Lutz's conceptual and empirical research. The persisting effects of schooling and the lifetime propensity to be in good or bad health are two examples of cohort progression.
- *Disaggregation.* Population means can hide a great deal of important information, and looking at variances may not yield much more insight. The age/sex/education pyramid, widely used by Lutz in analysis and presentation, is a powerful method of disaggregation with possible applications far beyond demography. More broadly, the disaggregation of data is among the first instincts of empirical demographers, much to the benefit of their science. The other social sciences are far less likely to make use of this approach.

These five principles—the balancing equation; age, period, and cohort effects; population size, composition and spatial distribution; cohort progression; and disaggregation—lend coherence to the practice of demographic description and analysis. It is also highly likely that these principles can prove useful in other social sciences, public policy, and civil discourse. These principles seem to be no less unifying within their discipline and no less broadly applicable than those of economics. If economics can be taken as an example, a first and perhaps necessary step to applying these principles more broadly is to distill them as a clear set of principles, based on my suggestions or others; and to elevate them explicitly to their proper role within the science and its teaching and exposition.

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Can Taylor's law of fluctuation scaling and its relatives help demographers select more plausible multi-regional population forecasts?

Joel E. Cohen, Helge Brunborg and Meng Xu*

Abstract

Which of several alternative population forecasts is the 'best' or the most plausible? In published work summarized here, we use Taylor's law (TL) and its quadratic generalization to select the best among six alternative projections (by Statistics Norway) of Norwegian county population density. We consider two time scales: long term (1978–2010 as the historical basis for projections of 2011–2040) and short term (2006–2010 as the historical basis for projections of 2011–2015). We find that the short-term projections selected as 'best' by TL are more closely aligned than the four other projections with the recent county density data, and reflect the current high rate of international net immigration to Norway. Our approach needs to be further tested using other data and demographic forecasts.

1 Introduction

Demographers use population projections and population forecasts to draw conclusions relevant to policy and planning, and to provide inputs for other social and natural sciences that depend on demography. But projections and forecasts differ in terms of the justifications of their assumptions.

* Joel E. Cohen (corresponding author), Laboratory of Populations, The Rockefeller University and Columbia University, 1230 York Avenue, New York, NY 10065, USA
Additional affiliations: Earth Institute and Department of Statistics, Columbia University, USA; Department of Statistics, University of Chicago, USA
E-mail: cohen@rockefeller.edu

Helge Brunborg, Previously with Statistics Norway
E-mail: Helge.Brunborg@gmail.com

Meng Xu, Department of Mathematics, Pace University, 41 Park Row, New York, NY 10038, USA
E-mail: mxu@pace.edu

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Projections are based on assumptions that are not necessarily intended to be realistic. Alternative projections can illuminate multiple counterfactual worlds by showing the results of 'what-if' or *Gedanken* experiments, such as assuming constant fertility or constant mortality in the future, or no migration. For example, Abel et al. (2016) projected the effect on world population growth of implementing the Sustainable Development Goals using a demographic model that stratified national populations by age, sex, and level of education; and that took into account the different levels of fertility and mortality associated with the different levels of education.

Forecasts, by contrast, are based on assumptions about the future that are intended to be realistic (e.g., Lutz et al. 1997; Bongaarts and Bulatao 2000; Gerland et al. 2014; United Nations 2015). Demographers compute alternative forecasts because they are uncertain about the model assumptions and the parameter values in the future. Demographers have to assume when they are making forecasts that some features or trends of the past will continue into the future – because otherwise, they would have no basis for saying anything about the future. The question demographers are attempting to answer is which features or trends, based on how much of the past, will continue into the future.

We have been exploring unconventional answers to this difficult question using the special case of spatially explicit multi-regional forecasts. We summarize here our recent, and still tentative, progress on these issues, which we have published in detail elsewhere (Cohen et al. 2013; Xu et al. 2017). We offer this summary to increase awareness of our explorations, to motivate others to test our approach using other multi-regional data, and to encourage the development of similar methods for other kinds of demographic forecasts. We do not attempt here to provide a review of demographic projections or forecasts.

Our case study of Norwegian counties uses historical population data and a set of population projections prepared by Statistics Norway (2011) based on the Central Population Register (StatBank Norway 2015). Xu et al. (2017) treated the projections as if they were alternative forecasts, i.e., as if they were intended to be realistic; and tried to evaluate their realism ex ante, i.e. before observations of the future became available. Unlike stochastic forecasting, our method does not require probabilistic estimates of demographic variables in the future based on observations from the past, and can be implemented using simple statistical procedures.

We use a standard statistical concept called a variance function. In a family of random variables indexed by space and time, such as the population density of a fixed set of counties at different times, a spatial variance function describes the spatial variance (across counties in a given year t) in population density as a function of the spatial mean of population density (across counties in year t) over the course of various years. We call a plot of log(variance in year t) on the vertical axis as a function of log(mean in year t) on the horizontal axis, with one dot for each year t, a (log-transformed) 'variance function plot'. Here 'log' means '$\log_{10}$'. Fig. 1(c, f) are examples of the spatial variance function plots for the historical data and the projections of Norway's population by county. Our selection criterion for the best projection(s) assumes that the trend in the historical ‘variance function plot’ will continue through the projection period.

Using methods developed by Cohen et al. (2013), Xu et al. (2017) tested a particular form of variance function known as Taylor’s law (Taylor 1961; review by Eisler et al. 2008; henceforth abbreviated to TL, eqn (1)) and its quadratic generalization (eqn (2)) for six projections of Norwegian county population density from 2011 to 2040. We define as the ‘best’ long-term projections those projections for which the estimated parameters of TL and its generalization for the period from 2011 to 2040 most closely match the corresponding parameters of TL and its generalization fitted to the historical data (1978–2010).

We also define the ‘best’ short-term projections as those projections for which the estimated parameters of TL and its generalization for the period from 2011 to 2015 most closely match the corresponding parameters of TL and its generalization fitted to the historical data (2006–2010). To evaluate the accuracy of the ‘best’ short-term projections, we examine whether the short-term projections our method selected as ‘best’ are most closely aligned with the population density data from 2011 to 2015.

We summarize the procedure for selecting among various multi-regional projections or forecasts using the proposed variance function method so that the method can be tested further and, if it is successful, used. First, historical population multi-regional time series that immediately precede and are comparable in length to the projections should be chosen. Second, for the historical observations and for each of the projections or forecasts separately, the spatial mean (among spatial units) and the spatial variance (among spatial units) should be calculated for each year; and the multiple regression models (or analysis of covariance: eqns (3) and (4), Materials and Methods) should be constructed across years to compare the variance function parameters of the historical observations with the corresponding variance function parameters of each projection or forecast. Third, the projections or forecasts for which the variance function parameters most closely approximate those of the historical observations should be selected. These steps do not depend on heavy computational machinery, and require only a level of statistical analysis that is available in standard statistical software.

2 Materials and methods

Statistics Norway (2011) projected the populations of each county from 2011 to 2040 under L (low), M (medium), H (high), and 0 (no effect) assumptions for four demographic variables: fertility, life expectancy, internal migration, and net immigration. The label of each projection lists the four variables in the order just given. For example, MMM0 assumes medium trajectories for fertility, life expectancy, and internal migration; and 0 net immigration. Statistics Norway (2011) tabulates projected values of the four demographic variables under each assumption. For example, the projected low, medium, and high total fertility rates for 2015 are 1.85, 1.97, and 2.12 children per woman; and for 2060, they are 1.71, 1.93, and

2.08 children per woman. Detailed projected trajectories of all variables are given in Statistics Norway's Statbank. The six projections analyzed here are MMM0, MMML, MMMM, MMMH, LLML, and HHMH.

For each year t in the historical (1978–2010) data and in each of the six long-term (2011–2040) projections, we calculate a population-weighted spatial mean of each county's population density ($D_{t,j}$) in year t weighted by the number of persons $N_{t,j}$ in that county in year t:

$$mean_t = \sum_{j=1}^{n} \left(\frac{N_{t,j}}{\sum_{j=1}^{n} N_{t,j}} \right) \times D_{t,j},$$

and a population-weighted spatial variance of county population density

$$variance_t = \sum_{j=1}^{n} \left(\frac{N_{t,j}}{\sum_{j=1}^{n} N_{t,j}} \right) \times (D_{t,j} - mean_t)^2.$$

$N_{t,j}$ is the number of persons in year t ($t = 1978, 1979, \ldots, 2010$ for historical data; $t = 2011, 2012, \ldots, 2040$ for projections) of county j ($j = 1, 2, \ldots, n$), and $n = 19$ is the number of counties in Norway. We weight counties by their population size because we are interested in determining the variation in population across Norwegian counties, rather than in examining land use or political issues, for which areal and equal weighting would have been most appropriate (Cohen et al. 2013).

Taylor's law (TL) is a widely applicable empirical variance function that reflects the population density of nonhuman species. For the multi-regional time series analyzed here, the spatial TL reads:

$$\begin{aligned} &\log(\textit{variance across counties of population density in year } t) \\ &\quad = \log a_1 + b_1 \log(\textit{mean across counties of population density in year } t). \end{aligned} \tag{1}$$

Cohen et al. (2013) tested TL against population data for Norway from 1978 to 2010 at three spatial levels (municipality, county, region) using three weightings (equally, by area, and by population size) of the population density. For each year, the spatial mean and the spatial variance in population density among the studied spatial units were calculated, plotted across years, and fitted on the log-log scale by a least-squares linear regression (eqn (1)). Cohen et al. (2013) found that, regardless of the weighting used, TL accurately described the variation in Norwegian population density at any spatial level (coefficient of determination R^2 of eqn (1) was above 0.96 at the county level; Fig. 4 and Table 2 in Cohen et al. 2013), even though the parameters of TL differed among the three weighting methods. Under each weighting, Cohen et al. (2013) also fitted the log(mean)-log(variance) pairs of Norwegian county population density by a quadratic generalization of TL (due to Taylor et al. 1978, their equation 14),

$$\begin{aligned} &\log(\textit{variance of population density in year } t) \\ &\quad = \log a_2 + b_2 \log(\textit{mean population density in year } t) \\ &\qquad + c_2[\log(\textit{mean population density in year } t)]^2. \end{aligned} \tag{2}$$

We found that the quadratic coefficient c_2 is statistically significantly positive, indicating convexity between log(mean) and log(variance) (Table 2 in Cohen et al. 2013).

We fit least-squares regressions (eqns (1) and (2)) to the spatial variance function plots of the historical data (1978–2010) and of each long-term projection (2011–2040) separately, with one point per year. For the linear regression model (TL), we compare the parameters of eqn (1) in the historical data and in the projections using a multiple linear regression model with interaction; which is commonly called analysis of covariance. Specifically, we combine the mean variance pairs from the data and the six projections, and define a categorical variable ‘source’, which specifies the data and the projections, with the level ‘historical’ indicating the historical data, and the projection name (e.g., ‘MMMM’) indicating the corresponding projection. We then incorporate ‘source’ into eqn (1) as:

$$\log(variance) = a_1 + b_1 \log(mean) + c_1(source) + d_1[\log(mean)]:(source). \tag{3}$$

Here ‘log(mean):source’ represents the interaction between the independent variables ‘log(mean)’ and ‘source’. With ‘historical’ as the reference source level, values of c_1 of eqn (3) show whether the intercept of TL in the historical data differ from the intercept of each projection; and values of d_1 show whether the slope of TL of the historical data differ from the slope of each projection. Similarly, the ‘source’ variable is included in eqn (2) to examine the differences in each parameter (intercept, linear coefficient, quadratic coefficient) of the generalized TL (eqn (2)) in the historical data and in each projection.

$$\begin{aligned}\log(variance) \;&=\; a_2 + b_2 \log(mean) + c_2[\log(mean)]^2 + d_2(source)\\ &\quad + e_2[\log(mean)]:(source) + f_2[\log(mean)]^2:(source).\end{aligned} \tag{4}$$

We use the values of d_2, e_2, or f_2 (eqn (4)) to examine the differences in the parameters in the historical data and in each projection. For each model (eqns (3) and (4)), projection(s) (if any) with parameter estimates that most closely resemble the parameter estimates of the historical data are selected as the ‘best’ projection(s).

We repeat the variance function analysis and the regression diagnoses for the historical data from 2006 to 2010, and for each projection from 2011 to 2015.

To measure the accuracy of a short-term projection selected as ‘best’, we compute for each year t from 2011 to 2015 the mean of absolute percentage error (MAPE) between the observed and the projected population density of each county across Norway,

$$MAPE_{t,k} = \frac{\sum_{j=1}^{n} \left| \frac{PD_{t,j,k} - OD_{t,j}}{OD_{t,j}} \right|}{n} \times 100\%,$$

and average them over the five years by

$$MAPE_k = \frac{\sum_{t=2011}^{2015} MAPE_{t,k}}{5}.$$

Here $OD_{t,j}$ is the observed population density of county j ($j = 1, 2, \ldots, n$) in year t ($t = 2011, 2012, \ldots, 2015$); $PD_{t,j,k}$ is the projected population density of county j from projection k in year t; and n ($n = 19$) is the number of counties in Norway. Each projection k yields five values of $MAPE_{t,k}$, one for each year t. These five values are then compared among the projections by using analysis of variance (ANOVA) to find the most accurate population projection (defined as the projection(s) k with the least value of $MAPE_k$) from 2011 to 2015. To examine the accuracy of our short-term projections, we also use a recently developed modification of MAPE called the rescaled mean absolute percentage error (MAPE-R) (Swanson et al. 2011).

3 Results

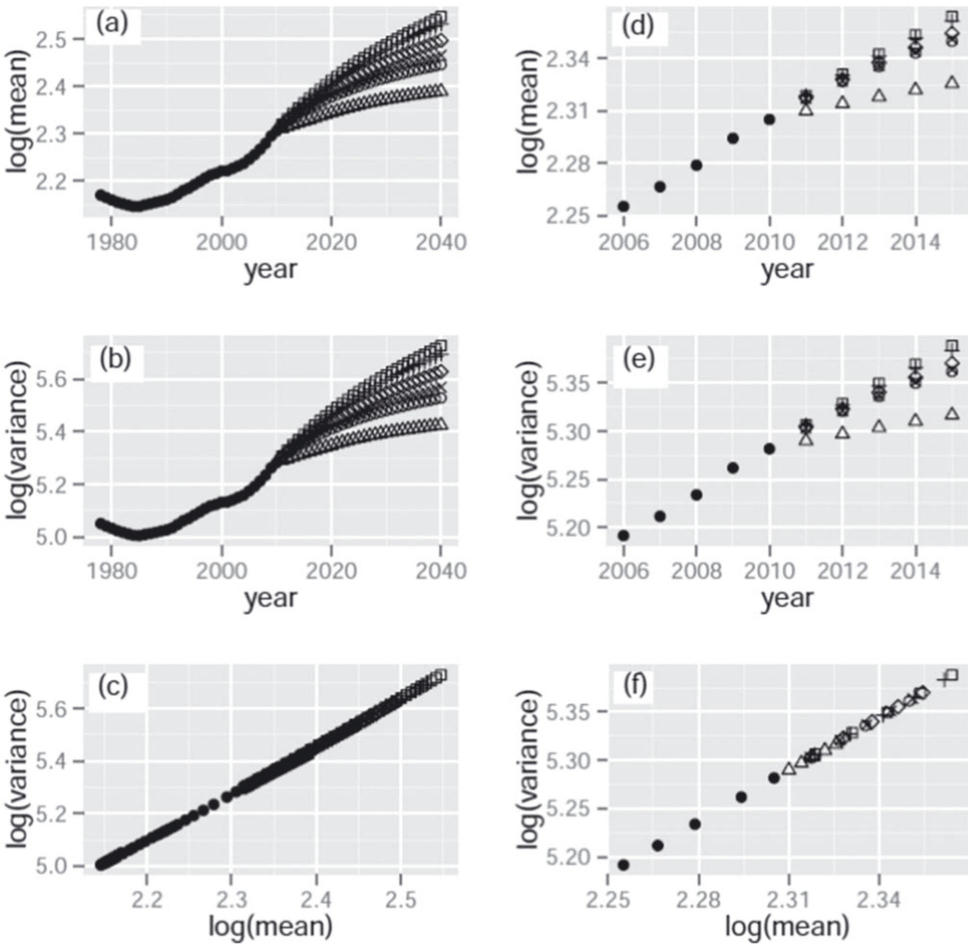
We find that TL describes well the spatial variance function of Norwegian county population density in the historical data from 1978 to 2010 and in each of the six projections from 2011 to 2040 (Fig. 1(c)). In all seven linear regressions (one historical and six projected) that are fitted to the spatial means and the spatial variances, the values of the coefficient of determination R^2 are greater than 0.999. The slopes of TL are between 1.5 and 2.

Further, we find that the slope and the intercept of TL differ between the historical data and five of the six long-term projections. For one projection, labeled MMM0, neither the intercept nor the slope differs significantly from the corresponding value of the parameter of TL fitted to the historical data. MMM0 is selected as the best model based on the similarities of the TL parameters between the data and projections. Because we find that the assumptions of the statistical tests (e.g., homoscedasticity and independence of errors) are not fully satisfied by the data, the alignment of the parameters between MMM0 and the historical data must be considered indicative and approximate.

The generalized TL significantly improves the fit by TL. The results of multiple linear regressions using eqn (4) indicate that in every parameter of the quadratic regression, the parameters of each projection differ significantly from the corresponding parameters of the historical data. No projection is selected as 'best' based on the generalized TL. This conclusion must be tempered by recognizing that the underlying assumptions of the statistical model we use are not always met.

Looking at the short-term historical data (2006–2010) and the six short-term projections (2011–2015) for Norway, we again find that TL describes the spatial variance function of county population density well (Fig. 1(f); $R^2 > 0.9999$). The parameters of TL differ between the historical data and four of the six projections. For the two projections labeled MMMH and HHMH, the outcomes of the multiple linear regression based on eqn (3) do not contradict the hypothesis that TL's intercept is equal to that of the historical data, nor the hypothesis that TL's slope is equal to that of the historical data. The two high-migration variants HHMH and MMMH are selected as the two best short-term projections. The high net immigration rate assumed in the short-term projections HHMH and MMMH reflects

Figure 1:
Log(mean) against year [a, d], log(variance) against year [b, e], and (log-transformed) variance function plots [c, f] of Norwegian county population density for (a–c) historical data from 1978 to 2010 and six demographic projections from 2011 to 2040, and for (d–f) historical data from 2006 to 2010 and six projections from 2011 to 2015. In a given year, the spatial mean and the spatial variance are calculated among counties weighted by county population sizes. On a log-log scale, the variance function during 1978–1984 overlaps the variance function during the later years (c), and generates an acute hook pattern at the lower left corner of the plot. Markers indicate historical data (•), HHMH (□), LLML (◯), MMM0 (Δ), MMMH (+), MMML (×), and MMMM (◇).



Norway's recent high and rapidly increasing levels of immigration due to the country's low unemployment and rapid economic growth rates.

The results of the multiple linear regressions based on eqn (4) show that none of the projections resembles the historical data in any parameter of the least-squares quadratic regression. Thus, no projection is selected using the generalized TL.

Among the six projections, we find that the annual average of the mean absolute percentage errors (MAPEs) and of the rescaled MAPEs (MAPE-R) between each short-term projection and recent (2011–2015) observations follow an identical ascending order: HHMH < MMMH < MMMM < MMML < LLML < MMM0. Under each measure, as HHMH and MMMH are the two projections with the smallest average errors, they are the most accurate. Thus, the two projections identified by TL as being most closely aligned with the historical data are the two projections that most closely approximate the observed county population densities after the projections were published.

4 Conclusion

Variance function analysis of the short-term historical data (2006–2010) and the short-term projections (2011–2015) of Norwegian county populations selected HHMH and MMMH as the two best projections. MAPE and MAPE-R selected the same two projections as being the closest to the recent data (2011–2015). This finding encourages further testing of the use of the variance function in selecting the most accurate short-term demographic projections. The long-term projection selected by the variance function method (i.e., MMM0) seems unrealistic, and its accuracy cannot be evaluated until data of the projection period become available for post hoc comparison. Other high-quality census or historical data and projections should be similarly tested to evaluate how general our method is, and the roles time scales play in the method. The historical data that could be used to further test this method could, for example, come from China's 34 provincial-level administrative units, the 50 states of the USA, or the roughly 200 countries of the world; while the projections that could be used to further test this method could, for example, come from national statistical offices, international statistical and economic agencies, and research institutes.

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Probabilistic demographic forecasts

Nico Keilman*

1 Why use probabilistic forecasts?

The Norwegian parliament (‘Stortinget’) has decided to buy 52 new JSF jet fighters type F35. When the decision was taken, the price for one F35 was unknown because the plane was still under construction. Therefore, the Stortinget demanded a total cost forecast that had a 50% chance of being accurate. In 2012, the price estimate was NOK 61 billion (approximately EUR 6 billion). In addition, the Stortinget wanted to have a cost estimate that had an 85% chance of being accurate. This estimate was NOK 72 billion; see https://www.regjeringen.no/no/dokumenter/prop-73-s-20112012/id676029/sec9, Section 2.4.4.

Requesting a probabilistic cost forecast with a 50% or an 85% chance of being accurate is established practice for large (>NOK 500 million) public projects in Norway. Probabilistic forecasts are necessary because the future is uncertain. There are many different possible futures, and some are more likely to come to pass than others. A probabilistic forecast, as opposed to a deterministic forecast, quantifies the uncertainty about future developments. While a probabilistic forecast is not necessarily more accurate than a deterministic forecast, the former contains more information, which is useful for planning purposes.

Let us assume that in a specific area, only a deterministic forecast of the relevant variable(s) is available. This may leave room for political decisions to be made. An example is the ‘shutdown’ of the U.S. government in December 1995. President Clinton proposed a seven-year budget plan that would produce a $115 billion deficit over the seven-year period, according to the economic forecasts of the Congressional Budget Office (CBO). However, the Office of Management and Budgets (OMB) estimated rather more optimistically that the budget would be balanced at the end of the period. Republican leaders demanded that Clinton propose a plan that would be balanced when using the CBO numbers, rather than the OMB’s; see https://www.washingtonpost.com/news/wonk/wp/2013/09/25/here-is-every-previous-government-shutdown-why-they-happened-and-how-they-ended/?utm_term=.4bb10057f0d9, shutdown # 17.

* Nico Keilman, Department of Economics, P.O. Box 1095 Blindern, N 0317 Oslo, Norway
E-mail: nico.keilman@econ.uio.no

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The following example illustrates why probabilistic forecasts are much more useful than deterministic forecasts. Let us assume that we are casting a die. The outcome is random, and has yet to occur. Before we cast the die, someone asks us to predict the outcome. This can be any value between one and six – all outcomes are equally likely. The expected value (equal to the median value in this particular case) is 3.5, which is our best guess. However, the probability that 3.5 will come up is zero. The probability of a result in the interval $[2, 5]$ – i.e., a two, a three, a four, or a five – is two out of three. A die with *five* faces numbered one, two, . . . , five has an expected value of three. This is our best guess if we have to predict the outcome. The probability that three will come up is only 20%, while the probability of a result in the interval $[2, 4]$ is 60%.

Now let us assume that we are predicting the population. The outcome is random. Why should we give only one (best guess/expected value, the probability of which is near zero) or three (high, medium, low) numbers, and not the whole set of possible results, like when casting a die? Many would argue that we cannot give the whole set because we do not know the probability distribution. However, we can estimate this distribution. Users should be told what the chance is of the real population falling between the high and the low value: is it 30%, 60%, or even 90%?

In the field of population forecasting, it is established practice to express uncertainty by means of variant predictions for fertility, mortality, and migration (UNECE 2017, 25). This leads to logical flaws in high and low variants of forecast results (Alho and Spencer 2005). Assume that $[\mathrm{B_L}, \mathrm{B_H}]$ and $[\mathrm{D_L}, \mathrm{D_H}]$ are high-low intervals for births B and deaths D. There is no guarantee that the two intervals will cover an equal probability range. Now assume that the intervals are given a probabilistic interpretation, such as 80% prediction intervals. $\mathrm{I} = \mathrm{B} - \mathrm{D}$ is natural population growth. $[\mathrm{B_L} - \mathrm{D_H}, \mathrm{B_H} - \mathrm{D_L}]$ then has a higher than 80% probability of occurring (unless B and D are perfectly negatively correlated, which is unrealistic).

Another potential complication is that two variants that may be extreme for a certain variable need not be extreme for a different variable.

To illustrate additional problems that typically arise when forecast variants are used to reflect uncertainty, Table 1 shows the results for the 2014-based population forecast for Norway. The predicted number of people aged 20–66 varies from 3.42 to 4.05 million. The interval between these two extremes is 17.2% wide compared to the number in the variant with medium population growth. For the age group 67+, the interval is slightly wider (24.3%). However, the dependency ratio (defined as the ratio of the number of elderly people to the number of people aged 20–66) has a relative interval width of no more than 7.5%, which is much smaller than we would intuitively expect to observe. The explanation for this surprising finding is that the strong population growth variant combines high life expectancy with high fertility. These two variables move in the same direction for the population numbers in the first and second rows, but they counterbalance each other in the dependency ratio.

Table 1:
Number of people aged 20–66 and 67+, and the dependency ratio of elderly people, 2040, according to three forecast variants of population growth

	Weak growth (W)	Medium growth (M)	Strong growth (S)	(S-W)/M (%)
20–66 (mln)	3.42	3.63	4.05	17.2
67+ (mln)	1.10	1.26	1.41	24.3
Dependency ratio (67+/20–66)	0.32	0.35	0.35	7.5

Source: Statistics Norway.

2 Probabilistic demographic forecasting: general principles

Traditional *deterministic* population forecasts are computed by means of the so-called cohort-component model $K_{t+1} = P_t K_t$, used recursively. Here, K_t is a vector of population numbers broken down by age and sex as of time t; and P_t is a matrix of transition probabilities during the time interval $(t, t + 1)$ that account for fertility, mortality, and emigration. Immigration by age and sex is added as a vector. A forecast for the first year is obtained by combining the jump-off population K_0 with assumed values of the matrix P_0; for later years, the model is used recursively. This forecasting approach was first developed by Edwin Cannan in 1895. By the 1930s, it had become generally accepted by the statistical agencies of many countries (De Gans 1997). In the 1970s, the model was extended to include a regional breakdown of the population vector (multiregional model; see, e.g., Rogers 1995), or an extra dimension in general, such as educational level, labour market status, or household status (multistate/multidimensional model).

Thus, a deterministic forecast can be derived by combining specific assumptions about fertility, mortality, and migration. Different projections or scenarios can be produced by systematically combining different assumptions. Collectively, those different projections can give some impression of the degree of uncertainty, but not in any quantified way. The probability that an outcome will be above or below a given scenario is unknown (Dunstan and Ball 2016).

Various methods for *probabilistic* population forecasting have been developed since the 1960s, although Törnquist (1949) was probably the first to integrate probabilistic thinking into population forecasting. In this approach, the elements of the matrix P_t are random variables. Early contributions were made by Pollard (1966), Sykes (1969), Schweder (1971), and Cohen (1986). The initial aim was to find analytical solutions for the predictive distributions of the variables of interest. Due to correlations between components, ages and sexes, and autocorrelations in all variables, approximations were necessary. Later work (e.g., Keyfitz 1985; Kuijsten 1988; Lee and Tuljapurkar 1994) was based on Monte Carlo simulation.

In the past two decades, Alho's Model for Scaled Error has received some general acceptance. The simulation model is extremely flexible in specifying various correlation structures. The corresponding computer program PEP ('Program for Error Propagation') is available free of charge. The model assumes normal distributions (in the log scale) for the input parameters of the cohort-component model. See Alho (1998) and Alho and Spencer (2005). In the UPE (Uncertain Population of Europe) project, it was assumed that the expected values of the normal distributions would coincide with the mean variant of deterministic projections. The numerous (co-)variances and (auto-)correlations came from time-series analyses, errors in historical forecasts, and expert judgements. The volatility in the UPE forecast results was constructed to be similar to historical patterns of volatility. See http://www.stat.fi/tup/euupe/upe_final_report.pdf for the final project report and a general project description, and http://www.stat.fi/tup/euupe/index_en.html for stochastic forecast results for 18 countries in Europe.

3 Probabilistic demographic forecasting: the expert-based approach

During the second half of the 1990s, Wolfgang Lutz became one of the pioneers (together with Sergei Scherbov, Warren Sanderson, and Alexander Hanika) of probabilistic demographic forecasting. For example, applications were developed for Austria by Hanika et al. (1997) and Lutz and Scherbov (1998a); for Germany by Lutz and Scherbov (1998b); and for the global population by Lutz (1996) and Lutz et al. (1997, 1998, 2001).

Lutz and colleagues developed the so-called expert-based approach. Its main idea can be summarised as follows. Given a deterministic population forecast with high-low intervals for key forecast indicators (such as the total fertility rate, the life expectancy, or the level of net migration) together with point forecasts for these indicators (medium variant values), all in a future year t, experts can be asked to define the probability content for these intervals, such as 90%. Let us assume that the probability distribution at time t for the variables is normal, and perform random draws from that distribution by Monte Carlo simulation. Variables for intermediate years are found by straight-line interpolation between the value in the jump-off year and the drawn value for year t. In constructing such 'random slopes', perfect autocorrelation is assumed. This unrealistic assumption has been relaxed in later work to a time-series approach based on a moving average model (e.g., Lutz et al. 2001; Sanderson et al. 2004). The advantage of relying on the expert-based approach is that it is simple, and is thus easy to explain to demographers and forecast users with little or no statistical experience. However, a major drawback of using this approach is that there is no empirical basis for the (co-)variances implicitly selected by the experts. At the same time, experts tend to be overconfident in their opinions, which could result in the generation of forecasts that have a lower degree of variability than would be desirable; and in the selection of prediction intervals that are too narrow (Alho and Spencer 2005). Such overconfidence is problematic, given that sensitivity analyses by Lutz et al. (1996) have shown that assumptions of perfect or zero correlation between fertility and mortality might have a big impact on prediction intervals for total population size and broad age groups in the long run.

The expert-based approach stimulated further refinements. For instance, Billari et al. (2012, 2014) addressed some of the weaknesses with respect to autocorrelation. They proposed applying a Bayesian interpretation to expert-based predictions, and treating expert inputs as data. While there are good reasons to be sceptical about the use of a method that depends heavily on the opinions of experts (overconfidence, selection), the Bayesian approach is emerging as the state of the art in probabilistic population forecasting (Bijak and Bryant 2016).

4 Examples of official probabilistic demographic forecasts

Official probabilistic population forecasts have been published by the statistical offices of Italy, the Netherlands (since 1999), and New Zealand.[1] The statistical agencies in a few other countries, such as Norway and Sweden, have experimented with probabilistic population forecasts. An important example of the use of probabilistic forecasting based on Bayesian methods can be found in the United Nations' World Population Prospects; see https://population.un.org/wpp/ and Raftery et al. (2012).

The case of Statistics New Zealand is worth a closer look. As Dunstan and Ball (2016) reported, the shift from using a deterministic approach to using a probabilistic approach is less difficult to make than might be expected. Uncertainty in the different components can be modelled simply or with more complexity. The authors mentioned a number of benefits that the producers and users of New Zealand's probabilistic forecasts have noticed since such forecasts were first published in 2012. First, while the probability distribution of a certain forecast result is often skewed, this message is not conveyed in a deterministic forecast. For example, the share of elderly people in the future population is usually around 15–20% in developed countries (depending on the definition of 'elderly'). Since any share is restricted to the interval $[0, 1]$, an outcome that is five percentage points below the expected value is less likely than an outcome of equal magnitude above the expected value. Second, the fan chart for a particular forecast result tells us how

[1] See ISTAT (2018),
http://statline.cbs.nl/Statweb/publication/?DM=SLEN&PA=82683eng&D1=0,7,10-12,14-15,21&D2=0-4&D3=0-1,6,11,16,21,26,31,36,41,l&LA=EN&VW=T and
http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/NationalPopulationProjections_HOTP2016.aspx.

much more likely small or large deviations from the expected value or the median value are. Third, any user who wants one number can use the median value. Fourth, the stochastic results indicate how far into the future we can reasonably provide a precise forecast, and the horizon is different for each variable. The New Zealand Treasury is developing a stochastic version of its fiscal model in order to get a better idea of how uncertain their variables of interest are.

Indeed, "... a probabilistic projection clearly gives more useful information than the usual high and low variants..." (Lutz and Scherbov 1998a, p. 13).

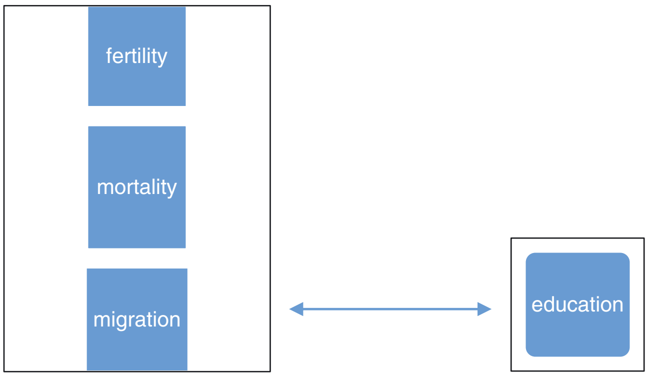
Finally, as UN Population Division director John Wilmoth stated in 2013: "... I expect that demographers will continue to be surprised by trends that do not follow our prior expectations. It is for this reason that the Population Division has worked hard in recent years to be more explicit and precise about the degree of uncertainty affecting projections of future population trends". http://www.un.org/en/development/desa/news/population/population-division-director.html

5 Quantifying uncertainty by means of the scenario approach

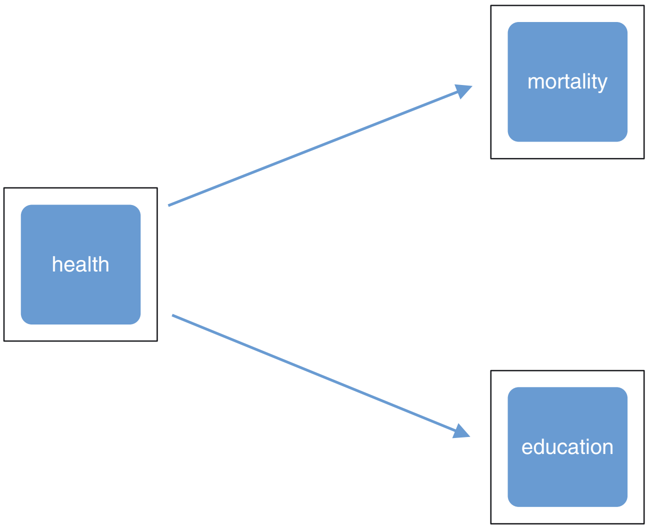
The book 'World population and human capital in the 21st century', edited by Lutz, Butz, and KC and published in 2014, represents an impressive summary of the work by Wolfgang Lutz and his team in the field of forecasting the world population broken down by age, sex, and educational level. It uses techniques of multistate modelling, but the forecasts are entirely deterministic. Here I would like to comment on two points: namely, the role of education and the use of scenarios.

5.1 Education

Does adding the dimension of education to the variables of age and sex completely fill the gaps in our knowledge of fertility, mortality, and migration behaviour? As Samir KC, one of the book's editors, states: "We have shown in the past that knowing the education level of the population can help us make better projections" (Samir KC in https://blog.iiasa.ac.at/2016/11/25/interview-defining-the-futures/). However, uncertainty remains, because the links between education and components of demographic change are not well modelled. In the analyses and forecasts by Lutz et al., education is seen as having an impact on fertility, mortality, and migration. This is certainly the case, but causality runs in the opposite direction as well. First, the number of children a woman has can have a large effect on her daughter's education: if the mother has more children than she can afford to educate (given the school fees and the need for the children's labour), the daughter's education is likely to suffer. Second, adolescent girls and young women with one or more children have fewer opportunities to attend school than childless women. Reverse causality of this type has been demonstrated for women in a number of countries, including Norway (Cohen et al. 2011) and Denmark (Gerster et al. 2014). An effect of this kind has also been observed in developing countries. For instance, a Tanzanian law dating back to the 1960s allows all state schools in the country to ban young mothers from attending. Over the past decade, more than 55,000 Tanzanian pregnant schoolgirls have been expelled from school (Center for Reproductive Rights 2013). For an early discussion of this issue, see Rindfuss et al. (1984). A population with high young adult mortality will have lower educational levels than a population with low mortality in this age group, all other things being the same. Brain drain affects the average educational levels of both the sending and the receiving country. Thus, the causal link runs not only from education to fertility, mortality, and migration; but in the opposite direction as well.



Alternatively, it can be argued that there are common underlying factors. For example, it is reasonable to assume that the health of the population aged 15–30 has an impact on both the mortality and the educational levels of the population as a whole, as being in better health leads to lower mortality and more years spent in education.



Another example is family background. Tropf and Mandemakers (2017) found a spurious correlation between education and fertility in twin data from the United Kingdom. The association between years of schooling and age at first birth depends strongly on family background factors (genetic and family environment).

In reality, both reverse causality and common underlying factors are likely to be at work. There is some discussion of causality issues in Chapter 2 of ‘World Population and Human Capital in the Twenty-First Century’. This discussion is, however, restricted to cases in which education is thought to have an effect on demographic behaviour. The authors do not mention reverse causality or common underlying factors.

It therefore appears that the link between education and demographic behaviour was poorly modelled by Lutz and colleagues, and that uncertainty remains. Hence, there is a strong need to create probabilistic forecasts for populations broken down by age, sex and, education. We hope that developing such forecasts is on the research agenda at the Wittgenstein Centre.

5.2 Scenarios

‘World Population and Human Capital in the Twenty-First Century’ contains projections that contributed to an ongoing international effort to develop a new generation of global change scenarios related to the Intergovernmental Panel on Climate Change (IPCC). These scenarios (called Shared Socioeconomic Pathways, or SSPs) have been designed to capture how socioeconomic challenges will affect future climate mitigation and adaptation trends. Each SSP is based on a set of assumptions about the components of change, and background stories for those assumptions. The book presents the ‘human core’ of the broader SSPs, which also include many other dimensions, such as energy and economic variables. Of the five SSPs, let us look at the following three scenarios:

- SSP1 assumes that large investments will be made in education and health.
- SSP2 assumes that the current demographic and education trends will continue.
- SSP3 assumes that current progress in increasing school enrolment rates and decreasing fertility and mortality will stall.

Imagine a government official whose task it is to formulate policies that prepare his country for the challenges associated with climate change. He wonders which set of projections among the three mentioned above is more likely to be proven correct. Here is the answer from the demographer:

> “Pick SSP1 if you believe its assumptions are likely; but
> pick SSP2 if you believe its assumptions are likely; and
> pick SSP3 if you believe its assumptions are likely”.

This example illustrates the point that scenarios have limited relevance for the user. They are useful as a basis for discussion about consistent patterns between input variables. Moreover, since they are examples of sensitivity analysis, they are relevant for modellers (and a few skilled users) who want to distinguish between important and less important input variables. Scenarios are less suitable for a general user, because they answer a question the user did ***not*** ask (‘What . . . if. . .?’). Scenarios do ***not*** answer the question that the user asked (‘What can we expect . . . and how probable is a different path?’); see Bijak et al. (2015).

Indeed, as Lutz and Goldstein (2004) argued, “people interested in uncertainty should either use completely probability-free scenarios for sensitivity testing or fully probabilistic projections for a more comprehensive view of the uncertainty involved”.

Scenarios are also suitable for ‘users’ who are engaged in developing policies and want to reach a certain goal in the future, as they can use a certain scenario to check whether they are ‘on track’. However, many different paths can be taken to achieve the same goal.

6 Conclusions

Wolfgang Lutz and colleagues have made major contributions to the field of probabilistic population forecasting. While some of the details can be criticised, the pioneering work of Wolfgang Lutz et al. in the 1990s was important because it showed that probabilistic population forecasting is feasible, and does not have to be very complicated. At the same time, it should be stressed that the current world population forecasts (including education) made by Wolfgang Lutz et al. and the IPCC forecasts based on SSP scenarios will be much more useful and relevant for the user once they are formulated in probabilistic terms.

7 Acknowledgements

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Education and demography: a review of world population and human capital in the 21st century

Philip Rees*

Abstract

This discussion piece is an extended review of the work on projecting the world's population and human capital by country conducted by the Wittgenstein Centre (WIC). The project was led by Wolfgang Lutz, and its outcomes were published by Oxford University Press in a book that appeared in 2014. Using statistics from the book and elsewhere, this article starts with an overview of the development of educational attainment. The role that education plays in the WIC2014 model is identified. Definitions of 'multi-dimensional', 'multi-state', and 'micro-simulation' are offered, and are used to characterise the model. A thumbnail sketch of the main methods used in the projections is given. The final section sets out a possible agenda for the future development of the WIC2014 model. This review is intended to help readers tackle the more than 1,000 pages of argument and analysis in the book, which represents a major contribution to demographic research in the 21st century.

1 Introduction

This article is a discussion of the role of education in demography, and focuses specifically on efforts by Wolfgang Lutz and his team to add education as a fourth dimension to demographic projection models, after place, age, and sex. In this piece, I review a very important publication produced by the Wittgenstein Centre, *World Population and Human Capital in the* 21st *Century* (Lutz et al. 2014a). Lutz and his colleagues estimated the educational composition of the population for countries across the globe, and linked their findings to two drivers of population change: namely, fertility and mortality. It has been shown that fertility levels are highest among women with the lowest educational levels, and decrease systematically with increasing educational attainment (Basten et al. 2014; Fuchs and Goujon 2014). This phenomenon is embedded in demographic transition theory (Caldwell 1976)

* Philip Rees, Professor Emeritus, School of Geography, University of Leeds, Leeds LS2 9JT, UK
Email: p.h.rees@leeds.ac.uk

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and in theories of the role of human capital in economic development (Becker 1962; Becker et al. 1990). When this relationship is included in population models for countries of the world, the projected population numbers are found to be lower than they are in the equivalent forecasts carried out by the UN. There is also evidence that education affects mortality. As people who are better educated tend to live longer and with less disability than their lower educated counterparts, the populations of countries with relatively high educational levels are likely to experience additional population ageing. This trend is already being observed in countries with highly educated populations.

In Lutz et al. (2014a), projections were linked to scenarios (Shared Socioeconomic Pathways, or SSPs) used by climate change researchers in order to assess the impact of future populations on greenhouse gas emissions, and the impact of climate change on the welfare of affected populations. Recently, the Lutz team has carried out new world scenario projections in which they have aligned their assumptions as directly as possible with the United Nation's Sustainable Development Goals (2015–2030) that are likely to affect the demographic components of change (Abel et al. 2016). These projections have a message for international and national policy-makers: namely, that if you achieve these goals, then the world population is likely to grow more slowly than was forecasted in the medium scenario of the Lutz et al. (2014a) projections or in the World Population Prospects of the United Nations (UN 2015a; UN 2015b).

The final component of demographic change that has been shown to be influenced by education is migration. A systematic gradient of increasing migration activity with increasing educational attainment has been established for internal migration by Bernard and Bell (2018). Bélanger et al. (2017) included education and international migration in a microsimulation model that is under development for projecting the populations of Canada, the European Union (EU28), and the USA. However, the influence of education has not yet been fully incorporated into the migration component of published projections. We know that through international migration, there is a transfer of highly educated individuals to highly developed countries that offer attractive employment opportunities. This form of migration increases the productivity and incomes of the migrants, and results in a substantial flow of remittances from higher to lower income countries. Do both richer and poorer societies benefit from these global talent flows, or is there an imbalance?

The aim of this paper is to share the author's understanding of the contribution of Lutz and his colleagues at the Wittgenstein Centre (WIC) to the topic of the relationship between education and demography. The focus of this discussion piece is on the main model employed in *World Population and Human Capital in the 21st Century*, which we refer to as the WIC2014 model. Section 2 of the paper provides a brief overview of educational development across the world, drawing on some WIC2014 country results. In Section 3, the role of education in demographic change is reviewed. Section 4 situates the WIC2014 model within a typology of demographic projection models. In Section 5, the (almost) impossible task of summarising the essential features of the WIC2014 model is attempted. The paper concludes in Section 6 with suggestions for a continuing research and impact agenda to be undertaken by the WIC team.

2 Overview of educational development across the world

Educational attainment has risen significantly over the past 50 years. While the highly developed countries of Europe and North America had achieved universal literacy by 1965, many countries in other regions of the world had not yet reached this level. By 2016, an estimated 86% of the world's population aged 15 or older were literate. While this finding suggests that substantial progress has been made, it also means that some 750 million people are still illiterate (UNESCO 2017), the bulk of whom are living in southern Asia or Sub-Saharan Africa. However, literacy rates are much higher among the younger (aged 15–24) than among the older (aged 65 or older) people in these regions. The literacy gap between these age groups has, for example, been estimated at 36% in Northern Africa and Western Asia, 47% in Southern Asia, and 39% Sub-Saharan Africa (UNESCO 2017, Table 2). Literacy enables people to acquire skills that are useful in the economy, and to receive and understand messages aimed at improving their health and well-being (e.g. messages about vaccination against dangerous infections). Literacy in a population can also help governments gather information that can be used in preparing social and physical plans. Face-to-face interviews – which are labour-intensive, and are therefore expensive – can be replaced by paper questionnaires that respondents can self-complete. With further technical education and the spread of internet-connected devices, the task of digitising survey or census questionnaires or tax returns can be delegated to respondents or householders (Rees 2018). Lutz (2014) has rightly argued that literacy and universal primary schooling will not provide countries with the human capital (skills, cognitive abilities) necessary for success in the 21st century, and that governments should therefore ensure that their populations have universal upper secondary qualifications and enhanced access to post-secondary education.

Barakat and Durham (2014) have argued that educational attainment levels are likely to continue to improve in most countries over the next 50 years, except when crises (especially civil wars) disrupt a country's progress. Table 1 displays forecasts of educational attainment in the world, and in seven countries with large populations spread across the range of the Human Development Index (UNDP 2018). The WIC2014 projections (Lutz et al. 2014, Appendix II; Barakat and Durham 2014; Goujon et al. 2016) indicate that globally, educational levels will improve markedly and continuously over the next half century. Specifically, the projections show that by 2060, a majority of the world's 25-year-olds will have upper secondary or post-secondary education, and a majority of German and American adults will have post-secondary education. In China, just over half of the population will have upper secondary or post-secondary education, although nearly 40% of the population will have lower secondary education only. Indonesia is expected to perform even

Table 1:
Educational attainment, 2010 and 2060, selected countries

	Population aged 25+, % by highest educational attainment								
		World		Germany		USA		Russian Fed.	
	Education	**2010**	**2060**	**2010**	**2060**	**2010**	**2060**	**2010**	**2060**
	HDI 2017	0.728		0.936		0.924		0.816	
E1	No education	18	5	1	0	1	0	0	0
E2	Incomplete primary	7	2	0	0	1	0	0	0
E3	Primary	19	12	3	1	4	1	4	0
E4	Lower secondary	20	16	16	7	7	4	8	1
E5	Upper secondary	25	37	51	40	52	43	67	68
E6	Post-secondary	14	28	30	52	36	52	21	31
	MYS	7.9	10.99	13.71	14.93	12.86	13.88	10.44	12.05
		China		**Indonesia**		**India**		**Zimbabwe**	
	Education	**2010**	**2060**	**2010**	**2060**	**2010**	**2060**	**2010**	**2060**
	HDI 2017	0.752		0.694		0.640		0.535	
E1	No education	1	1	1	1	39	11	9	0
E2	Incomplete primary	0	0	9	1	8	2	17	1
E3	Primary	28	8	36	14	14	12	19	4
E4	Lower secondary	42	39	16	12	11	12	13	5
E5	Upper secondary	13	27	21	49	18	41	37	76
E6	Post-secondary	7	25	8	23	9	22	6	15
	MYS	7.36	10.38	7.96	11.67	5.53	10.12	9.16	13.30

Note: HDI = Human Development Index, 2017. MYS = mean years of schooling.
Source: UNDP (2018, Table 1); Lutz et al. (2014a, Appendix II).

better, with 72% of the population reaching the upper secondary level. India will have substantially reduced but not eliminated the share of the population left behind with no education, and a majority of the country's population will have upper secondary or post-secondary education. In Zimbabwe, three-quarters of the population will have upper secondary or post-secondary education, provided the persistent economic problems (hyper-inflation, high unemployment, corruption) the country has experienced under the Mugabe regime are resolved.

What has driven these improvements in education? Becker (1962), in a theoretical analysis of investment in human capital (the stock of knowledge and skills acquired through education and training), showed how in-firm investment in on-the-job training produces long-term benefits for the firm and for the worker, provided labour productivity continues to rise. His subsequent work added analysis of the effect of human capital investment on fertility and economic growth (Becker et al. 1990), and on the gender division of labour (Becker 1985). Becker's work on this topic is summarised in his book on human capital (Becker 1993). Parents invest in the education of their children so that the children's future life-time earnings will be higher and their lives will better than they would have been in the absence of such investments. The state invests in education in order to raise the productivity of the national workforce in a competitive world economy. Difficult decisions must be made about how the costs of education are divided between the state (i.e. the taxpayers), the firm/organisation, and the family. While the share of educational costs carried by the state has risen in most countries over time, this share can fall when national and local budgets are under pressure. But productivity also depends on investment in physical capital, and in new technologies in particular. To reap the benefits of these new technologies, education – especially in science, technology, engineering, and mathematics (STEM) – is vital. Crespo Cuaresma (2017) combined the WIC educational attainment forecasts with assumptions about investment in technology to generate projections of income (GDP per capita) under different SSP scenarios for countries of the world. According to these projections, world income in purchasing-power-parity US dollars per annum could rise from $10.7k in 2017 (The World Bank 2018) to between $20k (least favourable scenario) and $100k (most favourable scenario) in 2100.

3 The role of education in population change

Lutz and Skirbekk (2014) set out the basic rationale for including education as a variable in world population projections. Education is an important determinant of fertility, as more educated women tend to have fewer children and to have them later in life, while less educated women tend to have more children and to have them earlier in life. Education is also an important determinant of morbidity (health) and mortality (longevity), as more educated people have higher levels of health and longevity, while less educated people have lower levels of health and longevity. Finally, education is an important determinant of international migration, as more educated people migrate at higher rates across international boundaries than less educated people (Dustmann and Glitz 2011). Education is, of course, not the only determinant of the future age- and sex-specific component rates used in demographic projection models, but it is undoubtedly a crucial factor.

To capture the effects outlined above, educational attainment shares by age and gender are introduced in the WIC2014 model as independently forecast determinants. This is a pretty rare strategy in demographic forecasting models, in which most drivers of change are endogenous. Barakat and Durham (2014) explained their rationale for projecting educational grade shares independently, and described the methods they adopted. Goujon et al. (2016) provided a detailed explanation of the complex process of assembling and harmonising the international and national datasets required for estimating the baseline educational distributions.

4 Multi-dimensional, multi-state, or micro-simulation models?

To implement the projections of the population classified by educational grade, Lutz et al. (2014a) used an expanded version of the cohort-component model. In various papers, this model is described as multi-dimensional or as multi-state. These descriptions are somewhat vague; and this fuzziness has persisted since Land and Rogers (1982) edited *Multidimensional Mathematical Demography,* a volume that featured articles with a mixture of the terms 'multidimensional' and 'multi-state' in the chapter titles. A clarification of the differences between these types of models is proposed here.

Multi-dimensional population models incorporate a variety of population attributes, and use these attributes to influence the component assumptions and generate outputs. Thus, for example, the addition of education to age and sex means that differences in fertility rates by education influence future births. Specifically, based on survey and vital statistics evidence, it is assumed that in most countries, there is a gradient of fertility from high to low among people with low to high educational attainment levels.

Multi-state models classify the population by groups beyond age and sex, and, crucially, allow people to transition between one state and another. Multi-state models were initially used to project population flows between sub-national regions (Rogers 2008). They have since been employed extensively in academic research and in official projection methodology. The use of these models in international contexts lagged behind their use in national or sub-national projections by several decades. Essentially, it was not until a new method was developed by Abel (Abel 2013; Abel and Sander 2014; Sander et al. 2014; Abel 2018) that estimating country-to-country flows from information on migrant stocks (population by country of residence and birth) collected by the United Nations became possible (UN 2017). The WIC 2014 model applies migration transition rates from a single country to the rest of the world, and vice versa. International emigration flows by age and sex are multiplied by the proportions of the origin country's population in each educational grade. The net numbers of international migrants by age and sex are then computed and multiplied by the proportions in each educational grade for each country of destination. It is therefore clear that this projection model is unable to determine whether a country is experiencing a 'brain gain' or a 'brain drain'.

Some educational projection models incorporate state-to-state transitions (Stone 1965; Stone 1971). Lutz et al. (2004) experimented with models using transition rates between educational grades. But in the WIC 2014 projections, future shares of the population by educational grade are used. Goujon et al. (2016, p. 322) clarified this approach as follows:

> "... the reconstruction model that we have developed – presented in more details in Barakat and Durham (2014) – ultimately requires not transition *rates* between attainment at time t and $t + 5$, but the *shares* of different attainment levels at ages 15–19, 20–24, and 25–29 years, conditional on (presumed) final attainment at age 30–34 years or above".

This approach to projecting population levels resembles methods used to estimate healthy life expectancy that added health state prevalence rates to a standard life table (Jagger et al. 2008; Jagger et al. 2014).

A final category of projection model is the micro-simulation model, in which the unit modelled is not the group or the state population, but the individual. Van Imhoff and Post (1998) showed that macro- or micro-projection models can be designed to implement the same processes. They discussed the advantages and disadvantages of each of the two representations. In micro-simulation models, the individual profiles can be extensive, and can include many characteristics that influence the components of population change. For example, Bélanger et al. (2017) have proposed, and are currently working on, a demographic micro-simulation model that uses a variety of survey and census micro-datasets for Canada, the European Union, and the USA. This model, which was developed as part of an EU/IIASA project on population and migration (CEPAM 2018), will, when implemented, enable the prediction of current fertility, mortality, internal migration, and emigration rates by age, sex, educational grade, and other variables, such as place of birth, race/visible minority group, immigration generation, age at immigration, language, and religion. The aim is not to include all such variables in a prediction model, but to use those variables that appear to be significant determinants. It is also necessary to project as many determinants as possible into the future, either within the micro-simulation model or via an external model.

5 The Wittgenstein Centre 2014 model: a reader's summary

Underpinning the WIC2014 model is the concept of demographic metabolism (Lutz 2013; Lutz and Skirbeck 2014), which is the process through which the ageing of successive birth cohorts changes the nature of the population, assuming that each cohort differs from the previous and the following cohorts. If a new but persisting trait is acquired by the young and not by the old, the trait will be transmitted upwards in the age distribution to become more common over time. Educational attainment is such a trait. It is assumed that education is acquired in the early years of life, or up to ages 30-34 in the WIC2014 model. In recent years, successive birth cohorts have been progressing further in the educational process than the preceding cohorts. Thus, even if the typical educational career ends by age 30 to 34, the make-up of the whole population will change as newer cohorts replace older cohorts, or age by age. The main processes that contribute to the changes in the educational composition of the population are cohort replacement and education differentials in fertility, mortality, and international migration. Educational differentials decline in strength through this sequence.

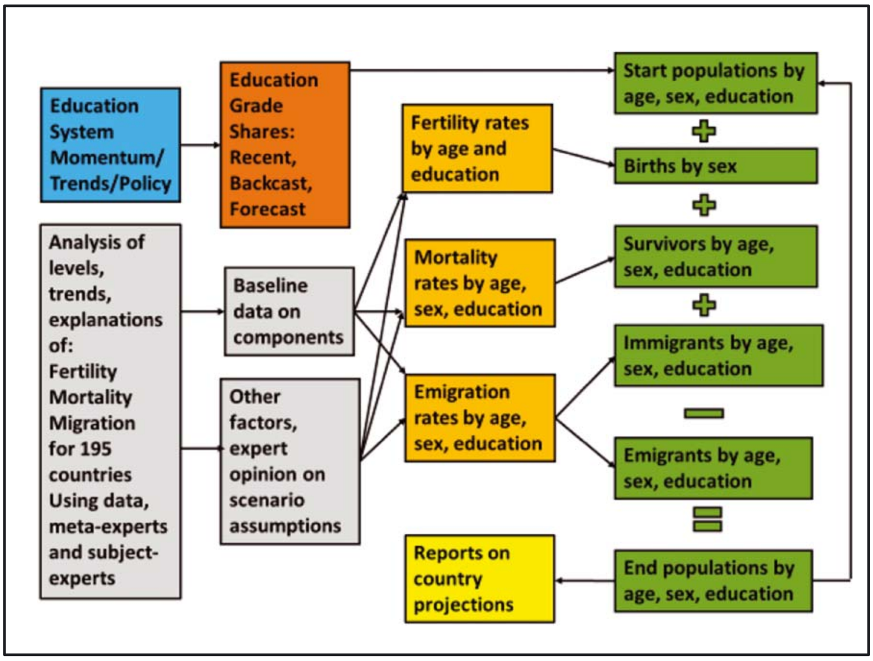
Mortality and fertility rates by educational grade are estimated so that the future numbers are dependent on this additional variable. However, educational composition (attainment rates by ages 30–34, and fixed at ages 35+) is projected independently for each country using a sigmoidal model fitted to past trends of percentages in each grade by age and sex. This is a projection of stock compositions. Transitions between educational grades are inferred from projected stock composition at five-year intervals, with no regression recognised (transitions to a lower grade from a higher grade) because the educational grade is defined as completed education.

The multi-state model is used to project emigration by multiplying the populations of countries by the emigration rates from the origin countries to the destination countries, and summing these rates over all flows to other countries. Immigration is projected by projecting emigration from all other countries to the country in question. For each time interval, a check is made to ensure that when all emigration flows are added to all immigration flows, net international migration worldwide is zero. If it is not zero, the emigration flows are adjusted to be equal to the sum of all immigration flows.

Because of the way net migration is used to estimate the educational composition of immigration flows, immigrants will have the educational composition of the destination country. Thus, the changing educational composition of the population will not influence the projection of total flows. The corollary of this observation, if correct, is that the Wittgenstein model cannot say anything about 'brain gain' (in advanced receiving countries) or 'brain drain' (in many developing and sending countries).

The WIC2014 model is described in Lutz et al. (2014a) using 665 pages of text, followed by 357 pages of results. Here, I offer one reader's understanding of the model through one figure and one table. While these observations are undoubtedly huge simplifications of a highly complex construction, and thus probably contain some errors, they may provide new readers with a useful overview of the model. Figure 1 presents a flow diagram of the WIC2014 model. On the top left-hand side is a box that refers to analyses of educational attainment in all countries, and that provides the knowledge that is employed to estimate educational grade shares by age and sex, and to construct a model for projecting those shares in three educational development scenarios (Barakat and Durham, 2014; Goujon et al. 2016). The projected shares are drawn upon at each five-year time step of the demographic projection model, and are applied to the end populations of countries. Below the education box is a box that refers to the analyses of levels, trends, and explanatory factors for the demographic components (Basten et al. 2014; Fuchs and Goujon 2014; Caselli et al. 2014; Garbero and Pamuk 2014; Sander et al. 2014; KC et al. 2014). These analyses produce baseline estimates of fertility, mortality, and emigration rates by age, sex, and education. The authors produced assumptions for the component rates for the medium scenario (SSP2) of the projections, and for four other SSP scenarios. The boxes on the right side of Figure 1 show the products of populations multiplied by the component rates – namely, births, survivors, immigrants, and emigrants – which cumulate to the end population in each five-year interval. The results of the projections for each country are organised into an elegant two-page spread. The first page shows indicator tables for the medium scenario populations and education shares, and graphs for population sizes

Figure 1:
The structure of the WIC 2014 model of population and human capital



Note: Author's interpretation

by education scenario and population pyramids. The second page presents five tables of populations and associated indicators for SSP scenarios that are also graphed, plus three tables of indicators summarising component assumptions by SSPs and a table of ageing indicators discussed in Scherbov et al. (2014). Table 2 provides more details on the WIC2014 model. The top panel describes the variables and the categories used to describe the country populations. The middle panel provides notes on the data and methods used to prepare the baseline population and components. The third panel summarises the assumptions made for the component rates and for the development of SSP scenarios.

In an epilogue to *World Population and Human Capital in the 21st Century,* Lutz (2014) summarised the work carried out by the Wittgenstein Centre team on the consequences for the future of embedding education in demographic projections. Crespo Cuaresma et al. (2013) showed that without the development of education, the advantage of the population concentrating at working ages will not be realised. Striessnig and Lutz (2013) and Lutz and Striessnig (2014) argued that the optimum fertility rate for European countries is a TFR that is below the replacement level if education and associated productivity are built into the calculations, at least in the medium term. This is because future cohorts will be better educated and more

Table 2:
Summary of the WIC2014 population and human capital projection model

Dimension	Categories	Documentation & sources
Country	171 countries plus 24 countries for which the educational grade distribution was inferred from similar countries. 195 countries with populations > 100,000	KC et al. (2014, p. 436)
Age	5-year ages: 0–4, 5–9 to 100+	UN population estimates
Sex	Male, female	UN population estimates
Education	E1 = no education, E2 = incomplete primary, E3=primary, E4 = lower secondary, E5 = upper secondary, E6 = post-secondary	Barakat and Durham (2014); Goujon et al. (2016)
Component	**Baseline estimates: data and methods**	**Documentation**
Population stock	Multiplying population by projected shares by education grade	KC et al. (2014)
Education	Mainly census data from IPUMS, EUROSTAT, CELADE, NSOs, UNESCO standardised & adjusted	Barakat and Durham (2014); Goujon et al. (2016); KC et al. (2014)
Fertility	Age-specific and total fertility rate series are assembled for low- and high-fertility countries (below and above a 2.1 TFR). Rate ratios are computed for educational grades.	Basten et al. (2014); Fuchs and Goujon (2014); KC et al. 2014
Mortality	Detailed analysis of life expectancy trends in low- and high-mortality countries. Education-specific life tables are developed.	Caselli et al. (2014); Garbero and Pamuk (2014); KC et al. (2014)
International migration	Origin to destination country flows are estimated from UN compiled census tables of population by country of residence and country of birth. Age is estimated by applying model migration schedules. Aggregated to origin country to rest of world flows, and emigration rates are computed.	Abel (2013); Abel and Sander (2014); Sander et al. (2014); KC et al. (2014)

productive. The WIC team has proposed that the more educated populations of the future will be better able to cope with the environmental challenges of climate change (Muttarak and Jiang 2015; Lutz, Muttarak and Striessnig 2014).

Table 2: Continued

Component	Assumptions (medium)	Documentation
Education	Age-specific educational grade shares are moved forward as successive birth cohorts transition to older ages with an S-shaped model for projecting changes in shares.	Barakat and Durham (2014); Goujon et al. (2016); KC et al. 2014
Fertility rates	TFRs are projected using a combination of time series models, meta-expert views, and responses to an online survey by experts.	Basten et al. (2014); Fuchs and Goujon (2014); KC et al. (2014)
Mortality rates	Statistical model and country-specific expert assessments are used with assumptions about convergence to the best current levels. Country-specific factors (e.g. HIV/AIDS) are added.	Caselli et al. (2014); Garbero and Pamuk (2014); KC et al. (2014)
Emigration rates	Emigration rates are applied to origin countries; immigration = emigration from other countries. Educational composition of emigration flows is proportional to the origin country's educational composition. Educational composition of immigration is linked to a destination country's educational distribution. After 2060, emigration and immigration are assumed to converge to zero net international migration by 2100. Meta-expert and expert views are reported but are not built into the assumptions.	Sander et al. (2014); KC et al. (2014)
Alternative scenarios	Educational development under different assumptions. Alignment with Shared Socio-economic Pathways (SSPs) of IPCC.	KC and Lutz (2014)

Note: WIC2014 = Wittgenstein Centre projection model as described in Lutz et al. (2014a).

6 A future agenda

I hope that this review will help more readers come to grips with *World Population and Human Capital in the 21st Century*, and will, as a consequence, agree with me that this volume represents a huge contribution to our knowledge of the likely future of the people on our planet, and can therefore help us in navigating the challenges humanity will face over the rest of the 21st century.

What kind of work on education and demography will Lutz and colleagues turn to next? We discuss in this final section of the paper the following topics: the updating of the projections; efforts to convince international agencies to adopt the innovations of the WIC2014 model; controlled comparisons with alternative models and historical sensitivity tests used to convince the demographic community and agencies; improvements in the international migration component of the projections and links to migration policies; and the embedding of the population and human capital model in a world ecosystem that captures population-environment-economy linkages.

The first challenge is updating. As new data and new trends may have emerged since 2014, the projection's baseline data, and possibly its assumptions, need to be updated. Lutz et al. (2018) have already produced a revision of the WIC2014 results and introduced alternative migration scenarios by level of migration. One feature of the model that will need to be updated in the future is the treatment of education as attainment levels steadily increase; i.e. further differentiation of the types of learning and skills acquired will become necessary, particularly at the upper secondary and post-secondary levels. In the 2018 update for the 28 EU member states, a more detailed set of educational categories has been introduced that distinguishes between three levels of higher education: short post-secondary education, bachelor's degree, and master's degree or higher. Are national educational systems graduating people with the right skills? What is the optimal balance between the fields of science, technology, engineering, and mathematics (STEM) on the one hand, and humanities, arts, and social sciences (HAS) on the other? In addition, more attention should be paid to the quality dimension of education, which is the current focus of UNESCO international research on education (UIS 2017a; UIS 2017b). For example, the UIS (2017b) has found a huge disparity in outcomes at any given grade of education between countries across the world. In Sub-Saharan Africa, 88% of children and adolescents fail to achieve minimum performance levels in reading; while in North America and Europe, this figure is 14%. Thus, the transformation in the educational compositions of developing countries in the WIC projections needs to be accompanied by a quality assessment. Such research would help in further developing the education-specific labour force projections developed for the EU-28 countries by Loichinger and Marois (2018).

The second challenge is to convince international agencies to adopt the two key innovations of the WIC2014 model by adding education and international migration to the dimensions of world projection models. The agencies that might be involved in these efforts include the UN Population Division; the UN Development Programme; the UN Educational, Scientific and Cultural Organisation; the UN World Health Organisation; and the World Bank. Strengthening the argument for adopting the WIC2014 approach will require some additional research. First, historical evaluations of the model are needed. This would entail calibrating the model for one period (e.g. 1985 to 2000) and producing a forecast for a second period (e.g. 2000 to 2015) for which good estimates of the population by educational distribution have been created in the production of WIC2014.

Second, comparisons between the WIC model results and those of international agencies need to be performed by running the projections on software generalised to offer alternative model designs (e.g. no education vs. education included). Currently, comparisons of WIC model results with UN, World Bank, or US Census Bureau projections have focused on differences in the assumptions underlying the outputs (Abel et al. 2016). Studies on country-based sub-national projections have explored the consequences of alternative model designs with the same assumptions (Rogers 1976; van Imhoff et al. 1997; Wilson and Bell 2004; Wilson 2015), while another study has discussed the difficulties of making comparisons between published projections if model design differences are not considered (Rees et al. 2018). A recent systematic review of this question with applications of models of different degrees of complexity and assumptions for India is given in KC et al. (2018). However, Rees et al. (2018) has called such comparisons 'interpretative', as they are based on subjective judgements, rather than on 'controlled' experiments (e.g. Wilson and Bell 2004).

The WIC2014 model introduces international migration flow estimates produced by Abel and colleagues (Abel 2013, Abel and Sander 2014), while Abel (2018) has extended and improved these estimates. However, the ways in which these flow data are used in the WIC model could be improved.

First, there are survey and census data available on international migration from the destination countries that can be added to immigration-specific rate ratios by educational grade. Bernard and Bell (2018) have derived education rate ratios for internal migration for 56 countries covering 65% of the world's population by employing International Public Use Microdata Samples (IPUMS) and census data to establish rate ratios that are both crude and controlling for other variables. However, most of the IPUMS datasets lack emigration data by origin country. Population data by country of birth and current residence, which are already used to generate the flow estimates of Abel and colleagues, might be employed to distribute immigrant rate ratios back to the countries of origin.

Second, the flow estimates themselves could be improved by adding the missing migration transitions of new-born survivors, migrants who have died, and new-born migrants who have died, as well as additional repeat and return flows, through assumptions like those employed by Rees and Wilson (1977) in their development of transition-based population accounts. It would also be helpful to clarify whether the WIC model used movement or transition concepts when incorporating international migration (Rees and Willekens 1986).

Third, there is an opportunity to develop a 'gravity' model of international migration flows that predicts flows using the population and labour market attributes of the origin and the destination countries, and impedance factors (e.g. distance in transfer costs, distance in language and culture, former coloniser-colonised relations, membership in a federation or a union of states) (Kim and Cohen 2010). Policy (controls on immigration) could be introduced into such a model. This model might be used to explore the transfers of human capital between countries ('brain drain' for developing countries vs. 'brain gain' for developed countries) and the role of 'counter-flows' of international remittances.

My final suggestion for a future agenda would be to take one step further and embed the population and human capital model in a world ecosystem that captures population-environment-economy linkages. In the WIC2014 model, the SSP scenarios are designed to supply alternative future populations for use by climate modellers. How would different climate change scenarios affect the growth and the distribution of the human population? Wittgenstein Centre research has already looked at the ways in which raising educational levels might help populations in adapting to climate change. Work on Population-Development-Environment models has been carried out by the IIASA leg of the WIC tripod (e.g. Lutz 1994).

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RESEARCH ARTICLES

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Population dynamics and human capital in Muslim countries

Mohammad Jalal Abbasi-Shavazi and Gavin W. Jones*

Abstract

Muslim countries have experienced unprecedented demographic and social transitions in recent decades. The population dynamics in most of these countries have led to the emergence of a young age structure. High-fertility countries such as Yemen and Afghanistan have the highest proportions of children in the population; while countries like Indonesia and Bangladesh, where fertility is approaching replacement level, have relatively high proportions of youth (aged 15–29) in the population. In Iran, fertility is below replacement level. Education, as an indicator of human capital, has also been improving in all Muslim countries, albeit with considerable variation. These dynamics are creating opportunities and challenges related to the economy, wealth distribution, health, political governance, and socio-economic structures. National development policies should emphasise human development to enable countries to take advantage of these emerging population trends, and to ensure that sustainable development is achieved at all levels. But given the cultural and socio-economic diversity among Islamic countries, context-specific analysis is needed to provide us with a deeper understanding of these population issues, as well as of the pathways to achieving population policy objectives.

1 Introduction: a demographic perspective

There is enormous international interest in Muslim countries and Muslim populations, stemming in part from the increasing recognition that Muslims make up a substantial part of the world's population. In addition, there are growing

* Mohammad Jalal Abbasi-Shavazi (corresponding author), Department of Demography, Faculty of Social Sciences, Jalal Al Ahmad Avenue, University of Tehran, Tehran, Iran and Professorial Fellow, Melbourne School of Population and Global Health, Medicine, Dentistry and Health Sciences, The University of Melbourne, Australia
Email: mabbasi@ut.ac.ir

Gavin W. Jones, Emeritus Professor, Australian National University, ACT, Canberra, Australia

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concerns about the tense international situations in the Middle East, through to Afghanistan, and Pakistan. In recent years, the focus of these concerns has been on the flow of refugees from these areas to other parts of the world; and on the growth of radical groups who espouse terrorism in the name of Islam, and are rejected by the vast majority of Muslims.

At the time Kirk (1966) published his article about the fertility levels of Muslims, there was a widespread “idea of a monolithic, unchanged (perhaps ‘immutable’) Muslim fertility” (Jones and Karim 2005, 3). Today, however, Muslim populations are very diverse, with many reporting declining fertility. Yet the share of Muslims in the populations of Europe is increasing, in part because the age structure of Muslim immigrant populations is young (Hackett 2016), and in part because of recent refugee inflows into Europe from the south and east. Thus, it is now widely recognised that in Europe, Muslim populations are increasing more rapidly than non-Muslim populations. In light of these developments, the need for dispassionate discussion of the demography of Muslim populations has never been greater.

Utilising various published data sources, this paper presents a comparative perspective on demographic trends and the human capital situation of Muslim populations. The main data sources for the figures presented in this chapter are the Wittgenstein Centre Data Explorer (http:www.wittgensteincentre.org/dataexplorer); the United Nations *Demographic Yearbooks*; and publications of the International Labour Organization, the Organization of Islamic Cooperation (http://www.sesric.org/), the World Economic Forum, and the Pew Research Center. Although these are standard sources of data, the indicators expressed in these publications may not always be accurate. Wherever the data presented differ from the data from national sources, the latter will be used.

The basic statistics on the number of Muslims in the world, and the growth of the Muslim population over time, are presented in Table 1. In 2017, the world’s Muslim population was estimated to number over 1.8 billion, or 24 per cent of the world’s population. Out of all Muslims, 74 per cent live in the 49 Muslim-majority countries, and 64 per cent live in countries where the share of Muslims in the population exceeds 70 per cent. Also in 2017, it was estimated that around 469 million Muslims are living in countries where less than 50 per cent of the population are Muslims; i.e., in Muslim-minority countries (Appendix Table A.1). The largest populations of Muslims living in countries where Muslims are not a majority are found in India (around 193 million Muslims, or 14 per cent of the population), Nigeria (93 million Muslims, or 49 per cent of the population),[1] and Ethiopia (36 million Muslims, or 34 per cent of the population). Other large minority Muslim populations are found in China (25 million), Russia (14.4 million), and Tanzania (20.1 million).

[1] Given the questionable quality of the available data for Nigeria, and estimates indicating that Muslims represent close to 50 per cent of the country’s population, it is impossible to know for certain whether Muslims are in the majority.

While the Islamic heartland is in the Middle East among Arabic populations, Islam has spread widely around the world. Currently, only 13.2 per cent of all Muslims live in Western Asia, and 12.3 per cent live in Northern Africa – which means that only about a quarter of the world's Muslims are Arabs. Around 39.3 per cent of the world's Muslims live in South and Central Asia, about 14.5 per cent live in Southeast Asia, and about 17.1 per cent live in Sub-Saharan Africa. Thus, almost 98 per cent of the world's Muslims live in Asia and Africa. Viewed from a different perspective, these statistics show that Muslims constitute approximately 45 per cent of the population of Africa, and approximately 29 per cent of the population of Asia. The regions of the world where relatively few Muslims live are North and South America, Europe, East Asia, and Oceania.

As the number of Muslim-majority countries is large, we do not attempt in this brief paper to provide a detailed analysis of the demographic trends and characteristics of them all. Instead, we have chosen to focus on six of the seven largest Muslim-majority countries (in order of population: Indonesia, Pakistan, Bangladesh, Iran, Turkey, and Egypt) plus three others to give representation to the Maghreb (Algeria) and to countries with very low levels of economic and human development (Niger and Afghanistan). After presenting estimates of the population sizes in Muslim-majority countries, we analyse the fertility trends and age-structural transitions in the nine selected Muslim countries, and look at the implications of these trends for the demographic dividend. The progress these countries have made in improving the educational levels of their people is discussed in detail, as education plays a crucial role not only in raising levels of human capital, which enables countries to benefit from the demographic dividend; but in lowering levels of mortality and fertility (Lutz 2009). We then look at the question of whether these countries are taking advantage of the demographic dividend. As has been widely noted in the literature, the key prerequisites for benefiting from the demographic dividend are not just raising the educational attainment levels of the cohorts entering the workforce, but providing a growing supply of job opportunities for the burgeoning workforce. In this paper, we pay particular attention to women's education and gender equality indices in Muslim-majority countries. We conclude by discussing the future of population growth in these countries, and the implications of these growth rates for human capital.

2 The Muslim world: unity and diversity

The two main divisions in Islam are between the Sunni and the Shi'ite. After the death of the Prophet Mohammad (AD 632), those who believed that he had not appointed a successor, and accepted the selection of a successor by his senior companions became the Sunni; whereas those who believed that the Prophet Mohammad had rightfully designated Ali, his cousin and son-in-law, as his successor became the Shi'ite. These sects are further divided into sub-groups. The Sunnis are believed to constitute about 85–90 per cent of all Muslims, while the

Table 1:
Population and percentage of Muslims in countries with Muslim-majority populations in 2017

Country/region	Population in 2017, (m) (1)	% Muslim (2)	Estimated Muslim population in 2017 (m)	Country/region	Population in 2017, (m) (1)	% Muslim (2)	Estimated Muslim population in 2017 (m)
Africa	**367.00**		**337.24**	**Asia**	**1,096.91**		**1,006.14**
Eastern Africa	**16.75**		**16.67**	**South-Eastern Asia**	**296.04**		**250.66**
Somalia	14.74	99.8	14.71	Indonesia	263.99	87.2	230.20
Comoro	0.81	98.3	0.80	Brunei	0.43	75.1	0.32
Mayotte	0.25	98.6	0.25	Malaysia	31.62	63.7	20.14
Djibouti	0.95	96.9	0.92				
				South/Central Asia	**549.61**		**518.33**
Northern Africa	**233.57**		**223.65**	Maldives	0.43	98.4	0.42
West Sahara	0.55	99.4	0.55	Iran (Islamic Republic of)	81.16	99.5	80.75
Algeria	41.30	97.9	40.43	Afghanistan	35.53	99.7	35.42
Morocco	35.74	99.9	35.70	Pakistan	197.01	96.4	189.92
Tunisia	11.53	99.5	11.47	Bangladesh	164.66	90.4	148.85
Libya	6.37	96.6	6.15	Uzbekistan	31.90	96.7	30.85
Egypt	97.55	94.9	92.57	Turkmenistan	5.75	93.0	5.35
Sudan	40.53	90.7	36.76	Tajikistan	8.92	96.7	8.63
				Kazakhstan	18.20	70.4	12.81
Western Africa	**116.68**		**96.92**	Kyrgyzstan	6.05	88.0	5.32
Mauritania	4.42	99.1	4.38				
Gambia	2.10	95.1	2.00	**Western Asia**	**251.26**		**237.15**
Senegal	15.80	96.4	15.23	Yemen	28.25	99.1	28.00
Mali	18.54	94.4	17.50	Turkey	80.74	98.0	79.13

Continued.

Table 1:
Continued

Country/region	Population in 2017, (m) (1)	% Muslim (2)	Estimated Muslim population in 2017 (m)	Country/region	Population in 2017, (m) (1)	% Muslim (2)	Estimated Muslim population in 2017 (m)
Niger	21.47	98.4	21.13	Palestine **(3)**	4.92	97.6	4.80
Guinea	12.72	84.4	10.74	Iraq	38.27	99.0	37.89
Sierra Leone	7.55	78.0	5.89	Saudi Arabia	32.93	93.0	30.62
Chad	14.89	55.3	8.23	Jordan	9.70	97.2	9.43
Burkina Faso	19.19	61.6	11.82	United Arab E	9.40	76.9	7.23
				Qatar	2.64	67.7	1.79
Europe	**4.83**		**4.13**	Azerbaijan	9.82	96.9	9.52
Albania	2.93	80.3	2.35	Oman	4.63	85.9	3.98
Kosovo	1.90	93.8	1.78	Syria	18.26	92.8	16.95
				Kuwait	4.13	74.1	3.06
				Bahrain	1.49	70.3	1.05
				Lebanon	6.08	61.3	3.73
				Total	**1,468.74**		**1,347.52**
				Total in countries with less than 50%			**469.50**
				Total Muslims			**1,817.02**

Note: **(1)** United Nations Population Division, 2017. **(2)** % Muslims were obtained from Pew Research Center 2010 (http://assets.pewresearch.org/wp-content/uploads/sites/11/2015/03/PF_15.04.02_ProjectionsFullReport.pdf); **(3)** State of Palestine (Including East Jerusalem).
Source: United Nations Population Division, https://esa.un.org/unpd/wpp/DataQuery/

Shi'ite make up about 10–13 per cent of Muslims (PEW 2009). Shi'ites constitute a majority of the population in Iran, Iraq, Azerbaijan, Yemen, and Bahrain. The world at large has become well aware of Sunni–Shi'ite tensions, as the conflicts between these two sects have been highlighted in news reports about Iraq since the overthrow of Saddam Hussein in 2003; the Syrian civil war, which began in 2011 and is still ongoing; protests in Bahrain in 2011, where the Sunni minority control the state; and the civil conflict in Yemen, which began in late 2014 and is still continuing.

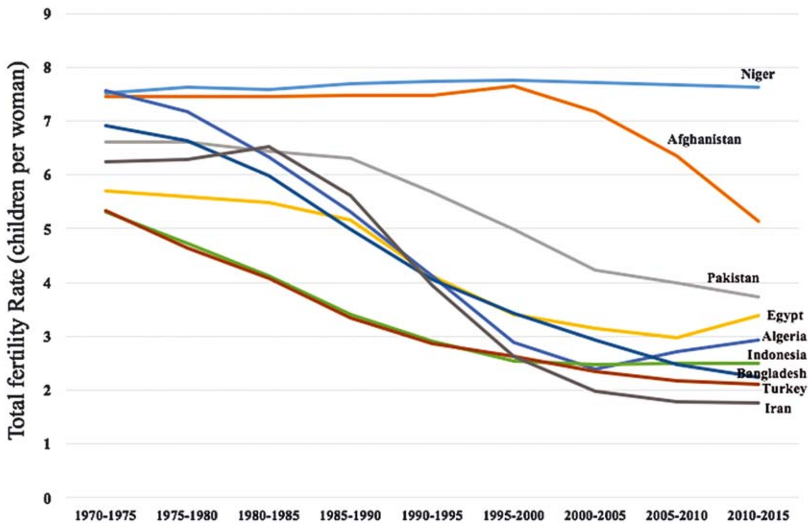
While the Muslim world is a unique *ummah* with a common set of core religious beliefs, Islamic countries have a very wide range of cultural and socio-economic characteristics (Abbasi-Shavazi and Jones 2005). The outside world's reaction to 'Islam' appears to be grounded in stereotypes of the cultural characteristics of particular ethnic groups who follow the Islamic faith. It is important that the diversity of those groups, and the rich tapestry of cultures that have embraced Islam, be recognised.

3 The fertility transition in Muslim-majority countries

Population change in Muslim-majority countries (hereafter referred to as Muslim countries, for the sake of brevity) is mainly the result of differences in birth and death rates, although net migration also affects population growth in some of the West Asian countries and in Malaysia. Moreover, refugee flows have recently had large effects on population trends in several of these countries, including Pakistan, Afghanistan, and Iran. According to the United Nations Population Division, the population growth rate in the world as a whole was 1.18 per cent in the 2010–2015 period. This rate was, however, higher in 42 of the 46 Muslim countries. In the less developed regions of the world (excluding China), the population growth rate over the same period was 1.62 per cent; but again, this rate was higher in 33 of the 46 Muslim countries. These broad comparisons clearly indicate that the Muslim countries have growth rates well above the average. However, if weighted by population, the excess growth rate in Muslim nations becomes smaller, because population growth rates have been relatively low in some of the most populous Muslim nations. For example, the growth rate in the 2010-2015 period was 1.20 per cent in Bangladesh, 1.28 per cent in Indonesia, and 1.27 per cent in Iran.

Both mortality and fertility rates have fallen considerably in most Muslim countries. The mortality transition will not be discussed in detail here, but it should be kept in mind that a declining rate of infant and childhood mortality is generally considered to be an important prerequisite for declining fertility. The infant mortality rate (number of infant deaths per 1,000 live births) has fallen sharply over the past three decades in most of the nine countries this paper will focus on. For example, over this period the infant mortality rate has declined from 80 to 25 in Indonesia, from 126 to 33 in Bangladesh, and from 71 to 15 in Iran. However, the infant mortality rate has remained very high in Afghanistan (71), Pakistan (70), and Niger (60).

Figure 1:
Trends in the total fertility rate in nine Muslim-majority countries, 1970–75 to 2010–15



Source: United Nations Population Division, 2015.

Turning to fertility, we see that the transition to low levels has proceeded remarkably rapidly in some of the main Muslim countries, as shown in Figure 1. The most spectacular case is that of Iran, which experienced one of the most rapid fertility declines ever recorded (Abbasi-Shavazi *et al.* 2009; Hosseini-Chavoshi and Abbasi-Shavazi 2012). Indeed, efforts to reduce fertility have been so successful in Iran that the country has recently shifted its population policy from being anti-natalist to being pro-natalist (McDonald *et al*. 2015; Hosseini-Chavoshi *et al.* 2016). Bangladesh and Indonesia have also recorded very rapid declines; although in Indonesia, fertility decline has stalled over the past 15 years, and currently remains substantially (about 19 per cent) above replacement level. Turkey has experienced a steady fertility decline, and recently reached replacement level. Pakistan's fertility remained very high until the 1990s. The country's fertility level has declined substantially since then, but remains far above replacement level. Given the continued pyramidal age structure in Pakistan, massive population increases are projected for the country in the coming decades, even if fertility decreases fairly rapidly from the current point onwards.

In Algeria, fertility fell precipitously over the 1980s and 1990s, and was close to replacement level when, in the early 2000s, it started increasing again. In Egypt, the TFR decreased more gradually, but after reaching a level of just below three, it resumed its upward trend around 2005-2010. This means that three of the major Muslim countries – Indonesia, Algeria, and Egypt – experienced either a stalling of the fertility decline or an actual increase in fertility around the same period. It has been argued that an increase in religiosity had something to do with the fertility increase in Indonesia (Hull 2016). But in Algeria and Egypt, it seems that high unemployment and the declining labour force participation of women – and particularly of the trend-setting group of women with more education – were the key reasons for the fertility increase (Ouadah-Bedidi and Vallin 2013; Assaad and Kraft 2015).

The final two countries plotted in Figure 1, Afghanistan and Niger, have both had extremely high fertility rates. In Afghanistan, there is some evidence of the beginnings of a decline, although the TFR remains above five; but in Niger, there is no such evidence, and the TFR remains above seven. Niger is representative of a number of Muslim countries in Sub-Saharan Africa (and of a number of Christian-majority countries in the same region) where fertility levels remain extremely high.

Because it concentrates on large countries, Figure 1 does not do full justice to the spectacular declines in fertility recorded by some Muslim countries. A recent study has noted that six of the 10 largest absolute declines in fertility ever recorded in a 20-year period have occurred in Muslim countries (Eberstadt and Shah 2012, 16). But except for Iran and Algeria, these were very small countries: namely, Oman, Maldives, Kuwait, and Libya. Interestingly, four of these countries are in the Arab world; and if we add Iran, five of them are located in the greater Middle East. These spectacular declines in fertility would have come as a surprise to those earlier commentators who believed that there were reasons why 'Muslim fertility' would remain higher than elsewhere (e.g., Kirk 1966).

4 Age structural change and the demographic dividend

A history of high fertility leaves a population with an age structure that is highly conducive to further population growth. One reason why so many Muslim countries still have population growth rates above the world average is that even though a number of these countries have experienced major fertility declines, most have experienced them quite recently, and are therefore still experiencing age structure effects; or what is sometimes referred to as demographic momentum.

Table 2 shows the changes in the population age structures of the nine Muslim countries that are the focus of this paper. Three indicators are given: the percentage of children in the population, the median age, and the dependency ratio. Looking at the table, it is apparent that in the 1970s, these indicators were fairly similar across all nine countries. But in the 1980s and in the 1990s in particular, major differences began to emerge as some of these countries experienced major declines in fertility, while others experienced no decline at all. By the 21st century, these differences had widened substantially. For example, in 2015, the proportion of children in the population was, at 50 per cent, twice as high in Niger as it was in Iran or Turkey. Whereas half the population was under age 19 in all of these countries in the 1970s, by 2015, this was still the case in only two of the countries, and the median age

Table 2:
Indicators of age structure change, nine Muslim-majority countries

	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015
Children 0–14 as % of total population										
Indonesia	43.2	42.5	41.1	39.0	36.4	33.7	30.7	29.9	28.9	27.7
Bangladesh	44.9	45.1	44.8	43.8	42.3	39.9	37.1	34.5	32.1	29.4
Pakistan	42.4	43.1	42.9	42.6	43.0	42.7	41.1	38.2	36.2	35.0
Iran	44.1	43.3	43.5	45.4	45.4	42.2	34.9	26.0	23.5	23.6
Turkey	42.1	40.9	40.1	38.5	36.3	33.3	30.7	29.9	28.9	25.7
Egypt	41.3	40.3	40.0	40.3	41.0	39.5	36.3	33.1	31.9	33.2
Algeria	46.9	46.7	46.3	45.4	43.3	39.7	34.3	29.1	27.2	28.5
Afghanistan	44.2	45.2	46.0	47.3	48.1	47.8	48.6	47.6	47.6	44.0
Niger	48.2	47.9	47.5	47.7	47.7	47.4	47.9	49.1	50.0	50.5
Median age of population										
Indonesia	18.6	18.5	19.1	19.9	21.3	22.8	24.4	25.5	26.7	28.0
Bangladesh	17.8	17.6	17.3	17.7	18.6	19.5	20.9	22.4	23.9	25.6
Pakistan	19.3	18.6	18.5	18.6	18.5	18.6	19.2	20.2	21.4	22.5
Iran	17.7	18.1	18.1	17.3	17.2	18.5	20.8	24.1	26.9	29.5
Turkey	19.0	19.6	20.0	21.0	22.1	23.5	24.9	26.6	28.3	29.9
Egypt	19.0	19.2	19.4	19.5	19.6	20.1	21.2	22.6	23.9	24.7
Algeria	16.4	16.5	16.7	17.1	18.0	19.4	21.7	24.1	26.0	27.5
Afghanistan	17.9	17.4	17.0	16.3	15.9	16.0	15.7	16.1	16.0	17.3
Niger	15.6	15.7	16.0	15.7	15.8	15.9	15.9	15.4	15.0	14.9
Dependency ratio (population 0–14 + 65+/population 15–64)										
Indonesia	87.0	85.2	80.7	74.4	67.3	60.8	54.8	53.5	51.1	49.2
Bangladesh	91.0	92.7	91.9	88.0	83.3	76.4	69.2	63.1	58.2	52.6
Pakistan	85.9	88.3	87.8	86.8	88.4	87.6	82.4	73.6	68.4	65.3
Iran	90.1	87.0	86.9	93.6	95.0	84.8	64.3	44.9	39.6	40.2
Turkey	83.5	81.9	79.7	73.9	67.8	61.9	58.0	54.5	51.8	50.1
Egypt	86.0	84.0	82.9	82.7	83.5	79.6	70.8	61.9	58.4	61.8
Algeria	101.5	101.3	98.9	95.1	87.7	76.5	62.9	51.6	48.5	52.7
Afghanistan	88.1	91.3	93.6	97.9	101.0	100.5	103.3	99.0	100.4	88.8
Niger	101.6	101.1	100.2	102.4	103.2	102.0	102.5	106.5	110.2	111.6

Source: United Nations Population Division, 2017.

of the population had risen by more than 10 years in Indonesia, Iran, Turkey, and Algeria. The increases were not as large as they were in the other countries, and in two countries – Afghanistan and Niger – there was no increase at all.

The dependency ratio is only a notional indicator of real dependency for a number of reasons. For example, many young people aged 15–19 are still in education and are not available for work; and many older people continue working beyond age 64. Nonetheless, the dependency ratio remains useful as a rough shorthand indicator of the effect of changing age structures on the ratio of potential dependants to potential producers in the population. It is generally believed that a dependency ratio of below

60 provides a very favourable demographic structure for economic development. Indonesia was the first of the countries in Table 2 to enter this favourable zone around 1995, and was followed shortly thereafter by Turkey. In the early 2000s, a number of other countries moved into this zone as well, including Iran and Algeria, followed by Bangladesh and Egypt. The dependency ratio in Iran fell to a remarkably low level by 2010. However, Pakistan has not yet entered the favourable zone, and Afghanistan and Niger remain far away from the zone, burdened as they are by a large and rapidly growing population of children.

5 Education and human capital in Muslim countries

Education is the main driving force of development, autonomy, and demographic change; as it introduces men and women to modern ways of thinking, and it imbues them with the confidence they need to engage with the modern world. Education is thus known to promote lower infant mortality, higher ages at marriage, and higher levels of gender equity within couple relationships. As women who have attended school are more likely to participate in the cash economy labour force, having an education raises the opportunity costs of having children.

Islam values education for all human beings. This is evident from several Quranic verses (see, for instance, Quran, chapter 2, verses 30–33; chapter 20, verse 114; chapter 39, verse 9; chapter 96, verses 1–5) and from words and acts attributed to Prophet Muhammad (*hadith*) that emphasise the importance of education (Jafri 2011). The well-established *hadith* from Prophet Muhammad, "seeking knowledge is obligatory upon every Muslim" (Al-Kafi), makes it clear that both men and women are expected to pursue an education (Abbasi-Shavazi and Torabi 2012). After the death of the Prophet Muhammad in 632 AD, Islam spread to people with different languages, customs, religions, and legal systems (Makhlouf Obermeyer 1992, 42). Thus, cultural and religious practices vary across Muslim countries. Despite the historical evidence that Islam has always emphasised the importance of education, and that female education has been encouraged in some parts of the Islamic world, levels of education among women have, until recently, been low in some Muslim countries. Studies (Abbasi-Shavazi and Torabi 2012; Torabi and Abbasi-Shavazi 2015; Pew Research Center 2016) have shown that in Muslim-majority countries, educational levels have improved considerably in recent years; although the magnitude of these changes and the overall achievement levels vary across geographic regions, and within each region.

Table 3 shows the levels and trends in mean years of schooling for females aged 20–39 in the nine selected Muslim countries between 2015 and 2050. The countries' performance on this measure differs considerably. Levels of female education are highest in Algeria, Indonesia, and Iran; and are lowest in Niger and Pakistan. No data exist for Afghanistan, but it is estimated that the level in Afghanistan is somewhere between that of Niger and Pakistan. While the Wittgenstein Centre's projections show an increasing trend in mean years of schooling for females, the

Table 3:
Trends in mean years of schooling for females (20–39) in selected Muslim countries 2015–2050

Country	2015	2020	2025	2030	2035	2040	2045	2050
Algeria	10.7	11.3	11.9	12.3	12.7	12.9	13.1	13.3
Bangladesh	6.9	7.4	7.9	8.3	8.8	9.2	9.6	10.0
Indonesia	10.0	10.5	10.9	11.3	11.6	11.9	12.2	12.4
Iran (Islamic Republic of)	10.0	10.6	11.2	11.7	12.2	12.5	12.8	13.1
Niger	1.5	1.9	2.3	2.8	3.4	4.0	4.6	5.3
Pakistan	4.8	5.5	6.2	7.0	7.7	8.4	9.1	9.7
Turkey	8.7	9.3	10.0	10.5	11	11.4	11.8	12.1
Egypt	9.7	10.7	11.5	12.1	12.5	12.9	13.1	13.3
Afghanistan	–	–	–	–	–	–	–	–

Source: Wittgenstein Centre, http://www.wittgensteincentre.org/dataexplorer

magnitude of this trend differs across the selected countries. The projections indicate that by 2050, the mean years of schooling among females will increase from a relatively high 2015 base by 2.4 years in Indonesia; and will increase from a much lower base by 3.8 years in Pakistan and by 4.9 years in Niger.

Although the numbers of women in Muslim countries who are becoming literate are increasing over time, considerable gender gaps in access to education remain in these countries. The gender differences are generally larger in West Africa, where literacy levels are still much higher among young men than among young women. The educational gender gap in Islamic countries has been attributed to stratified gender roles, which are still in effect in these societies (see Makhlouf Obermeyer 1992; Roudi-Fahimi and Moghadam 2003). Other factors that may contribute to the existing gender gap in education include cultural objections to girls attending school; as well as the absence of or barriers to accessing educational institutions in rural or remote areas, which can make it difficult for girls in particular to attend school. But with rapid urbanisation, women in most of these countries have better access to education now than in the past. In addition, as development levels increase, access to education exists in the majority of rural areas in the Islamic world, although these schools are often of poor quality (Abbasi-Shavazi and Torabi 2012).

In a series of studies, Lutz et al. (2008) reassessed the macro-level returns to education using a newly reconstructed set of data of educational attainment distributions by sex and five-year age groups for 120 countries across the world. Lutz (2009 and 2014) argued that considering education as a source of observed heterogeneity can add greatly to our understanding of the forces driving population change.

Having shown the substantive importance of education for and the pervasive influence of education on demographic trends, Lutz et al. (1999) suggested in a

Figure 2:
Age and education pyramids of the selected Muslim countries in 2015 and projected to 2050

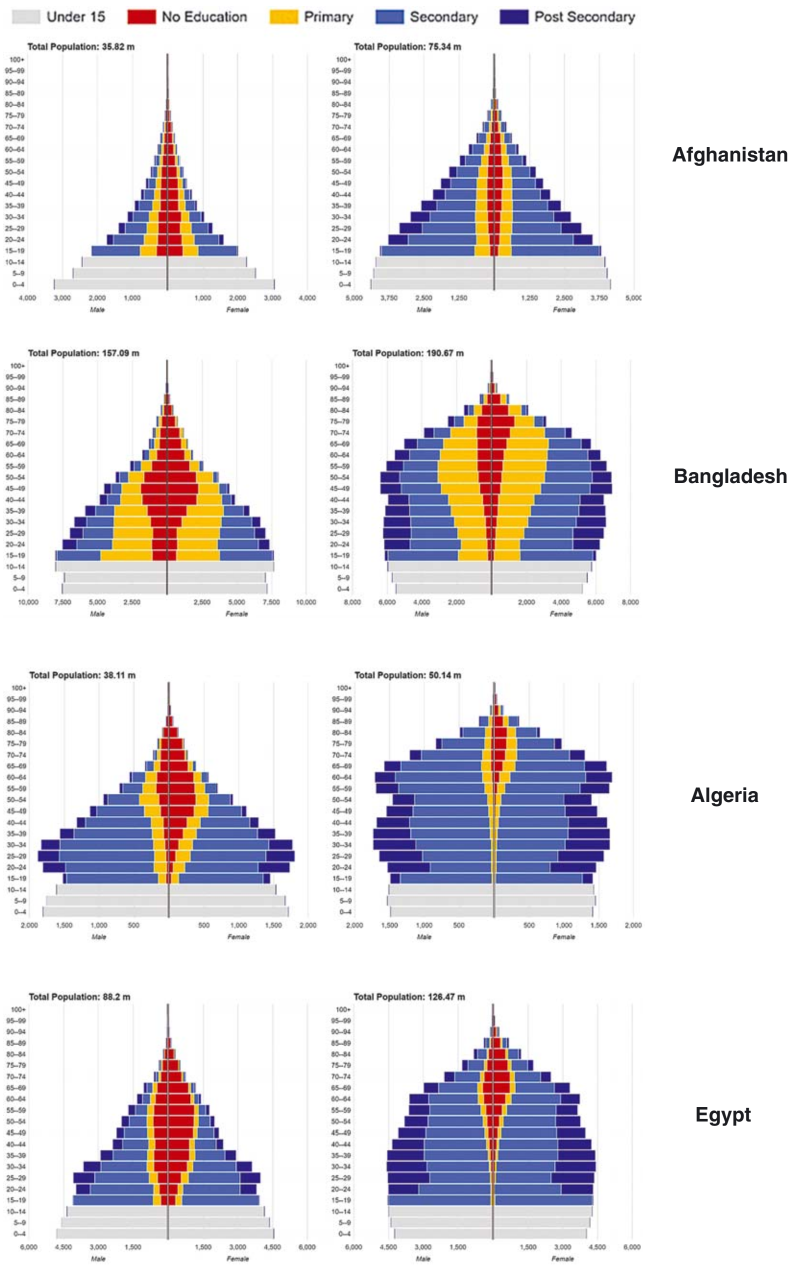


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Figure 2:
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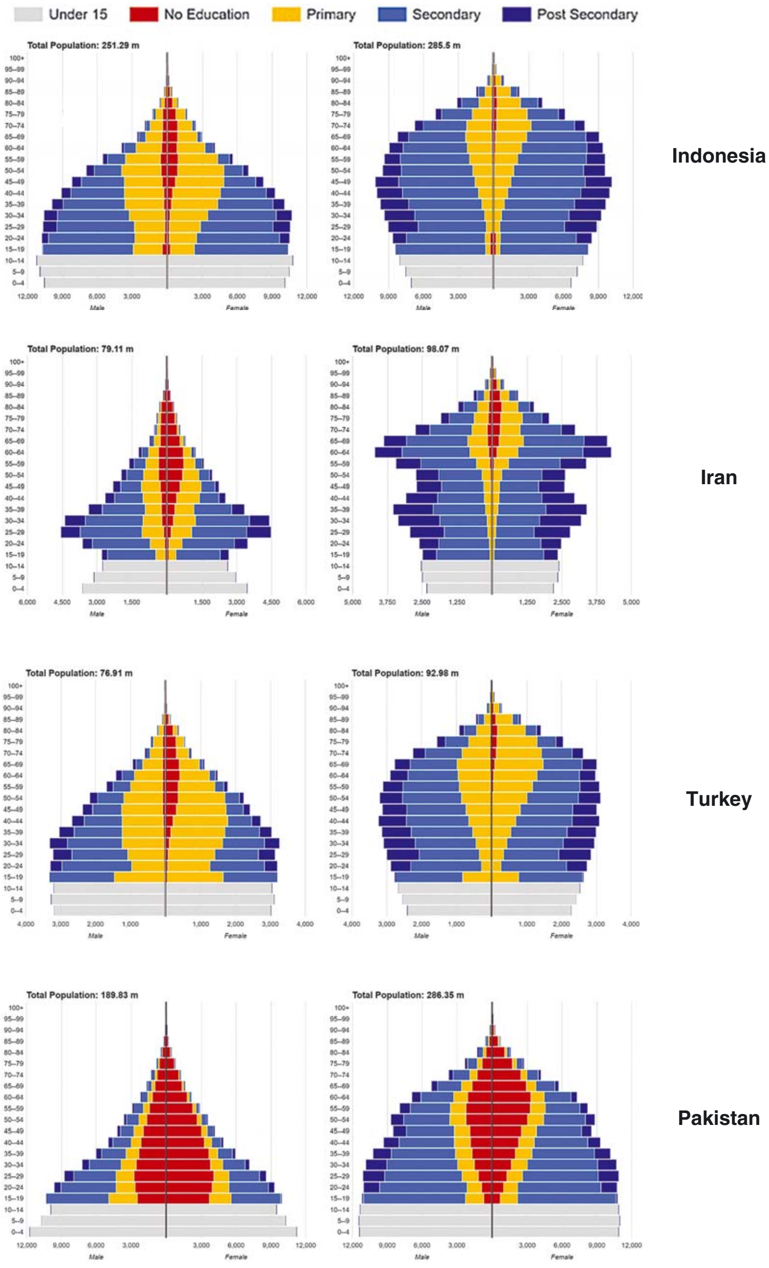

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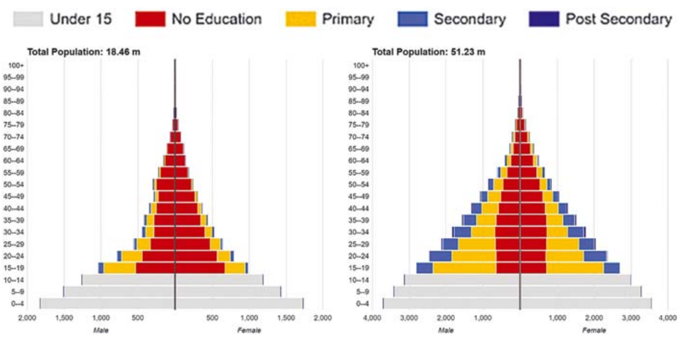


Niger

Source: Wittgenstein Centre, http://www.wittgensteincentre.org/dataexplorer

contribution entitled 'Demographic dimensions in forecasting: Adding education to age and sex' that education should be given a status in demography immediately after that of age and sex.

Following this principle, the International Institute for Applied Systems Analysis (IIASA), in collaboration with the Vienna Institute of Demography (VID) of the Austrian Academy of Sciences, has produced a new unique dataset that applies demographic multi-state projection techniques to reconstruct from empirical data the population by age, sex, and four levels of educational attainment. A comprehensive description of the methods and the results of this reconstruction is given in Lutz et al. (2007) and KC et al. (2008).

At any point in time, the distribution of the population by age, sex, and level of educational attainment reflects the history of changes in the proportions of a cohort who attended school and reached certain educational levels. Since formal education typically happens in childhood and youth, the current educational attainment distribution of 50–54-year-old women, for instance, reflects the education conditions and school enrolment levels of more than 30 years ago. This pattern can be observed in Figure 2, which shows the educational age pyramid of the selected Muslim countries in 2015 and 2050. The figure clearly indicates that younger Muslims are not only much more numerous (due to the history of very high fertility), but are, on average, much better educated than the older cohorts. This recent improvement in educational attainment has been particularly pronounced among women. In some Muslim countries, more than two-thirds of the current generation of young women have completed at least junior secondary education, compared with only a tiny fraction of their mothers' generation. Hence, the historic trend of educational levels increasing over time is reflected in today's age pattern of education.

high proportions of the population are under age 15; whereas in Iran, Turkey, and Indonesia, which recently underwent fertility transitions, the proportions of the population age under 15 are lower than in the other countries. The other noteworthy feature of these age pyramids is that they reveal wide differences in levels of education in 2015. Large proportions of the populations of Niger, Pakistan, and Afghanistan have no education; while only small proportions of the populations of Indonesia, Iran, and Turkey have no education. The age pyramids clearly show that in Niger and Pakistan, females have lower levels of education than males.

As Lutz (2013) has pointed out, as education advances, all countries will experience a 'demographic metabolism' through which the older and illiterate population will be replaced by an educated and younger population. Thus, there is considerable potential for human capital to increase and for educational levels to rise in these countries. It is obvious from the Wittgenstein Projections that by 2050, levels of human capital will have improved even in those Muslim countries that have lagged behind in recent years.

6 Is the demographic dividend being used effectively?

As we have noted, many Muslim countries currently have a demographic structure that is conducive to development. But are they taking effective advantage of this potential demographic dividend? There are a number of elements to take into account in answering this question. For the demographic dividend to be used effectively in raising per capita incomes, and hence in improving the wellbeing of the population, the high proportion of the population of potential working ages needs to be absorbed into productive employment. There are both supply and demand aspects of this need. On the supply side, those entering labour force ages need to be well educated so that they have the capacity to be productively employed, and they need to be available for work. On the demand side, sound economic planning is necessary to ensure that employment opportunities are expanding and unemployment levels are not increasing (Jones 2012).

On both these counts, the picture is a mixed one in Muslim countries. As we discussed above, educational levels are rising among each successive cohort, albeit at varying speeds across countries. But when we apply a simple measure used by the ILO – the employment-to-population ratio – to show the proportion of a country's working-age population who are employed, we find that many Muslim countries have relatively low ratios (see Table 4). This is because many people are either unemployed or (more commonly) out of the labour force altogether. Unemployment rates are very high in some predominantly Muslim countries, especially in MENA (Middle East and North Africa) countries. In 2014, unemployment among youth in the Arab region was more than twice as high (29.7%) as the global average (14.0%). This situation is projected to worsen in the near future (UNDP 2016). But the more important factor is that in many Muslim countries, the labour force participation

Table 4:
Employment-to-population ratios for a number of Muslim countries and some comparator countries, 2017

Country	Employment-to-population ratio
Afghanistan	48.0
Algeria	38.9
Bangladesh	59.8
Egypt	44.0
Indonesia	63.4
Iran	39.7
Iraq	35.8
Morocco	44.3
Pakistan	51.1
Saudi Arabia	51.2
Turkey	44.8
Yemen	42.0
Comparator Countries	
United Kingdom	59.5
Germany	57.7
USA	58.8
Thailand	70.6
Philippines	61.0
Brazil	58.5

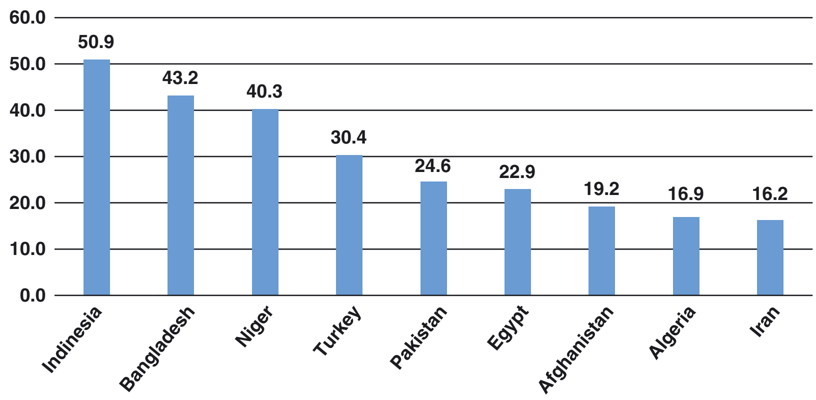
Source: ILOSTAT.

rates of women – including of women with relatively high levels of education – are very low (see Figure 3).

The low proportion of women in the workforce is an important factor holding down the average income levels in many Muslim countries. It is, however, clear from Figure 3 that there is enormous variation in female labour force participation in Muslim countries. The participation rate in Indonesia is twice that in Pakistan and three times that in Egypt and Iran. Similarly large differences can be observed if the comparison is restricted to the well-educated female population.

When data on female labour force participation rates (FLFPRs) are compared across all Muslim countries, enormous variation can be seen, with relatively high rates in some of the African countries and in countries such as Azerbaijan, Tajikistan, Bangladesh, and Indonesia; but extremely low rates in countries such as Algeria, Iraq, Iran, Jordan, and Syria. In many Muslim countries, FLFPRs have been rising over time. But the FLFPRs in these countries are, on average, lower than those in the rest of the world. These low rates represent an obstacle to achieving higher per

Figure 3:
Labour force participation (%) for females aged 15+, 2016



Source: Organization of Islamic Cooperation, http://www.sesric.org/

capita income levels, because (assuming roughly similar male participation rates across countries) lower proportions of the working-age (and of the total) population are in the workforce in Muslim-majority than in non-Muslim-majority countries.

We must be cautious in interpreting the FLFPR figures because the measurement of female economic activity can be affected by the content and the sequence of questions on economic activity in censuses and surveys, and by the person who provides the information to the interviewer. There is, for example, a tendency for male respondents to understate the extent of the workforce participation of the females in the household (Verick 2014, 8–9). However, the relatively low FLFPRs observed in the Arab countries in particular appear to be real, and to indicate "entrenched social biases against the employment of women" (*Arab Human Development Report* 2009, 10). Paradoxically, these restrictions on women's employment remain while educational opportunities for girls are improving, which points to a clear need to give urgent priority to the effective utilisation of the skills of the increasing number of young women receiving education. Making it easier for young women who currently face barriers to employment to participate in the labour market would contribute to economic development, and enhance the well-being of these women.

7 Gender equality indices

There are a number of indexes showing aspects of gender equality in Muslim countries. An index used by UNESCO and other agencies to measure the relative access of males and females to education is the gender parity index. This is a simple

Table 5:
Global Gender Gap Index for Muslim countries, 2016

Country name	Global gender gap index 2016		Country name	Global gender gap index 2016	
	Rank	Score		Rank	Score
Afghanistan	n.a.	n.a.	Maldives	115	0.650
Albania	62	0.704	Mali	138	0.591
Algeria	120	0.642	Mauritania	129	0.624
Azerbaijan	86	0.684	Morocco	137	0.597
Bahrain	131	0.615	Niger	n.a.	n.a.
Bangladesh	72	0.698	Oman	133	0.612
Brunei	103	0.669	Pakistan	143	0.556
Burkina Faso	123	0.640	Palestine	n.a.	n.a.
Chad	140	0.587	Qatar	119	0.643
Comoros	n.a.	n.a.	Saudi Arabia	141	0.583
Djibouti	n.a.	n.a.	Senegal	82	0.685
Egypt	132	0.614	Sierra Leone	n.a.	n.a.
Gambia	104	0.667	Somalia	n.a.	n.a.
Guinea	122	0.640	Sudan	n.a.	n.a.
Indonesia	88	0.682	Syria	142	0.567
Iran	139	0.587	Tajikistan	93	0.679
Iraq	n.a.	n.a.	Tunisia	126	0.636
Jordan	134	0.603	Turkey	130	0.623
Kuwait	128	0.624	Turkmenistan	n.a.	n.a.
Kyrgyzstan	81	0.687	United Arab Emirates	124	0.639
Lebanon	135	0.598	Uzbekistan	n.a.	n.a.
Libya	n.a.	n.a.	Western Sahara	n.a.	n.a.
Malaysia	106	0.666	Yemen	144	0.516

Source: World Economic Forum, http://reports.weforum.org/global-gender-gap-report-2016/rankings/.

index that shows the ratio of girls to boys at each level of education: primary, secondary, and tertiary. The index clearly indicates that the situation of girls and women is improving at each level of education and for almost all countries. At the secondary level of education, considerably more Muslim countries show parity or better for females in 2012 than in 1990. Some countries still perform poorly, however, with indices below 0.7: namely, Afghanistan, Chad, Niger, and Yemen. At the tertiary level, there is enormous variation between Muslim countries, with some having indices well above one and others having indices as low as 0.34.

Two other indexes can be mentioned – although like all such indexes, both suffer from certain shortcomings (Klasen 2007; Permanyer 2013). The first is the

Gender Equity Index, which is designed to facilitate international comparisons by ranking countries based on three dimensions of gender inequity: education, economic participation, and empowerment. Of the 154 countries included in this index in 2012 with information on all three dimensions, no Muslim countries were in the top 43, 15 were in the middle 64, and 22 (59 per cent of the Muslim countries) were in the bottom 47.

Another index that measures gender equality is the Global Gender Gap Index, which is updated each year by the World Economic Forum. It scores countries on a number of variables under four headings: economic participation and opportunity, educational attainment, health and survival, and political empowerment. As Table 5 shows, the Muslim countries scored poorly on this index in 2016. Out of the 144 countries covered, only two Muslim-majority countries (Albania and Bangladesh) were in the top half of the rankings, and all but one of the lowest 17 places were held by Muslim countries. Thus, the indicators used in the Global Gender Gap Index clearly show that these countries still have a long way to go in the area of gender equality. While less stark, the findings of the Gender Equity Index are similar.

8 Conclusion

In 2017, the nine Muslim countries that are the main focus of this paper were home to nearly three-quarters (73 per cent) of the population living in all Muslim-majority countries. What are the growth projections for the populations of these countries over the 33-year period between 2017 and the middle of the 21st century? These figures, which are based on the United Nations medium projection, are shown in Table 6.

There are marked differences in the projected rates of population increase over this period. Niger, which is representative of a number of African countries, is on track to have an extraordinarily high level of population growth – the country's projected growth rate is three times as high as that of Afghanistan, which, at 74 per cent, is already very high. By contrast, in Indonesia, Bangladesh, and Turkey, the projected population growth rate over the period is 23 per cent or less. Overall, population in this group of countries is expected to increase by 39 per cent by 2050. This rapid rate of growth makes it very difficult for these countries to plan for the provision of infrastructure and services, notably those needed to further raise their levels of human capital.

In recent decades, levels of education have improved in Muslim countries, particularly for women. It is not surprising that these countries have experienced phenomenal demographic change, including reductions in infant mortality and increases in the average age at marriage – which have in turn led to fertility decline. Formal schooling has provided Muslim women with expanded opportunities for labour force participation. However, the extent to which women's access to schooling and educational attainment levels have improved varies across geographic regions and within each region, mainly due to differences in levels of development

Table 6:
Projected population growth in nine Muslim countries

Country	Population (million) 2017	2050	% increase 2017–2050
Niger	21,447	68,453	219.2
Afghanistan	35,530	61,928	74.3
Pakistan	197,015	306,940	55.8
Egypt	97,553	153,433	57.3
Algeria	41,318	57,436	38.8
Indonesia	263,991	321,550	21.8
Bangladesh	164,669	201,926	22.6
Turkey	80,745	95,626	18.4
Iran	81,162	93,553	15.3
Total	**983,463**	**1,360,850**	**39.3**

Source: United Nations Population Division, 2017, medium projection.

and in the specific cultural, economic, and political settings of these countries. Mean years of schooling for females have risen in some of the selected countries, but have lagged behind in others. Lutz (2013) has argued that as educational levels improve in Muslim countries, all of these countries will experience a process of demographic metabolism through which largely illiterate older populations are replaced by educated younger populations. As the new generation of Muslim men and women will have much higher levels of education than their parents and grandparents, there is considerable room for human capital to increase in these countries. Differences in educational levels remain within and between these countries, but the gender gap is narrowing across all measures of human capital.

In this paper, we have shown that many Muslim countries, including the largest, are making very impressive progress on measures of demographic and human development. While our findings provide grounds for considerable optimism about continuing improvements, it must be acknowledged that the demographic and human development situations in some Muslim countries remain very challenging. This is particularly true of the countries that are racked by war and civil conflict, as in those places, the resource base is limited, and fertility rates remain very high. For example, the picture of Yemen painted by Augustin (2012) is troubling, and the situation there has only worsened since she wrote about it. The issues faced by some of the poorest West African countries are also troubling. In Niger, for example, the younger population is growing very rapidly, even as educational and health facilities remain inadequate. Nevertheless, when we look at Muslim countries as a whole, we see the emergence of a young and educated population who have the potential to build a brighter and better future.

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Appendix tables are on the following pages.

Appendix

Table A.1:
Population and percentage of Muslims in Islamic countries in which less than 50% of the population were Muslim in 2017

Country/region	Population in 2017, (m) (1)	% Muslim (2)	Estimated Muslim population in 2017 (m)	Country/region	Population in 2017, (m) (1)	% Muslim (2)	Estimated Muslim population in 2017 (m)
Africa	**832.07**		**196.84**	**Asia**	**3,164.14**		**236.71**
Eastern Africa	**392.49**		**77.61**	**South/Central Asia**	**1,390.16**		**196.24**
Eritrea	5.07	36.6	1.86	India	1,339.18	14.4	192.84
Tanzania	57.31	35.2	20.17	Sri Lanka	20.87	9.8	2.05
Ethiopia	104.90	34.6	36.30	Bhutan	0.81	0.2	0.00
Mozambique	29.67	18.0	5.34	Nepal	29.30	4.6	1.35
Malawi	18.62	13.0	2.42	**Southeast Asia**	**344.56**		**13.03**
Mauritius	1.26	17.3	0.22	Singapore	5.71	14.3	0.82
Uganda	42.86	11.5	4.93	Philippines	104.91	5.5	5.77
Madagascar	25.57	3.0	0.77	Thailand	69.03	5.5	3.80
Kenya	49.69	9.7	4.82	Myanmar (Burma)	53.37	4.0	2.13
Reunion	0.86	4.2	0.04	Viet Nam	95.54	0.2	0.19
Burundi	10.86	2.8	0.30	Cambodia	16.00	2.0	0.32
Rwanda	12.20	1.8	0.22	**Western Asia**	**9.49**		**1.84**
Zambia	17.10	0.5	0.09	Cyprus	1.17	25.3	0.30
Zimbabwe	16.52	0.87	0.14	Israel	8.32	18.6	1.55
				East Asia	**1,419.93**		**25.60**
Middle Africa	**113.32**		**6.29**	Mongolia	3.07	3.2	0.10
Cameroon	24.06	18.3	4.40	China	1,409.50	1.8	25.37
Central African Republic	4.65	8.5	0.40	Hong Kong	7.36	1.8	0.13
Zaire		1.4					
Gabon	2.02	11.2	0.23	**Europe**	**452.78**		**31.33**
Equatorial Guinea	1.26	4.0	0.05	**Eastern Europe**	**170.74**		**15.43**
D. R. of the Congo	81.33	1.5	1.22	Bulgaria	7.08	13.7	0.97

Continued.

Table A.1:
Continued

Country/region	Population in 2017, (m) (1)	% Muslim (2)	Estimated Muslim population in 2017 (m)	Country/region	Population in 2017, (m) (1)	% Muslim (2)	Estimated Muslim population in 2017 (m)
Western Africa	**269.55**		**111.97**	Russian Federation	143.99	10.0	14.40
Nigeria	190.88	48.8	93.15	Romania	19.67	0.3	0.06
Cote d'Ivoire	24.29	37.5	9.11	**Southern Europe**	**122.43**		**6.16**
Guinea Bissau	1.86	45.1	0.84	Bosnia & Herzegovina	3.50	45.2	1.58
Liberia	4.73	12.0	0.57	Macedonia	2.08	39.3	0.82
Togo	7.79	14.0	1.09	Greece	11.15	5.3	0.59
Ghana	28.83	15.8	4.56	Italy	59.35	3.7	2.20
Southern Africa	**56.71**		**0.96**	**Western Europe**	**76.39**		**5.55**
South Africa	56.71	1.7	0.96	Belgium	11.42	5.9	0.67
North America	**361.07**		**3.69**	France	64.97	7.5	4.87
Canada	36.62	2.1	0.77				
United States	324.45	0.9	2.92	**Northern Europe**	**83.22**		**4.20**
Latin America & Caribbean	**6.80**		**0.24**	United Kingdom	66.18	4.8	3.18
Central America	**4.10**		**0.03**	Netherlands	17.04	6.0	1.02
Panama	4.10	0.7	0.03	**Oceania**	**25.35**		**0.64**
Caribbean	**1.37**		**0.08**	Fiji	0.90	6.3	0.06
Trinidad & Tobago	1.37	5.9	0.08	Australia	24.45	2.4	0.59
South America	**1.33**		**0.13**				
Suriname	0.56	15.2	0.09				
Guyana	0.77	6.4	0.05	**Total**	**4,842.21**		**464.95**

Note: (1) United Nations Population Division, 2017. **(2)** % Muslims were obtained from Pew Research Center 2010 (http://assets.pewresearch.org/wp-content/uploads/sites/11/2015/03/PF_15.04.02_ProjectionsFullReport.pdf)

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Survival inequalities and redistribution in the Italian pension system

Graziella Caselli and Rosa Maria Lipsi*

Abstract

The public pension system in Italy is a defined contribution scheme based on the principle of actuarial fairness. The pension annuity is calculated starting from capitalised value and the *Legislated Conversion Factors* (LCFs) for each retirement age. The demographic parameters used by legislators in computing the LCFs are the survival probabilities of an average Italian, irrespective of gender or any characteristic except age. The aim of this paper is to analyse the impact of the differences in survival between men and women, and between individuals with different educational levels, on the calculation of the pension annuity, starting from the specific *Conversion Factors* (CFs). The gap between the LCFs and the factors obtained by allowing for differential survival across gender and socio-demographic groups (CFs) gives us a means of making a quantitative assessment of the implicit redistributive impacts of the annuity redistribution from individuals with a lower life expectancy to individuals with a higher life expectancy.

1 Italian pension reform: an introduction

Since the mid-1970s, the demographic behaviour of Italians has undergone profound changes that have modified the population dynamics of the country both directly and indirectly, and have thus had significant consequences for various aspects of social and economic life in Italy. The slow but inexorable shift in the demographic profile of Italy has been caused by declining fertility on the one hand, and increasing survival on the other. It is generally understood that when the

* Graziella Caselli (corresponding author), Sapienza University of Rome, Department of Statistical Sciences, Viale Regina Elena 295, 00161, Rome, Italy
Email: graziella.caselli@uniroma1.it

Rosa Maria Lipsi, Italian National Institute of Statistics (ISTAT), Italy

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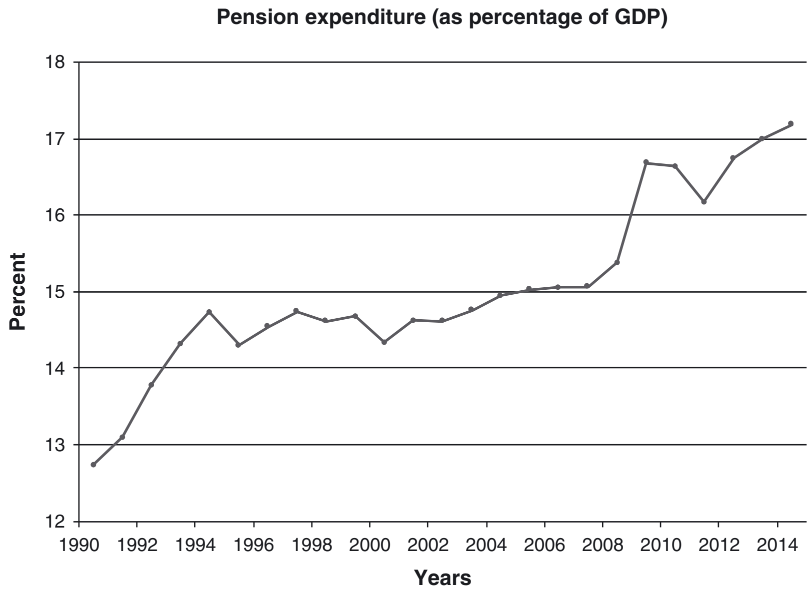
younger cohorts are constantly shrinking even as the older cohorts are expanding, the population will age. In 2016, Italy and Germany were the European countries with the highest shares of the population aged 65 or older: 21.9 per cent for Italy and 21.2 per cent for Germany. This figure for Italy seems even more significant if we consider that it represents a population of almost 14 million, up from four million in 1951 (eight per cent of the total population).

Although demographers had been issuing detailed warnings of this demographic shift since the late 1970s (Vitali 1976; Golini and Pinnelli 1983; Golini 1987), politicians were slow to realise that given the speed at which the ageing process was advancing, this shift would have an unprecedented impact on the country's public expenditures starting around the turn of the century. It was especially difficult to persuade politicians to pay attention to pension expenditures in the years when the combined effects of the growth of the population of working ages (due to the post-war baby boom that continued into the early 1960s) and high employment levels were pouring an unprecedented surplus into the coffers of the pension system. For many years, the retirement age and the pay-as-you-go system were not a problem – indeed, the revenue generated by this system could easily cover expenditures on welfare as well. When the first worrying signs of a rapid increase in pension expenditures began to appear in the 1990s, there was still no sense of urgency among policy-makers. While some minor adjustments to the retirement system were made, more drastic interventions would be required in the future. At that time, the retirement age was raised, early retirement pensions were scaled back (early retirement was still possible for workers with 35 years of contributions, and as little as 20 in the public sector), and years of contributions were tied more closely to pension size. From 1995 onwards, a new method of calculating pension benefits – a 'contribution system' that we describe in detail in this paper – was phased in (with the *'1995 Dini reform'*: Law of 8 August 1995, No. 335 (Table A.1, Appendix)). This system will go into full effect in 2030-35, when the baby boom generations born in the 1960s will have left the work force and become pensioners themselves.

It is becoming increasingly clear that the implementation of this reform has been too gradual. While additional legislative measures aimed at reforming the retirement system were approved in 2011, pension expenditures have continued to grow at an unsustainable rate, triggering the need for a further series of pension reforms (Figure 1).

Law Decree No. 201/2011 (known as the 2011 '*salva Italia*' decree), which included the '*2011 Fornero reform*' (Table A.1, Appendix), made two important changes to the retirement system. The decree brought the implementation of the *'1995 Dini reform'* forward many years by introducing a pro-rata contribution system for all workers starting on 1 January 2012. The legislation also raised the minimum retirement age to 66 for men; and from age 60 to age 62 for employed women, followed by a phase-in period to age 66 by 2018 (64 in 2014, 65 in 2016, and 66 in 2018). The minimum retirement age for self-employed women was set one year higher (65 in 2014, 66 in 2016, and 67 in 2018). The law also introduced a flexible retirement band that allows individuals who choose to work beyond the

Figure 1:
Italian pension expenditures as a percentage of gross domestic product (GDP) from 1990 to 2014



Source: Own elaboration on Istat data (Istat 2016c).

minimum retirement age to earn a larger pension. This band spans ages 63-70 for women and ages 66–70 for men.

The most important stages of the Italian pension reform from 1995 to 2016 are summarised in Appendix Table A.1. Examining these stages will help us better understand the impact the modifications of the retirement age have had on the calculation of the pension annuity, which currently affects millions of men and women in Italy, and will affect even more in the future. Survival probabilities at retirement age are used in calculating the *Legislated Conversion Factors* (LCF*s*), which were introduced by the *'1995 Dini reform'*. The LCFs were supposed to be updated every 10 years to take into account the dynamics of survival in old age. Obviously, if the gap between these updates is too long, the LCFs will fail to reflect the changes in length of life at these ages (Ediev 2014). For this reason, the most recent reform requires that the LCF*s* are updated every three years from 2013 to 2018, and every two years from 2019 onwards (Law Decree No. 201/2011 – Table A.1, Appendix).

The *'1995 Dini reform'* was based on the principle of *'actuarial fairness on average'*, which is only guaranteed in the LCFs *'on average'*, without distinguishing between different categories of workers or between men and women. This principle links the contributions and benefits of future pensioners at the age of retirement to the present value of their contributions (or the value of their retirement wealth), which should equal the expected present value of the benefit stream. Because the survival probabilities used by legislators are, broadly speaking, those of an average Italian (irrespective of gender or any other characteristic except age), the contributions of a given individual may exceed (or fall short of) the benefits received if the person's life span is below (above) average. Yet we would argue that no analysis of the links between survival, ageing, and pension expenditures (and, more generally, welfare expenditures) can afford to ignore the differential aspects of the demographic process, as survival varies by gender, social class, and educational level (Caselli et al. 2003; Lipsi and Tomassini 2009; Luy et al. 2011). Thus, to properly evaluate the redistributive effects of social security and health care policies, it is essential that we study the differential aspects of survival (Bommier et al. 2011; Donnelly 2015; Pestieau and Ponthiere 2016; Piggott et al. 2005; Sanchez-Romero and Prskawetz 2017).

The aim of this paper is to analyse the impact of the differences in survival between men and women, and between individuals with different educational levels (Table A.2, Appendix), on the calculation of the pension annuity. The gap between the conventional LCF*s* and the LCFs obtained by allowing for differential survival across socio-demographic groups (CFs) provides us with a starting point for making a quantitative assessment of the unintended redistributive impacts of a reform based on actuarial fairness.

In Section 2 of this paper, we will present the data and the methods used in calculating CF*s*. In Section 3, we will assess increasing longevity and social inequalities in survival using educational level as a proxy for social class. In Section 4, we will present the CF*s* by gender and educational level for the year 2012, and discuss the most important results. In Section 5, we will look at which differences should be taken into account, and explore some ideas for reducing the social inequalities produced by '*actuarial fairness on average*' (as discussed on page 85).

2 Data and methods

In the '*1995 Dini reform*' (Table A.1, Appendix), the pension annuity – or the annual pension benefits – at retirement P in [1] is proportional to the capitalised value M of lifetime social security contributions (Lipsi 1999, Caselli et al. 2003), that is,

$$P = C_x M, \tag{1}$$

where C_x is the *Legislated Conversion Factor* (LCF) for retirement at age x, with x ranging between 57 and 70 years, which are, respectively, the lowest and the highest retirement age for which the coefficients are computed. The LCF is the same for men and women, and is equal to the inverse of the coefficients D_x:

$$C_x = \frac{1}{D_x} \tag{2}$$

D_x [3] is equal to the average of age-specific coefficients $D_{x,m}$ and $D_{x,f}$, computed separately for men (m) and women (f)

$$D_x = \frac{D_{x,m} + D_{x,f}}{2}, \tag{3}$$

We denote with $D_{x,s}$ the generic coefficients where s = sex (m = men, f = women), and is expressed as the sum of two components: the expected present value of a real annuity of one euro paid to the pensioner until his/her death, and the expected present value of the corresponding annuity subsequently paid to the surviving spouse.

The formula adopted by the legislators (published many years after the *'1995 Dini reform'* by the State General Accounting Office – RGS, 2014) may be obtained for each sex s and retirement age x, as follows:

$$D_{x,s} = \sum_{t=0}^{w-x-1} \frac{l^v_{x+t}}{l^v_x}(1+i)^{-t} + \beta \sum_{t=0}^{w-x-1} \left(\frac{l^v_{x+t}}{l^v_x} q^v_{x+t} a^F_{x+t+1} (1+i)^{-(t+1)} \right) - 0.4615, \tag{4}$$

where w is the maximum life span (set equal to 105 years); l^v_{x+t}/l^v_x is the probability of the pensioner at age x being alive at age $x+t$; t are the years spent in retirement; v refers to the *old-age* pensioner; i is the annual real discount rate (set at 1.5 per cent, which is assumed to be equal to the long-run annual growth rate of gross domestic product in real terms); and $\beta = \alpha * \gamma_s$ (set at 0.54 for a male pensioner and 0.42 for a female pensioner) is the fraction of the pension paid out to any surviving spouse ($\alpha = 0.60$) adjusted for the income limits of the beneficiary ($\gamma_s = 0.90$ if $s = m$ and $\gamma_s = 0.70$ if $s = f$). The parameters α and γ_s were introduced in the course of the 1995 Dini reform, without any further justification from lawmakers. q^v_{x+t} is the probability of dying between age $x+t$ and age $x+t+1$ for a pensioner; a^F_{x+t+1} is the expected present value of a real annuity of one euro paid to any surviving spouse after the pensioner's death at age $x+t+1$; F refers to the household of the deceased pensioner; and the constant 0.4615 is an actuarial adjustment that takes into account the fact that pensions are paid monthly.

It is easy to verify that the *Legislated Conversion Factor* C_x (LCF) is an increasing function of the discount rate and a decreasing function of the survival probabilities, the maximum life span, and the fraction of the pension paid out to the surviving spouse.

In this paper, the demographic parameters used in computing the conversion factors are as follows: the survival probabilities for both the pensioner and his/her surviving spouse, based on the life tables of the Italian National Institute of Statistics (Istat) for the year 2012; the death probabilities for old-age pensioners, which are the same as those of the Italian population considered in the previous 2012 life tables; and the annuity paid to the surviving spouse, which is calculated assuming a fixed age difference of three years between the husband and the wife. We based our assumption about this difference on our reading of the '*1995 Dini reform*', and not on any justifications provided by lawmakers. This aspect of the reform turned out to be so controversial that lawmakers decided to make this assumption explicit for the conversion factors that were updated in 2016.

We have chosen to use the life tables for 2012 in this paper, as life tables by educational level are available for this year only.

For the mortality differential by educational level, we use three levels that are aggregated as follows (see the population distribution by age groups, gender, and education in Table A.2, Appendix):

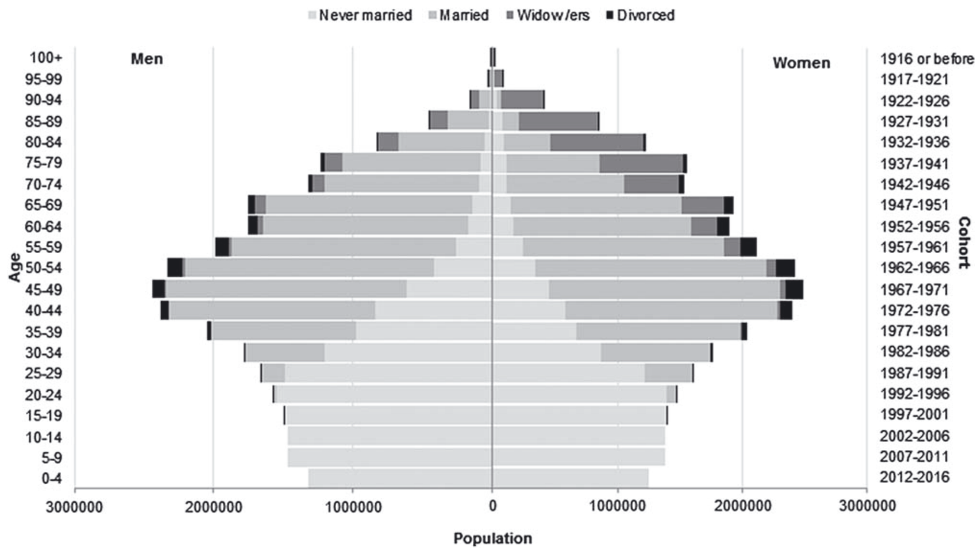
(a) Low for individuals with no qualifications, a primary school diploma, or a middle school diploma;
(b) Medium for individuals with a high school diploma; and
(c) High for individuals with a university degree or other higher education diploma.

3 Increasing longevity by gender, and survival differences by educational level

To provide a clearer picture of the ageing process in Italy, we present an image of the age pyramid of the Italian population (Figure 2). This pyramid takes the form of a tree with a trunk at the base that thins out as the number of births diminishes, while the foliage at the top grows as the number of individuals who reach old age rises. This structure is the result of the combined effects of the large generations born after the Second World War reaching old age and declining mortality rates at every age of life, which have allowed these numerous cohorts not only to reach old age, but also to survive into extreme old age. This growth pattern is more pronounced among women than among men: today in Italy, women over age 65 make up 24.4 per cent of the total population of women, whereas men over age 65 make up just 19.6 per cent of all men. The gender gap in survival is even greater after age 80, when the number of women who are widows and are living alone reaches its highest level (see Figure 2).

One relevant feature of this unprecedented imbalance in the age structure of the Italian population is an ageing process that shows no sign of stopping, and that is projected to peak in the 2030s, when the cohorts of baby boomers born in the 1960s reach retirement age. These are the cohorts that cause the central positions of the Italian pyramid to be so wide. However, in just over 20 years, when the baby boom cohorts are replaced by the baby bust cohorts born in the 1970s and 1980s, the share of the population supporting the growing number of retirees will inevitably decrease. According to Istat, the working age population (15–64) will decrease by three per cent between 2016 and 2031, even counting the arrival of new migrants (Istat 2017). Having recognised this process, and the advanced process of ageing combined with the increasing number of years lived in retirement, the Italian government has been

Figure 2:
Population by sex and marital status, Italy, 1 January 2016



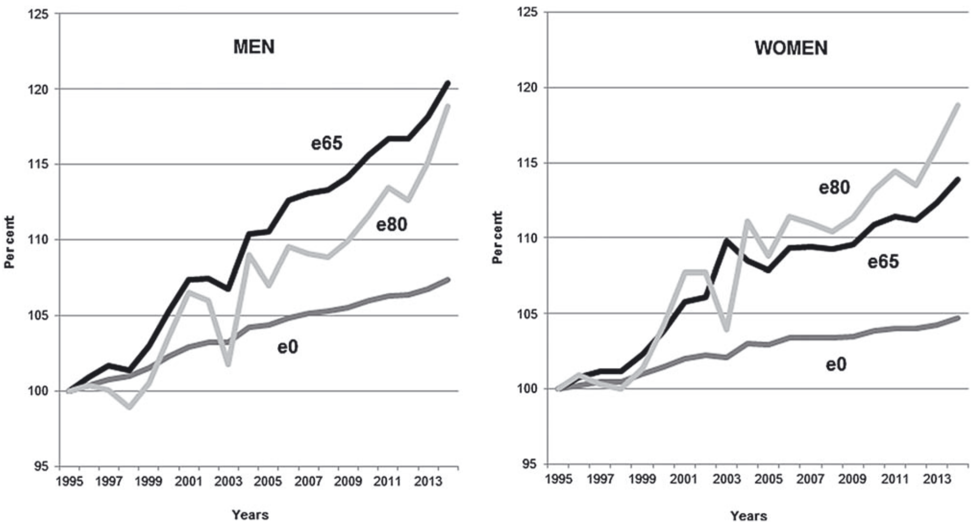
Source: Own elaboration on Istat data (Istat 2017).

forced to accelerate various aspects of pension reform, including the raising of the retirement age.

Figure 3 provides a clear picture of recent developments in longevity among Italians. The rates of increase in life expectancy at ages 65 and 80 have had much greater effects than the rates of increase in life expectancy at birth since 1995, the year of the *'1995 Dini reform'*. Between 1995 and 2014, average survival among men increased by 20 per cent at age 65 and by almost as much at age 80. Among women, who started with an advantage, average survival over the same period improved at a slightly lower rate, and increased the most among those aged 80 or older. While women maintained their survival advantage over the study period, the gender gap shrank from almost four years in 1995 to 3.5 years in 2014. The values displayed in Table 1 indicate that over this period, life expectancy at age 65 increased 3.2 years for men and 2.7 years for women. Thus, according to the life tables for 2014, an individual who had reached the age of 65 in that year could expect to live another 18.9 years if male or another 22.3 if female.

In line with recommendations made in the European White Paper (Zaidi 2010; European Commission 2012), Italian pension reform legislation has introduced control mechanisms for the number of years spent in retirement, which should remain more or less constant over time (around 20 years at the age of 65). These mechanisms help to ensure that the pension contributions are (more or less) evenly spread across an average number of years, and should make it easier to control the

Figure 3:
Index number (1995 = 100) of life expectancy at birth (e0), at 65 (e65), and at 80 (e80) by sex. Italy, 1995–2014



Source: Own elaboration on Istat data (Istat 2016a).

Table 1:
Life expectancy at birth (e0) and at age 65 (e65) in years, by gender, from 1995 to 2014, and differences (in years) between men and women at age 65. Italy

	Men		Women		Total (M and W)		Differences at age 65: W – M
Years	e0	e65	e0	e65	e0	e65	
1995	74.8	15.7	81.1	19.6	77.9	17.7	3.9
2009	78.9	17.9	84.0	21.5	81.4	19.7	3.6
2012	79.6	18.3	84.4	21.8	81.9	20.1	3.5
2014	80.3	18.9	85.0	22.3	82.6	20.6	3.4
Differences 1995–2014	5.5	3.2	3.9	2.7	4.7	2.9	0.5

Source: Own elaboration on Istat data (Istat 2017).

legal age of retirement when planning the pension system. We note that throughout the 1994–2014 period, if life expectancy at age 65 had been fixed at around 20 years, men would have been under the 20-year threshold, while women would have exceeded it by no less than two years.

The gap in life expectancy between men and women was ignored in the *'1995 Dini reform'* in the interests of actuarial fairness, as women pensioners were seen

Table 2:
Life expectancy at age 0 (e0), 65 (e65), and 67 (e67) in years by education and differences between levels of education (high and low). Year 2012. Men and women. Italy

Life expectancy	Men				Women			
	Level of education			Differences High – Low (in years)	Level of education			Differences High – Low (in years)
	Low	Medium	High		Low	Medium	High	
e0	78.6	80.9	82.4	3.8	83.2	85.3	85.9	2.7
e65	18.0	19.2	20.0	2.0	21.7	22.5	22.9	1.2
e67	16.5	17.6	18.3	1.8	19.9	20.8	21.1	1.2

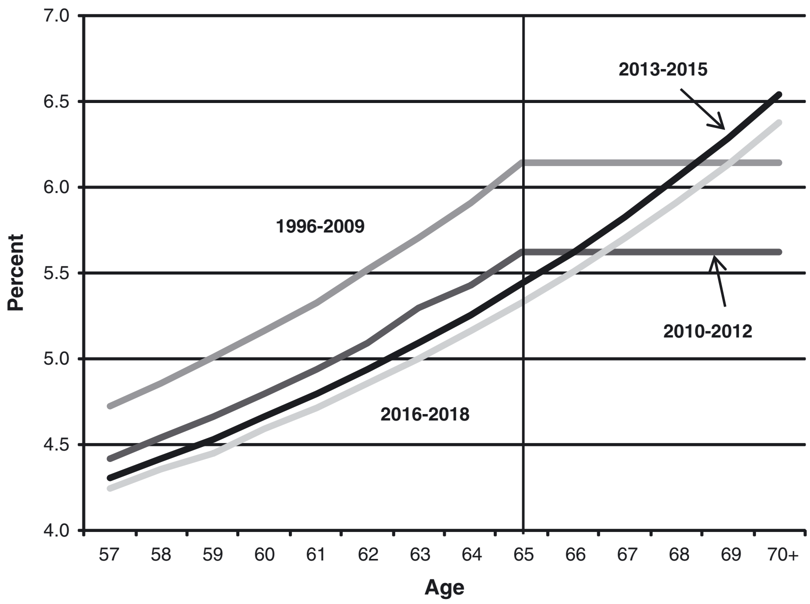
Source: Own elaboration on Istat data (Istat 2016a).

as receiving a ‘premium’ to compensate for maternity-related benefit losses. This turned out to be an exceptionally high premium, as 65-year-old women could look forward not only to surviving four years longer than men, but to retiring five years earlier (at age 60, their life expectancy was 24 years). As we have mentioned, the revision of this distortion was addressed in the 2010 reform, and was further corrected in the ‘*2011 Fornero reform*’, which introduced a retirement option for women that encouraged early retirement only if a woman had at least 41 years and one month of contributions (up to December 2016). However, the retirement age for women has been gradually brought into line with that for men, and will reach the same level in 2019 (66.7 years, plus the increase in life expectancy).

Although the official retirement age will soon be the same for women and men, the Budget Law of 2016 and the Enabling Acts of 2017 envisaged reducing the years of contributions necessary for women to retire. Such changes effectively bring forward the retirement age indicated in the ‘*opzione donna*’ decree of 2011, and thus reintroduce different retirement ages for men and women (for full information, see Pensioni Oggi (2017a)). But under these reforms, the choice to retire early will not be painless for women.

Levels of survival and of pension benefits vary not only by gender, but by social class. To understand this relationship, we look at educational level as a proxy for social class (see Luy et al. 2011; Zarulli et al. 2013). Table 2 shows that at birth, a man with a university degree can, on average, expect to live about four years longer than a contemporary with a low educational level. Among women, this difference is reduced to around three years. This gap is obviously smaller for survival at age 65, but it is still around two years for men and a little over one year for women (Marmot and Skipley 1996; Maier et al. 2011). If we then compare life expectancy at age 65 of a man with a low educational level and a woman with a university degree, we see that the woman has an advantage of no less than five years.

Figure 4:
Comparison between LCFs by age calculated from 1995 to 2018, annual real discount rate i = 1.5%



Source: Own elaboration on Pensioni Oggi data (Pensioni Oggi 2015).

How will these differences affect the calculation of the pension annuity, which is attributed to each individual of the same age and same life expectancy as the average Italian?

4 The impact of survival differences on annuity pension

4.1 Survival increase vs *Legislated Conversion Factors* (LCFs) decrease

We should recall that since 1995, when the first in a series of reforms in response to increased longevity was introduced, the LCFs have been updated no fewer than four times. Figure 4 compares the LCF*s* of the years 1996–2009 with those of the following years (Pensioni Oggi 2015). The life tables used in calculating these LCFs are the Istat life tables for 1995, 2002, 2008, and 2013.

The variations found in the LCFs are mainly attributable to increases in the probabilities of survival between ages 57 and 70. At the same ages, the coefficients have declined steadily from 1996–2009 until today. This was expected given the increase in survival at all ages. It is, however, worth noting that at age 65, the LCF updated for the 2010–2012 period (before the '*2011 Fornero reform*') is half a percentage point lower than the LCF for the 1996–2009 period. To have a coefficient equal to that of a 65-year-old at the time of the *'1995 Dini reform'*, a person today would have to retire at the age of 69, a full four years later. Indeed, if we calculate life expectancy using the 1995 life tables for men and women together, we see that the life expectancy of an individual retiring at age 65 in 1995 was equal to that of an individual retiring at age 69 in the years 2016–2018 (following the life tables of 2013 (Istat 2016a)). However, the retirement age is now lower, at 66.7 years for men and 65.7 years for women.

As an example, consider a theoretical pensioner with a capitalised value *M* of 270,000 euros. We assume that the pensioner is legally permitted retire at age 65 in 2018, and has a pension annuity (14,380 euros and an LCF equal to 0.05326) that is 13 per cent lower than that of a person who retired in 2009 at the same age (16,567 euros and LCF equal to 0.06136).

4.2 Actuarial fairness and gender survival differences

As we have mentioned above (page 85), *'actuarial fairness on average'* works through the use of LCFs, and is therefore indifferent to the effects of demographic processes, including those that are associated with socioeconomic inequalities between individuals. Leaving aside our personal opinions about the wisdom of these choices, we are in favour of evaluating their effects on the future life of each pensioner, whose retirement pension is calculated on the basis of his/her contributions during his/her working life, is revalued, and is sub-divided into annuities on the basis of parameters that have taken into account the life expectancy of the average Italian of that age. This average life expectancy may be much longer or much shorter than the life expectancy of a particular pensioner's demographic or social group.

The conversion factors by gender (as CFs), updated using the life tables for 2012 (Table 3), show the importance of the survival increase at old ages. Consequently, the annuity received by a person retiring at age 65 is 1.7 per cent lower than the annuity calculated for the 2010–2012 period, when the LCFs were based on the 2002 Istat life tables. If conversion factors were allowed to vary by gender, then the annuity obtained by retiring at age 65 would be only 0.3 per cent higher for men, but would be 3.7 per cent lower for women.

When CF*s* are computed separately by gender, it becomes clear that the pension reform penalises men more than women. Looking at Table 3, we see that the relative differences between the gender-specific conversion factors tend to increase with age. We also note that the gains for women and the penalties for men are not perfectly symmetric. This pattern reflects the gender differential in survival, and the fact that the component of pension wealth is less important for a widow (0.42) than for a widower (0.54).

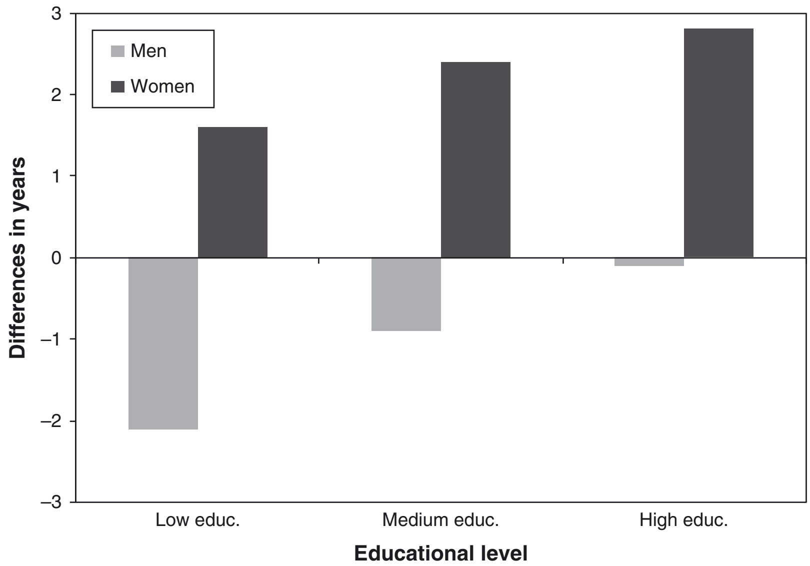
Table 3:
Comparison between Legislated Conversion Factors (LCFs) considered in the period 2010–2012 by age and those estimated by using 2012 life tables (CFs). Upper age at death 105 years. Men, women, and total. Italy

	Legislated Conversion factors updated 2010–2012	Conversion factors Life tables: ISTAT 2012 Maximum age 105			Deviations with current conversion factors (per cent)		
Age	Total	Men	Women	Total	Men	Women	Total
57	0.04419	0.04418	0.04276	0.04347	0.0	−3.2	−1.6
58	0.04538	0.04539	0.04388	0.04464	0.0	−3.3	−1.6
59	0.04664	0.04668	0.04508	0.04588	0.1	−3.3	−1.6
60	0.04798	0.04804	0.04635	0.04720	0.1	−3.4	−1.6
61	0.04940	0.04950	0.04771	0.04860	0.2	−3.4	−1.6
62	0.05093	0.05105	0.04915	0.05010	0.2	−3.5	−1.6
63	0.05257	0.05270	0.05069	0.05170	0.3	−3.6	−1.7
64	0.05432	0.05447	0.05234	0.05341	0.3	−3.6	−1.7
65	0.05620	0.05639	0.05412	0.05526	0.3	−3.7	−1.7
66	–	0.05846	0.05604	0.05725	–	–	–
67	–	0.06069	0.05811	0.05940	–	–	–
68	–	0.06310	0.06034	0.06172	–	–	–
69	–	0.06570	0.06277	0.06423	–	–	–
70	–	0.06851	0.06539	0.06695	–	–	–

Source: Own elaboration on Istat data (Istat 2016b).

Assuming a retirement age of 65 for men and women in 2012, and returning to the previous example, which fixes a theoretical capitalised value M of 270,000 euros for men and women, we can measure both the penalty for men and the differences between men and women. If the pension annuity is calculated for both men and women by following the CF_{65} (equal to 0.05526 – Table 3), the average annuity for a 65-year-old retiree with the sum indicated is equal to 14,920 euros. If, however, the CF_{65} is calculated separately by gender (0.05639 for men and 0.05412 for women – Table 3), each man has a pension annuity of 15,225 euros, and each woman has a pension annuity of 14,612 euros. The disadvantage for men produced by actuarial fairness is around 300 euros, and the difference between the annuities received by a man and a woman is no less than 613 euros (four per cent). These differences represent the impact of the annuity redistribution from lower male survival to higher female survival.

Figure 5:
Differences (in years) between life expectancy at age 65 by level of education (see Table 2) and life expectancy (M + W) at the same age (see Table 1) considered by the pension system (absolute values). Men and women. Italy. Year 2012



Source: Own elaboration on Istat data (Istat 2016b).

4.3 Actuarial fairness and educational survival differences

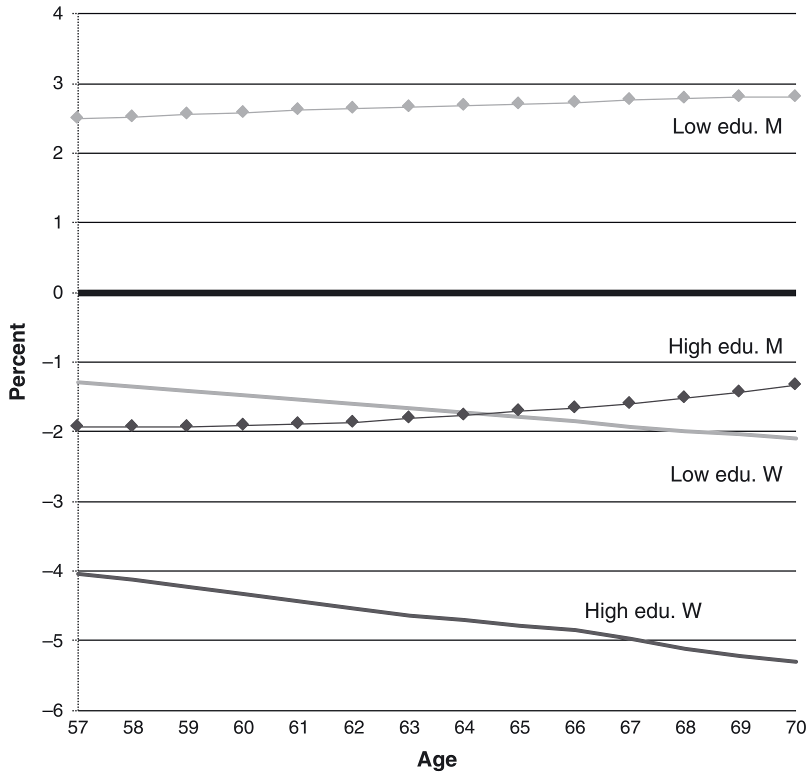
Before presenting the estimates of the CFs calculated on the basis of survival by educational level, it may be useful to examine the differences in life expectancy at age 65 for each group and gender, compared with the life expectancy used in calculating the legal coefficients at the same age ($e_{65(M+W)}$ = 20.1 years). It is clear from Figure 5 that among men, the most marked difference is negative, and is seen among men with the lowest educational level (2.1 years less than the average value). Among women, the maximum distance is positive, and is observed among women with a high educational level (2.8 years more than the average value). Among men, only those with a high educational level have a life expectancy at age 65 that is close to that of the average for 2012; while among women, there is a positive gap for all groups. These figures therefore show that even women who belong to the most disadvantaged group based on education have an advantage in the calculation of the CFs.

A comparison between the CFs that are estimated by level of education (low and high) that consider survival for men and women by age between ages 57 and 70 (see Appendix Tables A.3, A.4, A.5, and A.6 for a complete picture), and the CFs that are estimated using 2012 life tables (undifferentiated by gender), shows that the only positive values are observed among men with a low educational level (Figure 6). The principle of actuarial fairness leaves these men with a disadvantage that is always two percentage points higher than the legal CFs, and this disadvantage increases with age. Thus, a man with a low educational level may find it less advantageous to work longer rather than to take early retirement. Looking at Figure 6, we see that women, unlike men, would have an incentive to retire too late. Indeed, we observe that the CFs of women by educational level are always lower than the legal CFs among women of both low and high educational levels. The particular evolution of CFs, including the differences between the CFs of men and women, has not been studied previously. From a demographic point of view, there are valid explanatory hypotheses for these behaviours that would involve analysing the characteristics of mortality at different ages.

It is important to keep in mind the gap in mortality. Figure 7 shows that for men with a low educational level, the age probabilities of death increase more with age than those of the average individual (probability of death calculated for men and women together); while for highly educated men, the probabilities of death tend to come closer with age to those of the average individual. The outgoing and approaching processes observed among men with low and high levels of education, and among men in the older age groups, are probably due to a cohort effect. Many of the men at the highest ages belong to the cohorts born in the immediate post-war period, when more men worked in heavy industry, which tends to be associated with high health risks; whereas the men aged 57–60 belong to the cohorts who benefited from the transition from the industrial to the service sector, which tends to be associated with lower health and mortality risks. We can also see significant differences in mortality from life-style risks, and from cigarette smoking in particular, which are lower among the youngest cohorts than among their older counterparts. Recent studies have shown that the 50–60-year-olds of today are less likely to die from cardiovascular diseases and, in particular, from cancers of the respiratory system than the oldest cohorts at the same and successive ages (Caselli and Egidi 2011; Caselli 2016). It is therefore to be expected that with the passage of time, when the elongated lives of tomorrow are the lives of the latest cohorts, the effects on the CFs for men highlighted in Figure 6 will be less pronounced, and will probably follow the trends observed among women. Indeed, if we look at female probabilities of death in Figure 7, we can see that these probabilities are always lower than the average value, and that the gap increases with age. It is worth recalling that the present cohorts of older Italian women had been largely kept out of the workplace and protected by a traditional culture. It is thus likely that these older women are living longer than men in part because they were protected from more harmful life-styles (particularly smoking) (Luy et al. 2011).

In general, when we compare the different mortality curves in Figure 7, we can clearly see that for every educational level, the average value does not represent either male or female values. This is the fundamental reason why the pension annuity for a man with lower education is strongly penalised when calculated

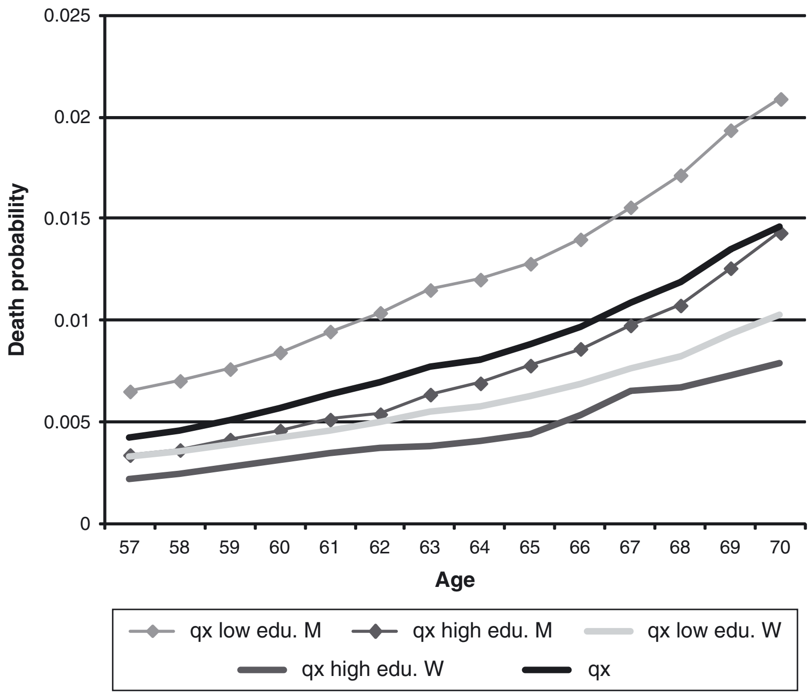
Figure 6:
Relative differences (per cent) by age, between CFs Total (=100) and CFs by level of education (low and high) for men (M) and women (W). Italy. Year 2012. (See data in Appendix Table A.6)



Source: Own elaboration on Istat data (Istat 2016b).

with the legal coefficients; while it is overvalued for a woman, regardless of her educational level. To evaluate the impact of education on pension annuities, let us consider here only the groups with extreme values, calculating their annuity levels by using the coefficients calculated for men and women together (CF Total) in one case, and the coefficients (CFs) that can be attributed to them according to specific survival levels in another case. Returning to the previous example, with a theoretical capitalised value *M* of 270,000 euros, it is interesting to note that (Table 4a) the pension received at age 65 by a man with a low educational level is 4.5 per cent – 659 euros a year – lower than that of a contemporary with a high educational level. This man is almost equally penalised if he delays retirement to age 67. Now let us compare the other extreme case: a man with a low educational level and a woman with a high educational level who are both retiring at age 65

Figure 7:
Death probabilities from ages 57 to 70 and by level of education (low and high) for men (M) and women (W). Italy. Year 2012



Source: Own elaboration on Istat data (Istat 2016a, 2016b).

with the same capitalised value *M*, and who therefore have an equal annuity of 14,920 euros. Differentiating their CFs by sex and educational level, we see that the pension annuity for the man would rise to 15,323 euros, while the pension annuity for the woman it would fall to 14,205 euros (Table 4b). The difference in the annuity amounts received by these two individuals is thus 1,118 euros (7.9 per cent). If the retirement age is raised to 67, the gender difference in annuity amounts at extreme educational levels is even higher in absolute (but also in relative) terms, at 1,237 euros (8.1 per cent).

The differences described in these examples illustrate very well the impact of the annuity redistribution from groups with lower life expectancy to groups with higher life expectancy. In general terms, as actuarial fairness does not take into account the heterogeneity of the population, and the varying prospects of survival between individuals belonging to different social classes in particular, the system fails to ensure a fair distribution of pension benefits between high-mortality groups (typically characterised by low levels of income and wealth) and low-mortality

Table 4:
Comparison between the pension annuity calculated with coefficients considering men and women together (CF Total), and CFs calculated for men and women by education. Retirement ages 65 and 67. Year 2012

(a)

			CF Men		Annuity Pension for men			Annuity differences between low high educ. for men**
Age	**M***	**CF Total**	**Low edu.**	**High edu.**	**CF Total**	**Low edu.**	**High edu.**	
65	270,000	0.05526	0.05675	0.05431	14,920	15,323	14,664	659
67	270,000	0.05940	0.06104	0.05845	16,038	16,481	15,782	699

(b)

			CF Men	CF Women	Annuity Pension for men and women			Annuity differences between low edu. men and high edu. women***
Age	**M***	**CF Total**	**Low edu.**	**High edu.**	**CF Total**	**Low edu. men**	**High edu. women**	
65	270,000	0.05526	0.05675	0.05261	14,920	15,323	14,205	1,118
67	270,000	0.05940	0.06104	0.05646	16,038	16,481	15,244	1,237

Source: Own elaboration on Istat data (Istat 2016b).
*M is the capitalised value of lifetime social security contributions.
**To explain – in part – the impact of the annuity redistribution from lower to higher survival for men by education.
***To explain – in part – the impact of the annuity redistribution from lower survival for men to higher survival for women by education.

groups (typically characterised by high levels of income and wealth) (Marmot and Skipley 1996; Elo 2009).

5 Reconciling actuarial fairness and inequalities in survival: New perspectives

In this paper, we have sought to highlight the importance of differential demographic processes, and of the crucial role played by varying prospects of survival in particular, when calculating conversion factors, which are among the key elements of the new Italian system of public pensions. How can we take the effects of these important differential processes into account?

Let us start with the assumption that the principle of actuarial fairness (*on average*) as defined by the system of the '*1995 Dini reform*' for calculating pension annuities will not be challenged, either politically or technically. We thus assume that the conversion factors will always be the same for all individuals, irrespective of differences in their life histories, including in their health conditions. Any reduction in pension annuities due to a calculation that overestimates the life expectancy of a pensioner who is already disadvantaged in terms of survival means that this pensioner will be penalised relative to those who will live longer than the survival level used in calculating the LCFs.

In addition, we should underline here that the example of the capitalised value *M* equal for all is a necessary simplification for measuring the sole effect of the CFs in calculating the pension annuity. It is, however, well known that in general, people who have a lower life expectancy are also more likely to belong to socially disadvantaged groups who tend retire at the same age with a lower capitalised value *M* as a result of the combined effects of a range of factors. First, because these groups have lower salary and income levels, the cumulative income from their contributions for the same number of years is lower. Second, these groups have lower annuity levels because, as we have seen, the coefficients for the calculation are based on life expectancies that are longer than theirs. The result is that the calculation of their pension annuity adds to the social inequalities these groups have experienced during their working lives and in their contributions.

Concerns about actuarial fairness *on average* should be even greater given that inequalities become more salient in the period of life when individual health is frailer. As well as having a lower life expectancy overall, people in the most disadvantaged social categories have a longer life expectancy in poor health (Coppola and Spizzichino 2014). A wide range of studies conducted in various European countries and the United States have shown that there are important differences by education in healthy life expectancy at each period of life and in old age in particular, and that differences in healthy life expectancy are even greater than differences in total life expectancy between educational groups (White and Edgar 2010; Crimmins and Saito 2001). This means that disadvantaged pensioners have to cope with poor health with limited resources. Moreover, having limited resources may itself lead to a poor state of health. We certainly know that differences in life histories influence people's health histories and final outcomes, and can raise or lower the age at death. Studies of mortality based on macro-data have shown that the differences in the mortality histories of cohorts are the result of different life experiences (Caselli 2016).

The social and political debate on gender difference does not follow the same pattern. We have seen that the female advantage in survival at advanced ages has been constant, although it seems to have been decreasing slightly in recent years. It is also known, however, that while older women tend to live longer than men, their health is often worse. It thus appears that retirement affects the health of men more than that of women (Coppola and Spizzichino 2014). Jean-Marie Robine and his colleagues observed in 2009 (Robine et al.) that women live an average of six years (about four at age 65) longer than men, but that most of these additional years are lived with moderate or severe limitations in activity. They concluded that the disability-free life expectancy (DFLE indicator) gender gap in favour of women is, at less than two years, much smaller than the total longevity gap. This observation provides a different perspective on many of our previous findings on the effects of the redistribution of pension annuity benefits from groups with lower life expectancy (men) to groups with higher life expectancy (women).

The most convincing argument for the political decision to create a pension system that provides equal benefits to men and women is not that it maintains the principle of actuarial fairness (which is more technical than political), but that it compensates women for the obstacles they face in their working lives, especially those related to gender discrimination, motherhood, and greater family responsibilities (De Santis 2012, 2014). It is generally known that in all European countries, including in Italy, there are income gaps between men and women that benefit men (in 2014, the average difference was 19.3 per cent in Europe; and was 5.6 per cent in Italy), and that have yet to be closed despite multiple appeals by the EU Commission to address the problem (OECD 2017). Even when women have the same qualifications and work experience as men, there appears to be a sort of 'vertical segregation' that prevents women from making it to the top in their careers. It is also well known that women have extremely disadvantageous career structures because of their prolonged periods of absence due to pregnancy, childbirth, and child care. Taken together, these disadvantages a woman experiences during her working career can have a significant impact on the number of years she contributes, and on the capitalised value *M* paid in.

It seems to us wholly acceptable that women should be compensated after retirement for the benefits they have lost by devoting large parts of their lives to bringing up their children and caring for their families. Nevertheless we might wonder whether it is right to decide that the most disadvantaged individuals should have to compensate women for their disadvantages through reductions in their pension annuity levels. In our view, we should take into account that the most disadvantaged categories of workers are penalised enormously, both because of the strenuous nature of their work, and, above all, because of the low pay they receive for doing it.

If we do not want to touch the principle of ‘actuarial fairness’ by setting up a pension system that is equal for everybody, we still need to intervene to prevent the already significant social inequalities from increasing upon retirement. Even as the various reforms were being passed, the need to bring forward the retirement age for some categories of workers without lowering their pension annuity levels was recognised. A proposal that was included in the Budget Law 2016–2017 strikes us as interesting. If implemented, it would represent the first improvement in pension benefits since the 2011 reform. Under this proposal, the retirement age would be made more flexible for the most disadvantaged workers (for the list see Pensioni Oggi (2017b)), allowing them to retire up to three years earlier without a reduction in their pension annuity benefits.

The only doubt we have about this proposal is that offering such flexibility to a limited category of workers might exclude many other workers who, though not included in the government’s list, are among those who have been disproportionately penalised by the pension reform. Our analysis of life expectancy by education showed that all Italians with a low level of education have a life expectancy level at age 65 that is 2.1 years lower than that average level used in calculating the LCFs. Would it be possible to offer this group a form of ‘free’ flexibility with a coefficient revalued by two years for the early retirement age? We hope that future interventions by the government will consider this option as well.

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Appendix

Table A.1:
The most important stages of the Italian pension reform from 1995 to 2016

Reform Law	Acronym of the reform	Main changes
Law of 8 August 1995, No. 335	*'1995 Dini reform'*	Introduction of the contribution system: The amount of the pension depends on the amount of the contributions paid by the worker during his/her working life. Introduction of *Legislated Conversion Factors* (*LCFs*) and their revision every 10 years.
Delegated Law of 23 August 2004, No. 243	*'2004 Maroni reform'*	Introduction of a bonus for individuals who postpone the age at retirement for the *seniority* pension. Increase in the age at retirement for both kinds of pension: *seniority* and *old-age*. For women, the age at retirement for the *seniority* pension remains 57, but with severe cuts to the retirement allowance being calculated in full under the contribution system.
Law of 24 December 2007, No. 247	*'2007 Prodi reform'*	Introduction of the so-called 'quotas' for access to the *old-age* pension, determined by the sum of the age and the number of years worked. Reduction from 10 to three years of the revision of the *Legislated Conversion Factors* (*LCFs*) according to life expectancy calculated on ISTAT data.
Law of 30 July 2010, No. 122	*'2010 Sacconi reform'*	Introduction of an automatic update mechanism, triggered every three years, of the retirement age requirements to life expectancy levels.
Law Decree of 6 December 2011, No. 201 (so-called '*salva Italia*' decree')	*'2011 Fornero reform'*	Introduction of a pro-rata contribution system for all workers with at least 18 years of contributions in 1995 who have accumulated a pension that is entirely retributive. Further increase in the minimum retirement age for *old-age* pensions, with a different flexible retirement band for men and women that also takes into account the years of contribution by differentiating regular employees from the self-employed.

Table A.2:
Population (absolute – in thousands – and per cent values) by age groups, gender, and education. Years 2015. Italy

	Education							
	Low		Medium		High		Total	
Age groups	Absolute values	Per cent	Absolute values	Per cent	Absolute values	Per cent	Absolute values	Per cent
				Men				
15–19	1,323	89.5	154	10.5	–	–	1,478	100.0
20–24	483	30.7	1,008	64.1	83	5.3	1,574	100.0
25–29	533	32.4	803	48.8	308	18.8	1,644	100.0
30–34	706	39.4	729	40.7	358	20.0	1,793	100.0
35–39	902	42.9	830	39.5	371	17.6	2,103	100.0
40–44	1,128	47.2	869	36.4	393	16.5	2,391	100.0
45–49	1,349	55.0	783	31.9	320	13.1	2,452	100.0
50–54	1,293	56.7	712	31.2	275	12.1	2,281	100.0
55–59	1,095	56.1	615	31.5	243	12.5	1,953	100.0
60–64	1,041	59.6	477	27.3	229	13.1	1,747	100.0
65 and over	4,266	75.6	906	16.0	472	8.4	5,643	100.0
Total	14,119	56.3	7,886	31.5	3,053	12.2	25,057	100.0
				Women				
15–19	1, 198	86.3	189	13.6	–	–	1, 387	100.0
20–24	320	21.4	1, 033	69.0	145	9.7	1, 498	100.0
25–29	405	25.1	706	43.7	504	31.2	1, 615	100.0
30–34	526	29.4	710	39.8	549	30.8	1, 785	100.0
35–39	701	33.3	837	39.8	567	26.9	2, 106	100.0
40–44	992	41.1	901	37.3	521	21.6	2, 415	100.0
45–49	1, 237	49.5	863	34.5	401	16.0	2, 500	100.0
50–54	1, 287	54.4	777	32.8	302	12.8	2, 367	100.0
55–59	1, 199	57.9	622	30.0	249	12.1	2, 070	100.0
60–64	1, 243	66.2	418	22.3	216	11.5	1, 877	100.0
65 and over	6, 295	85.2	758	10.3	339	4.6	7, 392	100.0
Total	15, 403	57.0	7, 816	28.9	3, 794	14.0	27, 013	100.0

Source: Own elaboration on Istat Labour Force Survey (Istat 2017).

Table A.3:
Comparison between conversion factors considered in the 2010–2012 period by age and those estimated using 2012 life tables. Low level of education. Upper age at death 105 years. Men, women, and total. Italy

	Conversion factors updated 2010–2012	Conversion factors Life tables: ISTAT 2012 Maximum age 105			Deviations with current conversion factors (per cent)		
Age	**Total**	**Men**	**Women**	**Total**	**Men**	**Women**	**Total**
57	0.04419	0.04455	0.04291	0.04373	0.8	−2.9	−1.0
58	0.04538	0.04576	0.04403	0.04490	0.8	−3.0	−1.1
59	0.04664	0.04705	0.04523	0.04614	0.9	−3.0	−1.1
60	0.04798	0.04842	0.04650	0.04746	0.9	−3.1	−1.1
61	0.04940	0.04987	0.04785	0.04886	1.0	−3.1	−1.1
62	0.05093	0.05142	0.04929	0.05036	1.0	−3.2	−1.1
63	0.05257	0.05307	0.05084	0.05196	1.0	−3.3	−1.2
64	0.05432	0.05484	0.05249	0.05366	1.0	−3.4	−1.2
65	0.05620	0.05675	0.05427	0.05551	1.0	−3.4	−1.2
66	–	0.05881	0.05619	0.05750	–	–	–
67	–	0.06104	0.05826	0.05965	–	–	–
68	–	0.06344	0.06049	0.06197	–	–	–
69	–	0.06604	0.06292	0.06448	–	–	–
70	–	0.06883	0.06555	0.06719	–	–	–

Source: Own elaboration on Istat data (Istat 2016b).
Note: Some slight differences between our CFs and the LCFs are due to rounding decimals up or down.

Table A.4:
Comparison between conversion factors considered in the 2010–2012 period by age and those estimated using 2012 life tables. Medium level of education. Upper age at death 105 years. Men, women, and total. Italy

	Conversion factors updated 2010–2012	Conversion factors Life tables: ISTAT 2012 Maximum age 105			Deviations with current conversion factors (per cent)		
Age	**Total**	**Men**	**Women**	**Total**	**Men**	**Women**	**Total**
57	0.04419	0.04343	0.04212	0.04277	−1.7	−4.7	−3.2
58	0.04538	0.04461	0.04321	0.04391	−1.7	−4.8	−3.2
59	0.04664	0.04585	0.04437	0.04511	−1.7	−4.9	−3.3
60	0.04798	0.04718	0.04561	0.04639	−1.7	−4.9	−3.3
61	0.04940	0.04859	0.04692	0.04775	−1.6	−5.0	−3.3
62	0.05093	0.05009	0.04831	0.04920	−1.7	−5.1	−3.4
63	0.05257	0.05170	0.04980	0.05075	−1.7	−5.3	−3.5
64	0.05432	0.05342	0.05139	0.05241	−1.6	−5.4	−3.5
65	0.05620	0.05529	0.05312	0.05421	−1.6	−5.5	−3.5
66	–	0.05731	0.05498	0.05614	–	–	–
67	–	0.05948	0.05698	0.05823	–	–	–
68	–	0.06182	0.05913	0.06048	–	–	–
69	–	0.06437	0.06148	0.06292	–	–	–
70	–	0.06713	0.06400	0.06556	–	–	–

Source: Own elaboration on Istat data (Istat 2016b).
Note: Some slight differences between our CFs and the LCFs are due to rounding decimals up or down.

Table A.5:
Comparison between conversion factors considered in the 2010–2012 period by age and those estimated using 2012 life tables. High level of education. Upper age at death 105 years. Men, women, and total. Italy

	Conversion factors updated 2010–2012	Conversion factors Life tables: ISTAT 2012 Maximum age 105			Deviations with current conversion factors (per cent)		
Age	**Total**	**Men**	**Women**	**Total**	**Men**	**Women**	**Total**
57	0.04419	0.04263	0.04172	0.04218	−3.5	−5.6	−4.6
58	0.04538	0.04378	0.04279	0.04329	−3.5	−5.7	−4.6
59	0.04664	0.04500	0.04394	0.04447	−3.5	−5.8	−4.7
60	0.04798	0.04629	0.04515	0.04572	−3.5	−5.9	−4.7
61	0.04940	0.04768	0.04644	0.04706	−3.5	−6.0	−4.7
62	0.05093	0.04916	0.04782	0.04849	−3.5	−6.1	−4.8
63	0.05257	0.05076	0.04930	0.05003	−3.4	−6.2	−4.8
64	0.05432	0.05247	0.05089	0.05168	−3.4	−6.3	−4.9
65	0.05620	0.05431	0.05261	0.05346	−3.4	−6.4	−4.9
66	–	0.05630	0.05447	0.05539	–	–	–
67	–	0.05845	0.05646	0.05745	–	–	–
68	–	0.06078	0.05857	0.05967	–	–	–
69	–	0.06332	0.06088	0.06210	–	–	–
70	–	0.06606	0.06340	0.06473	–	–	–

Source: Own elaboration on Istat data (Istat 2016b).
Note: Some slight differences between our CFs and the LCFs are due to rounding decimals up or down.

Table A.6:
Comparison between conversion factors, by age, estimated using 2012 life tables (CF Total) and those by level of education (low and high) and gender. Upper age at death 105 years. Italy

	CFs Life tables: ISTAT 2012 Max age 105	Conversion factors by level of education (low and high) and gender				Deviations between total conversion factors and those by level of education (low and high) and gender (per cent)			
		Low education		High education		Low education		High education	
Age	Total	Men	Women	Men	Women	Men	Women	Men	Women
57	0.04347	0.04455	0.04291	0.04263	0.04172	2.5	−1.3	−1.9	−4.0
58	0.04464	0.04576	0.04403	0.04378	0.04279	2.5	−1.4	−1.9	−4.1
59	0.04588	0.04705	0.04523	0.04500	0.04394	2.5	−1.4	−1.9	−4.2
60	0.04720	0.04842	0.04650	0.04629	0.04515	2.6	−1.5	−1.9	−4.3
61	0.04860	0.04987	0.04785	0.04768	0.04644	2.6	−1.5	−1.9	−4.4
62	0.05010	0.05142	0.04929	0.04916	0.04782	2.6	−1.6	−1.9	−4.5
63	0.05170	0.05307	0.05084	0.05076	0.04930	2.7	−1.7	−1.8	−4.6
64	0.05341	0.05484	0.05249	0.05247	0.05089	2.7	−1.7	−1.8	−4.7
65	0.05526	0.05675	0.05427	0.05431	0.05261	2.7	−1.8	−1.7	−4.8
66	0.05725	0.05881	0.05619	0.05630	0.05447	2.7	−1.9	−1.7	−4.9
67	0.05940	0.06104	0.05826	0.05845	0.05646	2.8	−1.9	−1.6	−5.0
68	0.06172	0.06344	0.06049	0.06078	0.05857	2.8	−2.0	−1.5	−5.1
69	0.06423	0.06604	0.06292	0.06332	0.06088	2.8	−2.0	−1.4	−5.2
70	0.06695	0.06883	0.06555	0.06606	0.06340	2.8	−2.1	−1.3	−5.3

Source: Own elaboration on Istat data (Istat 2016b).

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Does education matter? – economic dependency ratios by education

Alexia Prskawetz and Bernhard Hammer*

Abstract

When studying the economic consequences of changes in the age structure of the population, looking at economic dependency ratios provides us with some descriptive and intuitive initial insights. In this paper, we present two economic dependency ratios. The first ratio is based on economic activity status, and relates the number of dependent individuals to the number of workers. The second dependency ratio relates consumption to total labour income. To build up the second ratio, we rely on the recently set up National Transfer Accounts (NTA) for Austria. Simulations of the employment-based dependency ratio with constant age-specific employment rates indicate that the employment-based dependency ratio will increase from 1.23 in 2010 to 1.88 in 2050, based on a population scenario that assumes low mortality, medium fertility and medium migration in the future. The corresponding values for the NTA-based dependency with constant age-specific labour income and consumption are 1.12 in 2010 and 1.49 in 2050. We then compare how the dependency ratio would differ if we accounted for the increasing levels of educational attainment. While the education-specific age patterns of economic activities are kept constant as of 2010, the changing educational composition up to 2050 is accounted for. In Austria, higher educated individuals enter and exit the labour market at older ages and have more total labour income than lower educated individuals. Our simulations of the education-specific economic dependency ratios up to 2050, based on the optimistic projection scenario of low mortality and high educational levels in the future, show that the employment-based ratio will increase to 1.68 and the NTA-based dependency ratio will rise to 1.28. These increases are still considerable, but are well below the values found when changes in the educational composition are not taken into account. We can therefore conclude

* Alexia Prskawetz (corresponding author), Wittgenstein Centre for Demography and Global Human Capital, Welthandelsplatz 2/Level 2, 1020 Vienna, Austria and TU Wien, Austria
Email: afp@econ.tuwien.ac.at

Bernhard Hammer, Wittgenstein Centre for Demography and Global Human Capital, Vienna, Austria

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that the trend towards higher levels of educational attainment may help to reduce economic dependency.

1 Motivation

In recent decades, low fertility rates combined with increasing shares of the population surviving to old ages have induced a shift in the age structure of the populations in most industrialised countries towards older ages. Because consumption by elderly people is largely financed through transfers from the working-age population, these developments are putting pressure on the funding of public transfer systems. A second channel for financing consumption at older ages is through asset-based age reallocations, such as the accumulation of capital. The extent to which these different types of reallocations support consumption by older people is determined by the institutional settings of a given country, including its pension system, the organisation of its health and elderly care systems, and its financial and housing markets. Most importantly, the share of the population who are economically active and of working ages plays a central role in the robustness of these systems, since people who are working finance the public transfers through taxes and social security contributions that are linked to their labour income. It is therefore imperative that we gain a better understanding of how the ratio of dependent people to economically active people will change in the future, and of the policy approaches that are likely to facilitate the sustainable development of social security transfer systems, without overburdening the individuals who provide the transfers.

Most of the recent studies on the sustainability of social security systems have focused on two important parameters: the retirement age and the benefits received at older ages. It is often argued that delaying retirement not only decreases the share of dependent people, but increases the contributions paid into the system by the working-age population. We argue in this paper that encouraging higher levels of educational attainment might be a further important investment, as improvements in education may induce various behavioural changes that are conducive to the sustainable development of social security systems. Although higher educated individuals enter the labour market at older ages, they continue working until older ages and have higher levels of productivity and total labour income than lower educated individuals (EUROSTAT 2018). Higher educated individuals might therefore contribute larger transfer amounts at working ages than their less educated counterparts. On the other hand, compared to lower educated people, higher educated people might receive larger transfer amounts at older ages because they have more generous pension benefits and their life expectancy is higher (Philipov et al. 2014).

It is also possible that compared to their lower educated counterparts, higher educated individuals will receive less health and elderly care, given that education is positively related to health behaviour and healthy lifestyles (although these effects may differ across European welfare states, as shown in Avendano et al. (2009); reduced mortality and disability with higher education is reported in KC and Lentzner (2010)). Whether the changing educational structure alleviates the pressure on social transfer systems caused by demographic ageing will depend on the cost of education and the extent to which higher educational attainment is associated with higher productivity and larger contributions to the transfer system. To gain some initial insight into these mechanisms, we study age- and education-specific economic behaviour like consumption, employment, and labour income. We base our calculations on education-specific data from the Labour Force Survey and National Transfer Account dataset. In a second step, we combine these cross-sectional age and education profiles with education-specific population projections to simulate economic dependency ratios. By taking into account education-specific economic age profiles and increasing educational attainment, we obtain a lower economic dependency ratio than we do in a scenario in which we ignore the educational heterogeneity of economic behaviour and increasing educational attainment.

The paper is structured as follows. We start in Section 2 with a short review of the literature on approaches to measuring economic dependency and examine the role of education in alleviating the challenges associated with an ageing population. In Section 3, we introduce the concept of National Transfer Accounts (NTA), and present age-specific profiles of NTA for Austria in 2010. In Section 4, we discuss labour market and consumption characteristics by age and education. In Section 5, we combine these age- and education-specific profiles with education-specific population projections to simulate future employment-based and NTA-based dependency ratios. In the final section, we discuss our conclusions.

2 Quantifying economic dependency

Economic dependency ratios are indicators that provide aggregate information on the degree of economic dependency in a given society. Unlike demographic dependency ratios that are based on fixed threshold ages, economic dependency ratios take into account that the types and the intensity of economic activities vary across age groups and individuals.

Dependency ratios are built up by defining functions $Dep(x_i)$ and $Sup(x_i)$, which assign to each individual i a value for the degree of its dependency and its ability to support others (Loichinger et al. 2017). The exact value depends on individual characteristics x_i, such as age, employment status, income, and consumption. Dependency ratios are calculated by summing up the dependency measure and the support measure (i.e., the values of the $Dep(x_i)$ and $Sup(x_i)$ functions) over the population of N individuals, and by relating total dependency to total support:

$$Dependency\ Ratio = \frac{\sum_{i=1}^{N} Dep(x_i)}{\sum_{i=1}^{N} Sup(x_i)}. \qquad (1)$$

For the demographic dependency ratio, the dependency measure $Dep(x_i)$ takes the value of one for individuals under age 15 or over age 64, and the value of zero otherwise. The corresponding support measure $Sup(x_i)$ takes the value of one if a person is aged 15–64, and of zero otherwise. In Section 5, we will introduce an employment-based dependency ratio as well as a consumption/income-based dependency ratio.

The concept of the economic dependency ratio is closely related to the concept of the economic support ratio. Dependency ratios measure the number of people (or, alternatively, the share of the population) who rely on others, while support ratios measure the capacity of the active population to provide for the dependent population. Both measures take characteristics other than age into account. For instance, Cutler et al. (1990) defined the capacity to provide economic support by weighting the population with its age-specific labour income. They defined the economic dependency as the population weighted by age-specific consumption. In recent years, similar approaches to measuring the economic dependency and the support capability of people have been introduced. Mason and Lee (2006) and, more recently, Mason et al. (2017) used support ratios based on age-specific labour income and consumption (taken from the National Transfer Accounts project) to study the first demographic dividend across countries and time. Several authors have argued that measures of dependency and support based on chronological age are misleading (Sanderson and Scherbov 2013; Shoven 2010; Spijker 2015), and have suggested using prospective age measures that consider the remaining life expectancy. Moreover, Sanderson and Scherbov (2015) and Barslund and von Werder (2016) introduced alternative indicators that take into account health care and pension costs. Since younger cohorts are healthier than older cohorts, it may be assumed that the former are able to work longer than the latter. When such cohort effects are considered in projections of future levels of economic dependency, it appears that the demographic old-age dependency ratio overestimates the impact of the ageing of the population on public finances. Another interesting application that accounts for health improvements is presented in Muszyńska and Rau (2012), who decomposed the old-age dependency ratio into an old-age healthy and an old-age unhealthy dependency ratio.

A comprehensive overview of efforts to quantify economic dependency based on NTA data for 10 European countries is given in Loichinger et al. (2017). They argued that the level of economic dependency is largely determined by the design of the economic life course; i.e., by the age-specific type and intensity of economic activity. The analysis showed that the level of dependency varies significantly depending on which of five different measures of economic dependency is used. In each specific context, the dependency ratio chosen (e.g., a dependency ratio based on consumption and labour market age profiles versus a dependency ratio based on public sector transfers) is determined by the specific question posed.

Kluge et al. (2014) pointed out that increasing dependency ratios are likely to be a burden during a transitional phase spanning the next three decades, but that smaller cohorts will enter retirement in the years that follow. Kluge et al. (2014) identified five different areas in which population ageing may have positive consequences in the long run (including educational expansion, lower CO_2 emissions, larger intergenerational transfers in the form of bequests, increases in healthy life expectancy, and increases in the share of lifetime spent working). In particular, changes in the educational composition of the working-age population are expected to have positive effects. Higher educational levels are related to higher levels of labour force participation and to smaller gender differences in the labour force participation rates. The authors observed that while the future labour force is likely to be smaller and older, it is also likely to be more productive due to higher human capital levels. Thus, they argued, economic growth can be sustained despite the ageing of the population. Crespo-Cuaresma et al. (2014) also stressed the importance of education for economic growth. They found that the first demographic dividend was largely an educational dividend.

However, the labour force participation rates for a given educational group may change along with the educational composition of the population. Loichinger and Prskawetz (2017) have shown that given the educational expansion and education-specific patterns of economic activity, the labour supply may not decrease as much as expected as the population ages. Labour force projections up to 2053 for 26 EU countries by age, sex, and highest level of educational attainment are presented in Loichinger (2015). The results indicate that in all of the countries considered, educational expansion and education-specific patterns of economic activity are expected to alleviate the decrease in the labour supply due to the ageing of the population.

Loichinger (2015) summarised several micro-economic, sociological, and psychological explanations for the macro-level trend towards increased labour force participation with higher educational attainment. While education represents only one part of an individual's human capital, it affects the person's productivity and health, which are in turn positively related to his or her labour force participation. Moreover, the opportunity costs of not working are greater for individuals with higher levels of education than for their less educated counterparts.

An alternative measure that can be used to gain insight into the future development of the labour force is the concept of working life expectancy at age 50, as elaborated in Loichinger and Weber (2016). Since the mid- to late 1990s, working life expectancy at age 50 has been increasing in most European countries, in line with increases in healthy life expectancy. Because education is positively correlated with life expectancy and labour force participation, there are pronounced educational differences in working life expectancy at age 50.

At the micro level, several recent papers have considered the capacity to work at older ages. Changes in the skills demanded in the labour market resulting from technological and industrial changes may place older workers at a disadvantage. This issue was recently investigated in Gordo et al. (2013). Based on the results of a study on work tasks for Germany, they concluded that older workers are adapting to changes in the demand for skills, and that higher educated workers are adapting to these changing requirements more quickly than lower educated workers. In the seventh phase of a project on retirement programs around the world, Coile et al. (2016a) examined the extent to which the work capacity of older workers varies depending on their health. Using three alternative methods for measuring health and work capacity, they found that older workers have a greater capacity to work than their current employment levels would indicate. The gains in the capacity to work based on health have been greatest for older people in the higher socioeconomic status groups. For the US, Coile et al. (2016b) found that higher educated women have a greater work capacity than lower educated women. However, no such effect was found for men. Coile (2015) conducted a comprehensive study of the economic determinants of workers' retirement decisions, which include their public and private pension benefits, their wealth and savings, their health and health insurance, and the demand for their labour. Whether the capacity to work leads people to remain employed depends on institutional frameworks, labour demand, and social norms. Manoli and Weber (2016) showed for Austria that there is a rather low labour elasticity at the extensive margin of 0.6. If the severance payment increases, individuals are willing to delay their retirement only modestly, by around 1.25–1.5 years. In sum, these empirical results indicate that in Austria, retirement decisions are not very responsive to financial incentives. The observation that the pension reforms that were enacted in Austria in 2000, 2003, and 2004 did not result in increases in the labour force participation rate of older workers is also discussed in Schmidthuber et al. (2016). To some extent, the tightening of early retirement options led to increases in the number of claims made in other welfare programs, such as unemployment insurance. Schmidthuber et al. (2016) therefore argued that pension reforms need to be complemented by active labour market measures, including lifelong learning programs, flexible employment schemes, and health provisions. It is, however, possible that the combined effects of increasing educational attainment and pension reforms will lead to a stabilisation of the Austrian labour force up to 2030 (Horvath and Mahringer 2014).

In summary, as this short literature review indicates, ageing populations will face pressure to adapt their economic life courses. If, however, the older people of the future are healthier and better educated than the elderly population of today, they may cope well with these challenges. In this paper, we are particularly interested in exploring how educational expansion will affect economic dependency ratios in the future. We base our education-specific characteristics on the National Transfer Accounts data introduced in the next section.

3 National Transfer Accounts (NTA)[1]

The NTA measure how much income each age group generates through labour and through the ownership of capital; how income is redistributed across age groups

[1] This section is based on Fürnkranz-Prskawetz (2015).

through public and private transfers; and how each age group uses its disposable resources for consumption and saving.[2] In particular, the NTA show how children and elderly individuals finance their consumption through age reallocations. These reallocations can be transfers mediated by the public sector, private transfers, and asset-based reallocations. Asset-based reallocations are defined as asset income (i.e., dividends, interest) minus saving. Positive asset-based reallocations can be generated through asset income or dissaving; i.e., the selling of assets by, for example, drawing on privately funded pensions.

The National Transfer Accounts are consistent with the System of National Accounts. The aggregate values (i.e., the values for the total economy) are derived from National Accounts data. The NTA breaks down the National Accounts by age, and thereby introduces information on the relationship between the age of an individual and his or her economic activities. The NTA dataset contains an extensive number of age profiles with age-specific averages of various economic quantities. A detailed introduction to the methodology is given in United Nations (2013) and in Lee and Mason (2011). Details about the Austrian data are provided in Hammer (2014, Chapter 1) and in Sambt and Prskawetz (2011).

Like in the National Accounts, the account identity in the NTA requires that the disposable income in the form of labour income (YL), asset income (YA), public transfer benefits (T_g^+), and private transfer benefits (T_f^+) equals the use of resources for consumption (C), saving (S), and transfer payments (T_g^-, T_f^-). This identity (Equation 2) holds for all individuals, and, consequently, for all aggregates of individuals, such as households, age groups, and the whole economy:

$$YL + YA + T_g^+ + T_f^+ = C + S + T_g^- + T_f^-. \tag{2}$$

Transfer benefits and contributions are recorded from the individual's point of view. Public transfer benefits consist of benefits such as pensions, health services, and child benefits; while the public transfer contributions consist mainly of taxes and social contributions. Public transfers can be in kind, such as public education, health care, and defence; or in cash, such as public pensions and child allowances.

The *life-cycle deficit* is defined as the difference between age-specific consumption and labour income, and can be derived by rearranging Equation 2:

$$C(a) - YL(a) = YA(a) - S(a) + T_g^+(a) - T_g^-(a) + T_f^+(a) - T_f^-(a). \tag{3}$$

The life-cycle deficit at every age can be financed through net public transfers $T_g^+(a) - T_g^-(a)$ and net private transfers $T_f^+(a) - T_f^-(a)$ or asset-based reallocations, defined as the difference between asset income and savings $YA(a) - S(a)$. The ABR is positive at ages at which asset income is greater than savings, and is negative

[2] The NTA methodology is being developed in an international project that currently includes about 50 countries. It was initiated by Ronald Lee from the University of California, Berkeley, and by Andrew Mason from East-West Center, Hawaii. For further information, see also www.ntaccounts.org.

at ages at which savings are greater than asset income. How resources are shifted across ages determines the economic consequences of population ageing. Whether population ageing leads to the accumulation of assets or to the expansion of public transfers programs depends on the use of asset-based reallocations (Mason and Lee 2007, p. 130).

Figure 1 presents the NTA cross-sectional age profiles for Austria in 2010. On the x-axis, we plot age by single years; while on the y-axis, we measure the various NTA profiles in euros per capita. As these profiles indicate, at the beginning and at the end of life are periods with a positive life-cycle deficit in which people consume more than they earn. In between these two periods is a period in which individuals generate a life-cycle surplus and earn more than they consume. These three life-cycle stages are common to all societies. However, the length of these phases of life-cycle deficit and surplus, and the ways these phases are financed, differ across countries. Each country's institutional settings, together with the individual norms and behaviour of the population, shape the specific reallocations across ages in that country. Figure 1 shows for Austria that the life-cycle deficit at young ages is financed almost evenly by public and private transfers. In contrast, the life-cycle deficit at old ages is mostly financed through public transfers, while asset reallocations play a small role only. At very high ages, people receive more in public transfers than they consume; thus, asset reallocation becomes negative, leading to positive savings at these ages. At working ages, individuals earn more than they consume, accumulate assets, and generate private and public transfer outflows to the young and elderly dependent population.

4 Labour market characteristics and consumption by education

Hammer (2015) found that there is considerable individual variation in age-specific economic behaviour based on differences in preferences and life circumstances. Significant heterogeneities are observed across educational groups. The education of individuals influences not only their economic opportunities, including their wages and consumption levels, but their socio-economic behaviour as well. For example, compared to lower educated people, higher educated people are more likely to have a healthy lifestyle, to be engaged in non-manual work, and to exit the labour market at a high age. Consequently, the age reallocation of resources differs across educational groups.

Several countries have already investigated the impact of education on income inequality within the NTA framework (e.g., for Chile see Miller et al. (2014), for Colombia see Tovar and Urdinola (2014), and Turra et al. (2011) for Brazil and Chile). Recently, education-specific NTA age profiles have been set up for selected European countries (e.g., Renteria et al. (2016)).

Figure 1:
Overview of the National Transfer Accounts: age-specific income, transfers, and consumption, Austria 2010

Source: Hammer (2014).

In the following, we present selected age profiles of economic characteristics by education for Austria. We distinguish between three levels of education according to the International Standard Classification of Education (ISCED): (1) less than or equal to ISCED 2, including pre-primary, primary, and lower secondary education; (2) ISCED 3, including upper secondary education; and (3) equal to or higher than ISCED 4, including post-secondary and tertiary education.[3] For an overview of the Austrian educational system and its ISCED levels, see https://bildung.bmbwf.gv.at/enfr/school/bw_en/bildungswege2016_eng.pdf.

Table 1 summarises the distribution of the population by age and educational level in 2010 in Austria, as reported in WIC (2015). It clearly shows that the shares of the younger cohorts who are obtaining an upper secondary or tertiary degree are increasing (ISCED 4). Only about 11% of people aged 80+ have completed higher education, while about 33% of people aged 30–39 have earned a post-secondary or tertiary degree.

[3] Note that this choice of educational groups differs from the one applied by Hammer (2015) when setting up education-specific NTA. We have chosen to follow the ISCED classification so that we can combine our education-specific age profiles with the human capital projections provided by the WIC data explorer (http://dataexplorer.wittgensteincentre.org/shiny/wic/).

Table 1:
Population by age and educational level (in %), Austria 2010

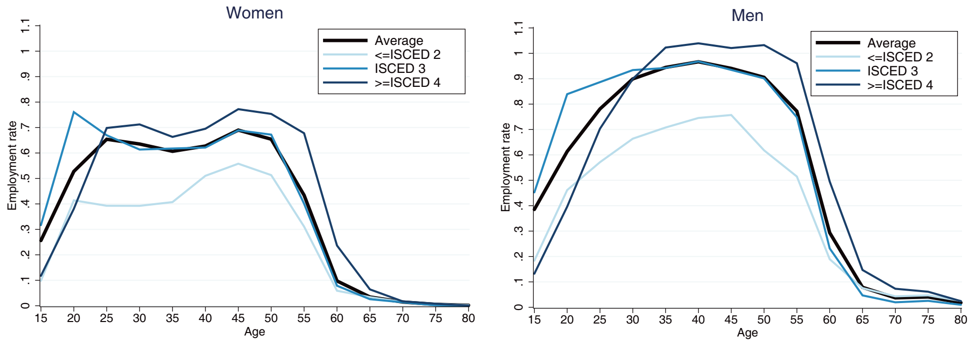
Age	≤ ISCED 2	ISCED 3	≥ ISCED 4
10–19	52	48	0
20–29	13	49	38
30–39	15	51	33
40–49	18	55	27
50–59	25	53	22
60–69	32	51	17
70–79	51	38	12
80+	55	33	11

Source: WIC (2015).

Higher education is correlated with higher employment rates (Figure 2),[4] except at younger ages. Individuals with lower education (ISCED 3) enter the labour force earlier than individuals with tertiary education (ISCED 4). The group of people with the lowest level of education tends to experience labour market difficulties (i.e., they are less likely to find a job), and are thus the group with the lowest employment rate. Note that Figure 2 plots employment in full-time equivalents; i.e., working 40 hours per week is regarded as full-time employment. The lower employment rates among women shown in Figure 2 are the result of two effects: on average, women work fewer hours per week and are less likely to participate in the labour market than men. Across all educational groups, women work less than 40 hours per week on average. Part-time work is most prevalent among the lowest educational group (with less than level ISCED 2). For all educational groups, the employment rates of females follow an M-shaped pattern, with women having higher employment rates before the onset of childbearing (in their early twenties); and again in their late forties, when they are spending less time on childrearing and care responsibilities. For males, employment rates are hump-shaped, with a maximum at around the ages of 40 to 50. Males in the highest educational group work even more than 40 hours per week on average at their peak employment ages. Men in the lower educational groups have lower employment rates and are less likely to be in full-time employment than their higher educated counterparts. Because part-time work is not common among men, lower educated men generally have low employment rates.

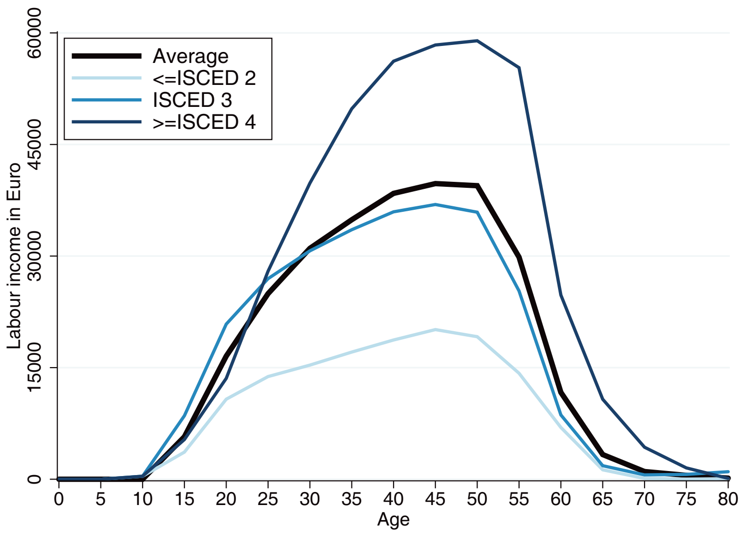
[4] Employment is measured in full-time equivalents; i.e., the total number of weekly hours worked divided by 40.

Figure 2:
Employment rate by age and education in full-time equivalents, Austria 2010



Source: European Labour Force Survey; own calculations.

Figure 3:
Labour income by age and education, Austria 2010

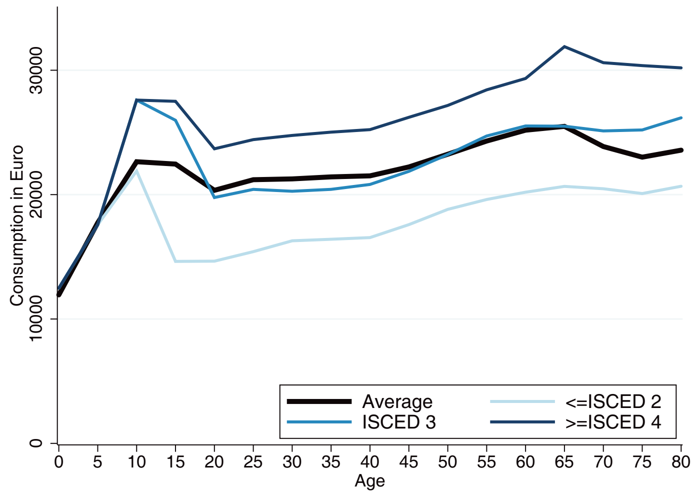


Source: EU-SILC; own calculations.

The difference in employment rates by education together with the difference in wages translate into the difference in labour income by education (Figure 3).[5]

[5] Note that for income and consumption levels we are not differentiating by gender. These profiles are based on survey data, a distinction by age, education, and gender is not feasible due to small sample size.

Figure 4:
Consumption by education, 5-year age groups, Austria 2010



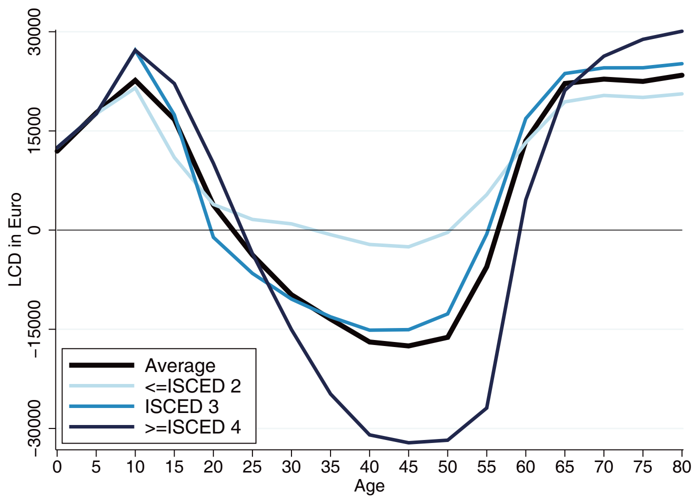
Source: Authors' own calculations based on various sources.

Total private consumption by education (including education, health, and other consumption) is plotted in Figure 4. The lower labour income of people with only basic education translates into lower consumption by this group than by higher educated people. The differences in consumption profiles by education are smaller than the differences in income profiles by education. This pattern can be explained by transfers across educational groups and differences in saving rates.[6]

A comparison of consumption (including private and public consumption) and labour income levels clearly reveals differences in the life-cycle deficit and surplus by education (Figure 5). The life-cycle deficit stays positive until people reach their early twenties, except among the group with upper secondary education, who enter the labour market between age 15 and age 19. Interestingly, the age at which the average age-specific labour income exceeds consumption is postponed to the mid-thirties for the lowest educational group (equal to or less than ISCED 2). The length of the period in which this lowest educational group has a life-cycle surplus (where labour income exceeds consumption) is therefore short, since their consumption again exceeds their labour income starting as early as age 50. The group of individuals with the lowest educational level have considerably lower employment rates and income levels than their better educated counterparts. The length of

[6] Note that consumption includes private and public consumption. We differentiate private and public educational consumption by education, but keep the other forms of public consumption independent of education.

Figure 5:
Life-cycle deficit and surplus by education



Source: Authors' own calculations.

the life-cycle surplus is almost the same for individuals with upper secondary, post-secondary, and tertiary education. However, the size of the surplus is much greater for tertiary educated people. The higher labour force participation rates observed for people with upper secondary and post-secondary education implies that they become economically dependent (when consumption again exceeds labour income) at older ages than people with basic education (less than ISCED 2) only. While higher educated people generate a larger economic surplus once they are active in the labour market, Figure 5 indicates that their life-cycle deficit is more pronounced at younger and older ages. This trade-off, together with the composition of the population by age and education, will ultimately determine the economic dependency ratio that we introduce in the next section.

5 Simulating economic dependency ratios – does education matter?

Children and retirees are economically dependent in the sense that they rely on transfers from the employed population. Given the relationship between age and economic activity, the ageing of the population raises concerns that public transfers to the elderly are not sustainable in the future, and require adjustments. Dependency ratios are used to evaluate the pressure on the transfer systems. Based on the education-specific employment rates and the education-specific income and consumption profiles, we define two alternative economic dependency rates and project them into the future, up to 2050.

The first ratio is based only on employment rates as presented in Figure 2. It takes the age- (a), gender- (g), and education-specific (e) employment rates in full-time equivalents of 2010 $lfpr_{a,g,e}$ and combines them with age-, gender-, and education-specific population numbers $N_{a,g,e}$ provided by the human capital database (WIC 2015):

$$EMPDR_{edu} = \frac{\sum_{a,g,e}(1 - lfpr_{a,g,e})N_{a,g,e}}{\sum_{a,g,e} lfpr_{a,g,e}N_{a,g,e}}. \tag{4}$$

Note that for our simulations we keep the employment rates fixed as observed in 2010, and only vary the population numbers. Summing over all ages, both genders, and all three educational groups gives the number of workers for each year in the denominator. We define the dependent population as the non-employed population. The term non-employed covers all individuals who do not work. Furthermore, individuals who work part-time are also counted as non-employed depending on the degree of their employment. Assuming that a person who works 40 hours a week is considered full-time employed, a person who, for example, works 20 hours a week is counted as 0.5 non-employed and 0.5 employed. Relating the non-employed (numerator) to the employed population (denominator) results in the employment-based dependency ratio ($EMPDR_{edu}$), as given in equation 4 and summarised in Table 2. As a comparison, we build up the same ratio without differentiating by education, and accounting for age and gender only. That is, we take the age- and gender-specific employment rates as observed in 2010 and multiply them with age- and gender-specific population numbers given in the WIC projections to obtain the number of employed people for each year. We then relate the non-employed population to the employed population ($EMPDR_{tot}$), as presented in equation (5):

$$EMPDR_{tot} = \frac{\sum_{a,g}(1 - lfpr_{a,g})N_{a,g}}{\sum_{a,g} lfpr_{a,g}N_{a,g}}. \tag{5}$$

As a comparison, we also present the demographic dependency rate (*POPDR*), for which all individuals under age 15 or above age 64 are counted as dependent, and all individuals between ages 15 and 64 are counted as non-dependent (compare equation 1 in Section 2). Relating the former group to the latter group results in the demographic dependency ratio.

We apply three different population projection scenarios by education that refer to three different Shared Socioeconomic Pathways (SSPs). SSPs have been developed as input for integrated scenarios of climate model projections that combine environmental, socio-economic, and climate policy scenarios (O'Neil et al. 2014). SSPs are set up to reflect plausible socio-economic developments over the time horizon of a century. All the elements of SSPs are given in Table 1 in O'Neil et al. 2014, p. 396. They include, for example, demographic characteristics like population growth, economic characteristics like GDP, urbanisation, and international trade. These SSPs are then combined with climate models to study possible adaptation and mitigation strategies related to these societal trends. Recently, SSPs have been extended by also incorporating educational scenarios (WIC 2015; KC and Lutz 2017). In the following, we briefly describe the main assumptions of the three SSPs we apply.

Population Component of Rapid Development (SSP1): In this scenario, it is assumed that educational and health investments accelerate the demographic transition, leading to a relatively low world population. Consistent with this storyline are assumptions that mortality remains low and levels of education remain high. The fertility assumptions differ across countries. For rich OECD countries, the emphasis on quality of life is assumed to make it easier for women to combine work and family. Thus, further fertility declines are unlikely in this scenario. For this reason, the medium fertility assumption was chosen for this group of countries. Low fertility assumptions were chosen for all other countries, based on the expectation that the demographic transition will continue at a rapid pace. Migration levels were assumed to be medium for all countries under this SSP.

Population Component of Medium Development (SSP2): This scenario can also be seen as the most likely path for each country. It combines for all countries medium fertility with medium mortality, medium migration, and the Global Education Trend (GET) education scenario.

Population Component of Stalled Development (SSP3): In this scenario, a stalled demographic transition is assumed. Fertility is assumed to be low in the rich OECD countries and high in the other country groups. Hence, population growth is assumed to be high in developing countries and low in industrialised countries. Furthermore, high levels of mortality and low levels of education are assumed for all country groupings. Due to the emphasis on security and barriers to international exchange, migration is assumed to be low for all countries.

In Table 2, we summarise how the different SSP scenarios translate into differences in the shares of the working-age population by education for Austria. In the SSP1 scenario, the share of the working-age population with only basic education is assumed to decrease from 25% in 2010 to 9% in 2050. A similar decline in the working-age population with the lowest educational level is assumed in the SSP2 scenario, while a much smaller decline is assumed in the SSP 3 scenario (from 25% to 18%). The share of the working-age population in the highest educational group will more than double in the SSP1 scenario (from 25% in 2010 to 56% in 2050), while it will increase the least in the SSP3 scenario (from 25% in 2010 to 33% in 2050). In the SSP2 scenario, the shares of the working-age population in 2050 in the medium and the highest educational groups are quite close, at 42% and 48%; while in the SSP1 (high education) and SSP3 (low education) scenarios, these differences are much larger.

Table 3 summarises the projections of demographic and employment-based dependency ratios for the three different SSP scenarios. The values of the demographic dependency ratios are below those of the employment-based

Table 2:
Share of the working-age population (aged 15 to 64) by SSP scenario in 2010 and 2050 (in %)

	SSP1			SSP2			SSP3		
Year	ISCED 2 or less	ISCED 3	ISCED 4 and higher	ISCED 2 or less	ISCED 3	ISCED 4 and higher	ISCED 2 or less	ISCED 3	ISCED 4 and higher
2010	25	50	25	25	50	25	25	50	*25*
2050	9	35	56	10	42	48	18	49	*33*

Source: WIC (2015).

Table 3:
Demographic- and employment-based dependency ratios, projections for Austria

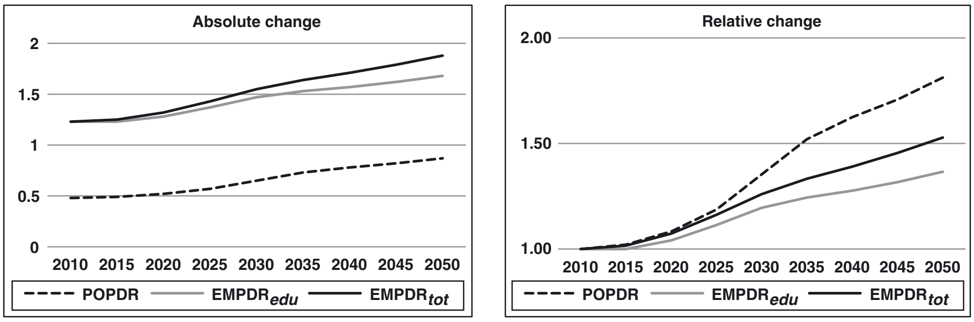
	SSP1			SSP2			SSP3		
	Type of dependency								
Year	POP	EMP_{edu}	EMP_{tot}	POP	EMP_{edu}	EMP_{tot}	POP	EMP_{edu}	EMP_{tot}
2010	0.48	1.23	1.23	0.48	1.23	1.23	0.48	1.23	1.23
2015	0.49	1.23	1.25	0.49	1.23	1.25	0.49	1.22	1.24
2020	0.52	1.28	1.32	0.51	1.27	1.31	0.50	1.26	1.29
2025	0.57	1.37	1.43	0.56	1.36	1.42	0.54	1.34	1.38
2030	0.65	1.47	1.55	0.64	1.45	1.53	0.60	1.42	1.48
2035	0.73	1.53	1.64	0.71	1.50	1.60	0.67	1.47	1.54
2040	0.78	1.57	1.71	0.75	1.54	1.65	0.71	1.51	1.59
2045	0.82	1.62	1.79	0.77	1.58	1.71	0.74	1.57	1.66
2050	0.87	1.68	1.88	0.81	1.63	1.78	0.78	1.64	1.73

Source: Authors' own calculations based on EU-LFS and WIC (2015).

dependency ratios in all three SSP scenarios. For the demographic dependency ratios, all individuals between ages 15 and 64 are treated as not economically dependent. However, many people in this age group are not active in the labour market, or they are not in full-time employment (i.e., they work less than 40 hours a week). On the other hand, there are a few individuals above age 64 who are still in the labour force. These individuals are treated as dependent in the common demographic dependency ratio, even though a small share of them are still working.

For the year 2010, the employment-based dependency ratios that do and do not differentiate by education are equal, since these numbers are based on observed data. However, for all other years, the projections that account for the educational change differ from the projections that ignore education-specific compositional change. From Table 3, we can see that in the SSPI scenario, the employment-based

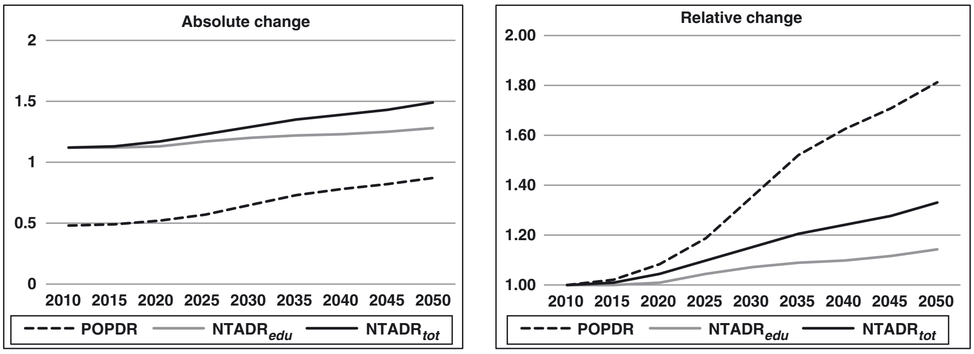
Figure 6:
Changes of the demographic and the employment-based dependency ratio 2010-2050, SSP1 scenario



dependency ratio increases from around 1.23 in 2010 to 1.88 in 2050, provided we ignore the change in the educational composition as projected in the human capital database. Alternatively, if we take these changes in the educational composition into account, this ratio increases to just 1.68 in 2050. In the future, increasing levels of education (as projected in the WIC database) will lead to higher numbers of employed people, and to a lower economic dependency ratio. The demographic and the employment-based dependency ratios are lower in the SSP2 and SSP3 scenarios than in the SSP1 scenario. The differences between these scenarios are explained by the higher mortality level in conjunction with the lower educational attainment of the working-age population in 2050 (see Table 2) assumed in the SSP2 and SSP3 scenarios. Obviously, the higher mortality and, hence, the smaller number of dependent individuals outweighs the impact of lower levels of educational expansion and, hence, lower rates of labour force participation. Consequently, the employment-based dependency ratio is lower in the SSP2 and SSP3 scenarios than in the SSP1 scenario. The differences between the education-specific and the non-education-specific projections of the employment-based dependency ratio are smaller for the alternative shared socio-economic pathways of the SSP2 and SSP3 scenarios (since they assume a medium or a low education expansion) than of the SSP1 scenario (see Table 2).

In Figure 6 we plot the changes in all three dependency ratios over time in the SSP1 scenario. The left panel shows the absolute change, while the right panel shows the relative changes. Although the absolute level of the employment-based dependency ratio exceeds that of the demographic dependency ratio, the relative changes in these indicators are in the opposite direction. While the demographic dependency ratio almost doubles from 2010 to 2050, the relative increase in the employment-based dependency ratio is only 50% if we ignore educational heterogeneity ($EMPDR_{tot}$), and is less than 40% if we take educational heterogeneity ($EMPDR_{edu}$) into account.

Figure 7:
Changes of the demographic dependency and NTA-based dependency ratios 2010–2050, SSP1 scenario



Another variant of an economic dependency ratio is based on the NTA age profiles, and relates the total consumption observed in a specific year to the total income generated in the same year.

We fix the age profiles of consumption and income in 2010, and again distinguish between two variants for the projections. First, we take the age- and education-specific consumption $C_{a,e}$ and labour income profiles $Y_{a,e}$ as of 2010 and multiply them by the age- and education-specific population numbers $N_{a,e}$ in each year of our simulations. Summing over all ages and all three educational groups gives the total amount of consumption and income in each year (Equation 6):

$$NTADR_{edu} = \frac{\sum_{a,e} C_{a,e} N_{a,e}}{\sum_{a,e} Y_{a,e} N_{a,e}}. \tag{6}$$

Alternatively, we build up the same ratio, but only account for age, ignoring the differences by education (Equation 7):

$$NTADR_{tot} = \frac{\sum_{a} C_{a} N_{a}}{\sum_{a} Y_{a} N_{a}}. \tag{7}$$

Looking at Table 4, we can see that in the SSP1 scenario, the NTA-based dependency ratio increases from about 1.1 in 2010 to 1.5 in 2050, if we ignore the changes in the educational composition over time. If we take the changes in the educational composition into account, the ratio increases to just 1.3 in 2050. Moreover, as in Table 3, these differences are smaller for the SSP2 and SSP3 projection scenarios. In all three scenarios, the increase in income that is associated with higher educational levels in the future outpaces the possible increase in consumption.

Table 4:
NTA-based dependency ratio based on education-specific data ($NTADR_{edu}$) and independent of education ($NTADR_{tot}$), Austria

	SSP1		SSP2		SSP3	
Year	$NTADR_{edu}$	$NTADR_{tot}$	$NTADR_{edu}$	$NTADR_{tot}$	$NTADR_{edu}$	$NTADR_{tot}$
2010	**1.12**	**1.12**	**1.12**	**1.12**	**1.12**	**1.12**
2015	1.12	1.13	1.12	1.13	1.12	1.13
2020	1.13	1.17	1.13	1.17	1.13	1.16
2025	1.17	1.23	1.17	1.22	1.17	1.21
2030	1.20	1.29	1.21	1.28	1.21	1.26
2035	1.22	1.35	1.23	1.32	1.24	1.30
2040	1.23	1.39	1.24	1.36	1.27	1.32
2045	1.25	1.43	1.26	1.39	1.30	1.36
2050	1.28	1.49	1.28	1.43	1.34	1.40

Source: Authors' own calculations based on NTA data for Austria.

Like the employment-based dependency ratio, the NTA-based dependency ratio exceeds the demographic dependency ratio in terms of absolute values (Figure 7, left panel). Note that in the NTA-based dependency ratio, a person may simultaneously contribute to the numerator (through his or her consumption level) and the denominator (through his or her labour force participation). When we look at the relative changes (Figure 7, right panel), we can see that the NTA-based dependency ratio increases by only around 30% if we ignore the educational composition, and by less than 20% if we take the educational composition into account. These relative changes are smaller than those plotted in Figure 6 for the employment-based dependency ratio. Note, however, that a direct comparison of the two dependency ratios is difficult because they measure different concepts of dependency.

While the employment-based economic dependency ratio measures dependency only in terms of numbers of people, the economic dependency ratio based on the NTA quantifies the degree of dependency. It has already been shown in Loichinger et al. (2017) that the NTA-based dependency ratio is lower than the employment-based scenario. The correlation between the two indicators is not unique across countries, as it will depend on the relationship between the level of consumption and labour income.

Differences in labour force participation, income, and consumption patterns by education are important, and therefore need to be considered when evaluating the degree of economic dependency. Accounting for increasing educational attainment leads to a reduction in the employment-based ratio and in the consumption- and income-based economic dependency ratio.

Our results are contrary to those of Philipov et al. (2014), who showed for Italy that increasing human capital may aggravate the consequences of population ageing if the possibility that public pension benefits will increase with higher levels of human capital is taken into account. Philipov et al. (2014) defined a human capital-specific old-age dependency ratio that applies weights to each person according to his or her education-specific income for those aged 20 to 64, and according to his or her education-specific gross public pension benefits for those aged 65 and above. Relating the latter group to the former group results in the human capital-specific old-age dependency ratio for this population. The human capital-specific old-age dependency ratio is lower than the conventional old-age dependency ratio. However, the pace at which the indicator changes in the future is faster for the former than for the latter ratio. These results can be explained by the way dependency is defined. A direct comparison of the human capital-specific old-age dependency ratio and our employment- and NTA-based dependency ratio is therefore difficult. Moreover, the focus in our study is to gain insight into whether economic dependency ratios are sensitive to the projected changes in the educational composition, and not into whether education-specific economic dependency ratios differ from demographic dependency ratios, as in Philipov et al. (2014).

6 Discussion

Population ageing will lead to an increase in the retired elderly population relative to the working-age population, and thus to an increase in the demographic dependency ratio. However, the demographic dependency ratio tells us little about economic dependency. Using data on age- and gender-specific working hours, we have introduced the employment-based dependency ratio, which relates the number of employed individuals to the number of non-employed individuals, with employment measured in full-time equivalents. If we assume that current labour force participation rates remain the same, population ageing will lead to an increase in the inactive and economically dependent population relative to the employed population. The employment-based dependency ratio is informative, and represents a considerable improvement over the demographic dependency ratio. However, the level of economic dependency depends not only on the share of dependent individuals, but also on the degree of dependency and the ability of the non-dependent population to provide support. An alternative dependency measure that takes the degree of dependency into account is the NTA-based dependency ratio. This measure is based on consumption demand in relation to income. Using data from the NTA project, we measured economic dependency by relating the total consumption to the total income generated in an economy, while taking into account the age- and gender-specific values of consumption and income.

When projecting economic dependency ratios, a common practice is to multiply age- and gender-specific economic characteristics observed in a given year by age- and gender-specific population projections. Such a shift-share analysis takes changes in the population structure into account, but ignores behavioural changes by keeping age- and gender-specific economic quantities constant. In this paper, we used a shift-share analysis that accounted for changes in the population structure, but also for changes in the educational composition. Many economic characteristics – like labour force participation, consumption, and labour income levels – vary across educational groups. By combining age-, gender-, and education-specific economic characteristics with education-specific population projections, we have illustrated the importance of taking education into account when estimating future dependency ratios. Indeed, this approach allowed us to relax the static assumption of fixed age- and gender-specific economic characteristics using a rather simple method. As the educational composition changes, the pattern of age- and gender-specific economic activities also changes. Nevertheless, our approach is still static, as we kept the age-, gender-, and education-specific characteristics constant over the projection period. As Loichinger and Prskawetz (2017) have observed, labour force participation rates within educational groups may change as well. We did not account for such behavioural changes in the labour force participation rates or in the consumption patterns. There are, however, plausible scenarios that would project the age-, gender-, and education-specific trends of economic characteristics from the past into the future; or, alternatively, would assume target values in 2050 towards which these age-, gender-, and education-specific patterns may converge. Methodologies that are more sophisticated would be based on computable general equilibrium models that allow for endogenous evolutions of household characteristics when macro-level conditions, like the age structure, change. Whether the inclusion of such behavioural changes in education-specific economic characteristics would further alleviate the projected challenges associated with population ageing remains an open question, as it would depend on how we define economic dependency, and on the extent to which such behavioural changes reduce the dependent population relative to the active population.

While the focus of our previous research (Loichinger et al. 2017) was the comparison of economic dependency ratios with the standard demographic dependency ratios, in this paper we extended our analysis to include two selected economic dependency ratios in order to account for educational heterogeneity. Our underlying hypothesis was that education is positively correlated with labour force participation rates and income, and that an educational expansion might therefore reduce the decline in the labour force due to population ageing. Thus, our aim was to investigate whether the projected changes in economic dependency due to changes in the age composition might be counteracted by taking increasing educational attainment into account.

Our results indicate that when we account for future changes in the educational structure, employment-based as well as consumption- and income-based dependency ratios are lower than in the projections that ignore the trend towards higher educational attainment in the years ahead.

We can conclude that educational expansion is related to changes in behaviour, such as increasing labour force participation and higher productivity. Thus, promoting higher levels of educational attainment could make it easier for countries to address the challenges associated with population ageing. Nevertheless, we also need to be aware that education is not a ‘free lunch’; and that continued investment in educational institutions is required. Future research needs to extend our analysis by also studying the trade-off between short-run educational costs and the long-run gains of higher levels of educational attainment. Our analysis is only a first stylised step towards making the argument that educational expansion may be an effective policy approach to reducing economic dependency. Moreover, we have assumed fixed age-, gender-, and education-specific characteristics of labour force participation, and fixed education-specific consumption and income levels. Obviously, such assumptions are quite restrictive, and further work is needed to explain how the behaviour of individuals is likely to change in response to economic and demographic changes.

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Multistate projections of Australia's Indigenous population: interacting area group and identification status change

James Raymer, Yanlin Shi, James O'Donnell, and Nicholas Biddle*

Abstract

In this paper, we develop a multistate projection model that allows the Australian Aboriginal and Torres Strait Islander (Indigenous) population to move between area classifications and Indigenous self-identification statuses. We combine data from the Australian Census Longitudinal Dataset and the 2011 census to estimate the transitions between 2006 and 2011. This information is then included in a multistate population projection model to illustrate the effects of migration and identification change over time in relation to natural increase (i.e., births–deaths). The results show how patterns of identification change differ by both age and type of migration, and how migration and identification change affect patterns of Indigenous population change across major cities, regional areas, and remote areas in Australia.

1 Introduction

The Aboriginal and Torres Strait Islander Australian population is made up of the self-identified descendants of the original inhabitants of the Australian continent and adjacent islands. Hereafter referred to as Indigenous Australians, this population has not only been growing rapidly due to natural population increase, but has been growing faster than the demographic components of fertility, mortality, and

* James Raymer (corresponding author), School of Demography, Research School of Social Sciences, Australian National University, 9 Fellows Road, Acton ACT 2601, Australia
Email: james.raymer@anu.edu.au

Yanlin Shi, Department of Actuarial Studies and Business Analytics, Macquarie University, Australia

James O'Donnell, School of Demography, Research School of Social Sciences, Australian National University, Australia

Nicholas Biddle, Centre for Aboriginal Economic Policy Research and ANU Centre for Social Research and Methods, Research School of Social Sciences, Australian National University, Australia

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migration can explain. While intercensal growth rates have varied, these trends been consistent features of the development of the population since it was first enumerated for all of Australia by the Australian Bureau of Statistics (ABS) in the 1971 census (Biddle and Wilson 2013). The non-demographic components of Indigenous population change are thought to be attributable to better enumeration practices and net increases in self-identification (ABS 2013b; O'Donnell and Raymer 2015). Not surprisingly, traditional demographic estimation and projections of Indigenous populations in Australia have been greatly hindered by these additional factors.

Understanding the drivers of Indigenous population change in Australia is important for many reasons. The Indigenous population has a unique and vibrant culture going back at least 40,000 years (Taylor 1997, 2003), with some evidence suggesting that the population underwent genetic divergence up to 72,000 years ago (Malaspinas et al. 2016). However, the Indigenous population is socioeconomically disadvantaged in comparison to the majority European-ancestry population (Steering Committee for the Review of Government Service Provision 2014) and most of the many migrant populations from around the world who have settled in Australia. Moreover, the demographic behaviours of the Indigenous people are known to differ from those of other population groups in Australia: e.g., their levels of fertility and mortality are higher, and their internal migration patterns are distinct (Biddle and Crawford 2015; Raymer et al. 2017). The causes of these demographic and socioeconomic differences are complex, but include Indigenous people's relative geographic isolation from the rest of the Australian population, their relatively poor access to services, the lingering effects of previous incidences of conflict and dispossession, and ongoing policy failures (Biddle et al. 2015). Understanding these issues is essential for planning and developing national- and local-level policies aimed at improving the conditions of the Indigenous population.

Our aims in this paper are to gain an understanding of the relationships between migration and identification change, and to develop a projection tool that can show the long-term effects of these factors on population change. To capture the dynamics and complexity of Indigenous population change, we utilise data on Indigenous and non-Indigenous births, deaths, and internal migration; and on identification change by age, sex and residence type. The identification and migration probabilities are obtained from the sample-based Australian Census Longitudinal Dataset (ACLD) representing the 2006-2011 period. We then enter the demographic and identification information into a multistate population projection model in order to explore the long-term consequences of migration and identification change.

The paper is structured as follows. In Section 2, we provide background on the Indigenous population and patterns of identification change in Australia. In Section 3, we describe the data, the multistate projection model, and the transition estimation methods. In Section 4, we present the results, focusing on the analysis of the interaction between identification change and migration and the multistate projections. The paper ends with a discussion and a conclusion.

2 Background

The Australian Indigenous population is unique in many ways, including in terms of its growth and spatial distribution patterns. Whereas just 115,000 people identified as Aboriginal[1] in the 1971 census (ABS 1971), the total Indigenous population count had grown to 548,000 by the 2011 census (ABS 2012). This implies an average annual growth rate of 4.0 per cent, which outstrips the average 1.3 per cent growth rate of the total Australian population over the same period (ABS 2014a). This rate is particularly impressive considering that the non-Indigenous population benefited from international migration, with the most recent (2011) census indicating that 27 per cent of the total population were born abroad.

In 1986, the ABS first began to apply post-enumeration estimates to Indigenous census counts. At that time, the resident Indigenous population was estimated at 240,000 people (ABS 2014a). By 2011, this figure had increased to 670,000 (ABS 2013a), reflecting an even higher average growth rate of 4.2 per cent per year. While these estimates partly reflect changes in post-enumeration methodologies and an expansion of the Post Enumeration Survey (PES) to remote areas, it is clear that the Indigenous population has been growing at a much faster rate than the rest of the population.

Demographers and other researchers have pointed out that in most intercensal periods, these estimated levels of growth have been higher than the demographic components of births, deaths, and marriages allow (Biddle and Wilson 2013; Gray 1997; Kinfu and Taylor 2005; O'Donnell and Raymer 2015; Ross 1996). Various explanations have been put forward for this otherwise unexplained growth trend, including improvements in enumeration practices, inter-partnering between Indigenous and non-Indigenous Australians, and an increasing tendency among Australians to identify as Indigenous (Gray 1997; O'Reilly 1994; Ross 1996). Until recently, however, there has been little direct evidence of the respective contributions of each of these factors to Indigenous population growth.

The 2006 to 2011 intercensal period was marked by particularly strong growth. In 2006, the ABS estimated that there were around 517,000 Indigenous Australians living in Australia, representing about 2.5 per cent of the overall population (ABS 2013a). By 2011, this share had increased to approximately 3.0 per cent of the total Australian population. The ABS (2013b) attributed 43 per cent of this growth to natural increase and 36 per cent to improved enumeration practices, leaving a further 21 per cent unexplained. Moreover, with the publication of the ACLD, the period marked the first time data became available that could be used to explore some of this unexplained growth (ABS 2013b). The ACLD is explained in more detail below, but in short it links a five per cent sample of census records from the 2006 to the 2011 census, which allows users to cross-tabulate identification status in 2006 by identification status in 2011.

[1] Note that Torres Strait Islanders were added as an additional category in subsequent collections.

Raymer et al. (2017) attributed the rapid increase in the Indigenous population between 2006 and 2011 to:

(1) the relatively large share of the population of childbearing ages;
(2) higher fertility rates;
(3) high partnering rates in urban areas between Indigenous males and non-Indigenous females that resulted in additional children being identified as Indigenous;
(4) better enumeration by the ABS; and
(5) identification change.

The ACLD data show that some Australians changed how they identify and how they were identified between the 2006 and 2011 censuses. Of the 775,000 sample respondents who identified as non-Indigenous in 2006, an estimated 1700 identified as Indigenous in 2011 (0.2 per cent). Over the same period, 1400 respondents changed how they identified from Indigenous to non-Indigenous (9.2 per cent) (ABS 2013b). Thus, while identification change evidently operates in both directions, it appears that over the study period it had a positive net impact on Indigenous population growth.

Applying population weights to the sample estimate (that take into account both the sampling strategy and differences in linkage rates) produces a net positive contribution of 21,000 people due to identification change. In their analysis of age and sex patterns, O'Donnell and Raymer (2015) found that a large proportion of identification changes occur in early childhood, with the probabilities of change in both directions peaking at ages 5–9. The results of the analysis by Biddle and Crawford (2015) suggest that identification is also associated with geographic location, as the change probabilities were shown to vary depending on whether the respondents lived in a major city, a regional area, or a remote area. Most importantly from the point of view of this paper, they found that geographic mobility between 2001 and 2006 predicted identification change patterns between 2006 and 2011.

The relationship between geography and identification change is particularly pertinent given how the Indigenous population is geographically distributed. As we describe below, the Indigenous population is more dispersed than the non-Indigenous population. While there are urban clusters of the Indigenous population in many Australian cities and regional towns, Indigenous individuals and families are also dispersed throughout the non-Indigenous population, and there are discrete Indigenous communities scattered across regional and remote areas.

Given the large landmass covered by regional and remote Australia, Biddle and Wilson (2013) pointed out that despite being relatively small in size, the Indigenous population have responsibility for, and stewardship over, most of the Australian continent. Regional and remote Indigenous communities are, however, under constant pressure from a range of challenges, including high rates of rural-urban migration; socioeconomic disadvantage and a lack of opportunities for young people; community dysfunction; volatile government policy; and the difficulties of remote service delivery, particularly in the areas of housing, health, education, and municipal services. While these challenges are not experienced to the same degree in larger towns and cities, urban Indigenous populations nevertheless experience higher levels of socioeconomic disadvantage than their non-Indigenous neighbours; as well as higher rates of discrimination (Biddle et al. 2013) and lower rates of subjective wellbeing (Biddle 2014) than their remote counterparts. Understanding the size, growth, and distribution of the Indigenous population is therefore of far-reaching importance.

Indeed, future patterns of inhabitation of inland Australia and their implications for land use, planning, and service delivery – as well as efforts to reduce economic inequality in Australia – depend to a great extent on the development of the Indigenous population. The proliferation of Indigenous population projections over the last 25 years attests to the importance of this topic (ABS 2004, 2009, 2014b; Biddle 2013; Biddle and Taylor 2009; Gray 1997b; Gray and Gaminiratne 1993; Khalidi, 2008; O'Donnell and Raymer 2015; Wilson 2009, 2014). But due to a lack of data, the twin issues of regional-remote-urban migration and identification change have rarely been appropriately addressed, and never in combination. In official and academic projections, it is typically assumed out of necessity that populations are closed to identification change (Wilson 2009). Similarly, in projections of interregional migration, it is usually assumed that net migration levels remain constant (e.g., ABS 2004, 2009, 2014b) – even though this approach is blind to the dynamic interactions between origin and destination populations.

Recent advances in thinking, data, and methods have created new possibilities for studying developments in the Indigenous population; most notably, opportunities to model the population within a multistate (or a multiregional) demographic framework (Wilson 2009; Biddle and Wilson 2013; O'Donnell and Raymer 2015). To demonstrate the potential effects of identification change on long-term Indigenous population growth, O'Donnell and Raymer (2015) constructed synthetic Indigenous and non-Indigenous populations and allowed them to interact through identification change probabilities calculated from the ACLD. The findings of this model suggest that identification change is most common in the relatively heavily populated and urbanised state of New South Wales (where observed rates of identification change are high), and is less common in the relatively regional and remote Northern Territory (where identification change is low). As these projections were closed to interregional migration, an important extension to this work lies in incorporating both identification change and interregional (or area group) migration into a similar multistate projection model.

3 Data and methods

3.1 Available data

The 2011 census population counts can be decomposed by sex, age, current residence, residence five years ago, and current identification status. In addition, the ACLD links a sample of the 2006 and 2011 censuses.

The ACLD was released by the ABS in late 2013, and 'a sample of almost one million records from the 2006 Census (wave 1) was brought together with corresponding records from the 2011 Census (wave 2) to form the largest longitudinal dataset in Australia' (ABS 2013c). To produce the ACLD, five per cent of records from the 2006 census were linked probabilistically with available data from the 2011 census based on the most likely match, given observed characteristics. Because this linking was done without knowing the individual's exact name and address, an unobserved minority of linked pairs are not of the same individual. We use data from the ACLD to calculate the age-specific probabilities of identification change between the two census periods.

Mortality data are sourced from the 2010–12 Indigenous life tables (ABS 2013d), while fertility rates are sourced from vital registration data compiled in the ABS (2015) *Births* publication. Net international migration data for the 2006–2011 period for the non-Indigenous population data were obtained from the Australian Bureau of Statistics, and represent the difference between immigration and emigration. International migration is measured using registration (passenger card) data. An immigrant (emigrant) is defined as a person who has entered and remained in (left and remained outside of) Australia for 12 out of 16 months. Finally, for the projections, the 2011 Estimated Resident Population is used as the starting point.

The population counts of the 2011 census by usual residence in 2006 (t), usual residence in 2011 ($t + 5$), and identification status in 2011 are presented in Table 1.[2] The major city, regional area, and remote area definitions are taken from the ABS (2013b). Collectively, they comprise a geographic area classification known as ASGS-RA, which reflects the relative proximity of every location in Australia to towns and cities. The classification is created by constructing a one-kilometre grid for all of Australia and assigning an index value, known as the Accessibility or Remoteness Index of Australia (ARIA+), to each square in the grid based on the average road distance from the square to the nearest town or urban centre of various population sizes. The grid is laid on top of the Statistical Area 1 (SA1) geographic structure to produce an ARIA+ score for each SA1. SA1s with an ARIA+ score of 0.0 to 0.2 are classified as major cities; of 0.2 to 5.9, as regional areas; and of greater than 5.9, as remote areas. These area classifications are presented for Australia in

[2] Three important components of the population are excluded from these counts: those who were under five years old in 2011, those who did not state their identification status, and those who did not state their location of usual residence in either 2006 or 2011.

Figure 1:
Map of Major Cities, Regional Areas, and Remote Areas in Australia

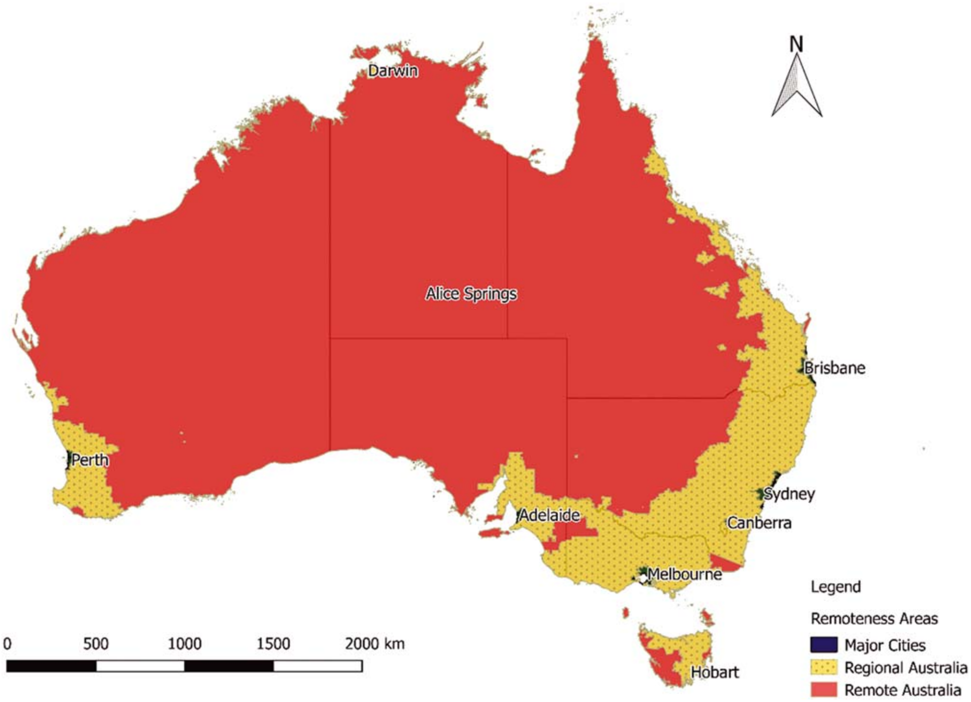


Figure 1. For example, an SA1 that lies within an urban area with a population greater than 250,000 or within one-fifth of the average distance to such a centre is classified as major city. An SA1 that is 0.5 times the average distance to a major city, 1.2 times the average distance to a town with between 48,000 and 250,000 people, and sits inside a town with between 18,000 and 48,000 people obtains an ARIA+ score of 1.7 (0.5 + 1.2 + 0.0), and is classified as a regional area ($0.2 < 1.7 \leq 5.9$). Meanwhile, remote areas are farthest from major urban centres. More information on how ARIA+ is calculated is available from the Hugo Centre for Migration and Population Research at the University of Adelaide.[3]

Table 1 shows that of the total Indigenous population in 2011, 185,000 (43 per cent) lived in regional areas, 150,000 (35 per cent) lived in major cities, and 95,000 (22 per cent) lived in remote areas. In contrast, of the total non-Indigenous population in 2011, 11.8 million (70 per cent) lived in major cities, while only 277,000 (2 per cent) lived in remote areas. The shares of the populations living in

[3] https://www.adelaide.edu.au/apmrc/research/projects/category/about_aria.html.

Table 1:
Inter-area group migration by identification status, 2006–2011

	Destination			
Origin	**MC**	**RG**	**RM**	**Total**
A. Indigenous				
MC	137,109	9,133	1,093	147,335
RG	10,434	168,782	3,746	182,962
RM	2,142	7,332	89,717	99,191
Total	149,685	185,247	94,556	429,488
B. Non-Indigenous				
MC	11,332,633	445,045	35,239	11,812,917
RG	390,835	4,280,232	41,505	4,712,572
RM	30,990	53,220	201,066	285,276
Total	11,754,458	4,778,497	277,810	16,810,765

Note: MC = Major Cities; RG = Regional Areas; RM = Remote Areas.
Source: 2011 Census.

these area groups did not change much between 2006 and 2011, but the population numbers grew by 11.9 per cent in major cities, 12.6 per cent in regional areas, and 8.2 per cent in remote areas.

Looking at the data on inter-area group migration in Table 1, we see some notable differences between the Indigenous and non-Indigenous populations. First, the Indigenous people living in major cities were more likely to move to a regional area or remote area (i.e., 9,133 + 1,093/147,335 = 7 per cent) than the non-Indigenous (i.e., 445,045 + 35,239/11,812,917 = 4 per cent). The opposite was the case for those living in regional and remote areas, where the Indigenous population had lower out-migration propensities than the non-Indigenous population. For example, almost 30 per cent of the non-Indigenous population but only 10 per cent of the Indigenous population living in remote areas moved to a major city or regional area between 2006 and 2011. Both populations exhibited higher propensities to move to regional areas when leaving major cities or remote areas. When moving from regional areas, both groups preferred to move to major cities.

3.2 Projection framework

The following multistate demographic accounting model (Rogers 1995) is employed to project the Indigenous and non-Indigenous populations of Australia.

$$\mathbf{K}^{(t+5)} = \mathbf{G}\mathbf{K}^{(t+5)} + \mathbf{I} \qquad (1)$$

where

$$\mathbf{K}^{(t)} = \begin{bmatrix} \mathbf{K}_0^{(t)} \\ \mathbf{K}_5^{(t)} \\ \vdots \\ \mathbf{K}_{75+}^{(t)} \end{bmatrix}, \quad \mathbf{K}_x^{(t)} = \begin{bmatrix} K_{11x}^{(t)} \\ K_{12x}^{(t)} \\ \vdots \\ K_{23x}^{(t)} \end{bmatrix}, \quad \mathbf{I}_x = \begin{bmatrix} I_{11x}^{t,t+5} \\ I_{12x}^{t,t+5} \\ \vdots \\ I_{23x}^{t,t+5} \end{bmatrix},$$

and

$$\mathbf{G} = \begin{bmatrix} 0 & 0 & 0 & \mathbf{B}_{10} & \cdots & \mathbf{B}_{45} & 0 & \cdots & 0 \\ \mathbf{S}_0 & & & & \ddots & & & & \\ 0 & \mathbf{S}_5 & & & \ddots & & & & \vdots \\ \vdots & \vdots & & & \ddots & & & & 0 \\ 0 & 0 & & \cdots & & & & \mathbf{S}_{70} & 0 \end{bmatrix}.$$

$K_{iax}^{(t)}$ is the population at time t by identification status i (1 = Indigenous, 2 = non-Indigenous), by area group a (1 = major cities, 2 = regional areas, 3 = remote areas), and by age group x (0–4, 5–9, . . . , 75+). I_{iax} reflects the corresponding net immigration totals between the two time points. As specified in Rogers (1995), $\mathbf{S}_x$ and $\mathbf{B}_x$ are six-by-six matrices that are composed of the survival probability of moving from identification status i and area group a to identification status j and area group b; and the survival fertility rate of women in identification status i and area group a contributing births to women in identification status j and area group b, respectively. The projection is performed separately for males and females. The six subpopulations are defined as Indigenous major cities (K_{11}), Indigenous regional areas (K_{12}), Indigenous remote areas (K_{13}), non-Indigenous major cities (K_{21}), non-Indigenous regional areas (K_{22}), and non-Indigenous remote areas (K_{23}).

In our model framework, births are produced by females. In the construction of the fertility rates, we assume that women can give birth to both Indigenous and non-Indigenous babies. Non-Indigenous women give birth to Indigenous children largely by partnering with Indigenous men (Biddle and Johnstone 2014); whereas a much smaller percentage of Indigenous women give birth to non-Indigenous children. While this pattern may seem counter-intuitive, it likely reflects personal factors that influence how people identify themselves and their children.

In this paper, we extend the multistate population projection of O'Donnell and Raymer (2015), which included age-specific transitions between Indigenous and non-Indigenous identification, by including transitions between residence area groups. Many standard cohort-component population projections models ignore transitions between states of residence, and instead rely on net migration or the slightly more detailed out-migration and in-migration rates. The problem with net migration and in-migration rates is that they include the incorrect population at risk of migrating in the denominator, which can seriously bias the projection results

(Rogers 1990, 2015). The same is true for other life course transitions in which populations can move in both directions; e.g., ethnic self-identification, marriage, health, and employment.

3.3 Indirect estimation

In order to account for the identification status transition and migration among area groups simultaneously, we need to estimate the rates $\mathbf{S}_x$ described in Equation 1. Although such information can be extracted from the ACLD directly, the quality of this approach is questionable. For one thing, the ACLD only accounts for five per cent of the total Australian population data. Thus, after the decomposition, many of the numbers in the cells of the above matrix are small or zero, especially when disaggregated by age and sex. Furthermore, small counts have been randomized by the ABS to protect individual confidentiality. Therefore, we propose combining the ACLD data with the 2011 census data to produce more reliable inputs for analysis and use in a multistate population projection.

3.3.1 Identification status transition and migration probabilities

The process used to estimate the age- and sex-specific probabilities of inter-area group migration and identification change is described in this subsection. This process involves smoothing the ACLD data and combining them with the full census data.

To smooth the randomness in the ACLD transition data, we use the log-linear model, following Rogers et al. (2010). Consider, for example, the following main effects log-linear model:

$$\ln(\hat{n}_{iajbxy}) = I_i + O_a + J_j + D_b + A_x + S_y \tag{2}$$

where $\hat{n}_{iajbxy}$ is the estimated table of transitions between area groups and identification status by age and sex. I denotes identification status in 2006, O denotes area group in 2006, J denotes identification status in 2011, D denotes area group in 2011, A denotes age group, and S denotes sex. The subscripts denote the categories in each variable. To choose the log-linear model for smoothing the data, we considered all two-way interactions of the above six factors and used the Akaike Information Criterion (AIC)[4] goodness-of-fit measure, which has a penalty for the number of parameters in the model. Furthermore, we separately modelled the people who changed their identification status and those who did not change their status. This was done to preserve the full census migration flow data among Indigenous

[4] $AIC = 2k - 2\log(L)$, where k is the number of parameters and L is the fitted likelihood. Hence, AIC balances the model fitness (higher L) and parsimony (lower k). The model with a smaller AIC is preferred.

and non-Indigenous populations, and to prevent the patterns of people who did not change their identification (i.e., the vast majority) from dominating the estimation of those who did.

The final model selected for those who *did not change their identification* contained the following two-way interaction terms in addition to all the main effect terms: IO_{ia}, ID_{ib}, IA_{ix}, IS_{iy}, OD_{ab}, OA_{ax}, OS_{ay}, DA_{bx}, DS_{by}, and AS_{xy}. The final model selected for those who *changed their identification status* was IA_{ix}, OD_{ab}, OA_{ax}, OS_{ay}, and DS_{by}. Note that identification change was treated separately in these models to prevent the patterns of people who did not change their identification from dominating the estimated patterns of those who did. Thus, because the patterns were treated separately, the variable of J (identification status in 2011) and all related interactions were not needed or were redundant.

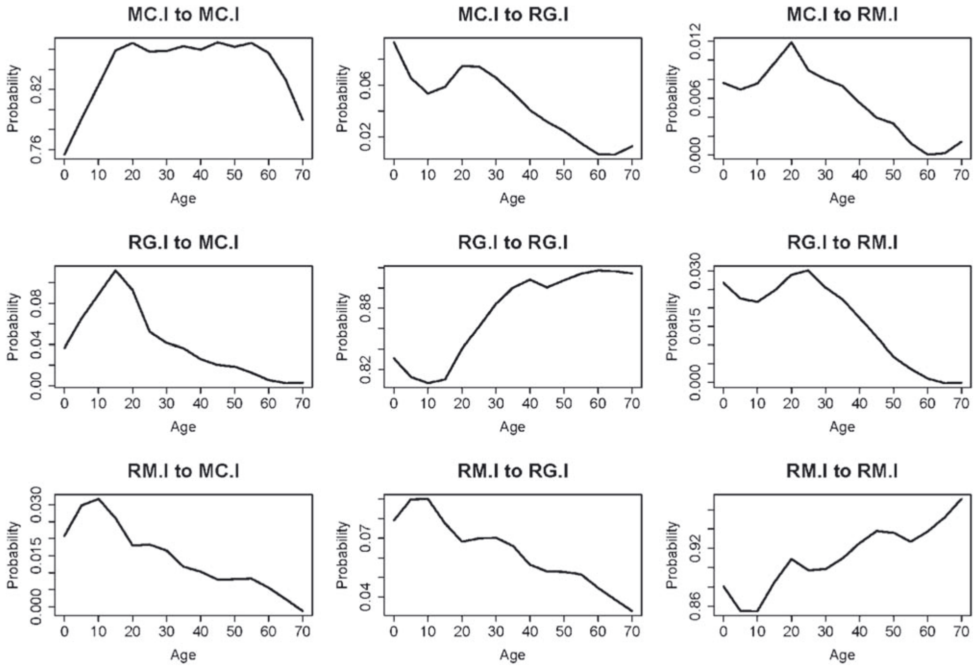
From the smoothed ACLD data, we can calculate $\hat{r}_{iajbxy}$, which is the ratio of $\hat{n}_{iajbxy}$ to $\hat{n}_{ijbxy}$, which can be used to augment the full census data. Therefore, the estimated full census table of transitions is obtained by $\hat{n}^c_{iajbxy} = \hat{r}_{iajbxy} n^c_{ijbxy}$, where n^c_{ijbxy} is the directly available data from the 2011 census (without 2006 identification status).

Hence, the age- and sex-specific migration probabilities can be calculated as $\hat{s}_{iajbxy} = \hat{n}^c_{iajbxy}/\hat{n}^c_{iaxy}$ where $\hat{n}^c_{iaxy} = \sum_{j,b=1}^{6} \hat{n}^c_{iajbxy}$ and $\hat{n}^c_{iajbxy}$ are the estimated census counts, reconstructed according to the new definitions of origins and destinations. In order to further smooth these probabilities across age groups, we employ the local polynomial regression (LOESS) methods to estimate age-specific probabilities, $\hat{s}_{iajbxy}$, plotted in Figures 2 to 5. Note that as there were only minor differences in the sex patterns, they are not presented in this paper.

The estimated age-specific probabilities of inter-area group migration for the Indigenous population are presented in Figure 2. Here, we see that the probabilities of staying in major cities (upper-left figure) remained at the same level (around 90 per cent) for most of the age groups, except for those aged 15 or younger and those aged 60 or older. For those staying in regional areas (centre figure) and remote areas (lower-left figure), there were relatively low probabilities in the childhood years (80–90 per cent), with steady increases thereafter. For the migration probabilities presented in the off-diagonal figures, the patterns were roughly similar; i.e., increasing until reaching the modal class (ranging between 10 and 20 years old) and then consistently decreasing. For the Indigenous population, the probabilities of migrating from major cities to regional areas and remote areas and from regional areas to remote areas were declining in early childhood, but then started increasing at around age 10 until reaching the modal class.

The estimated age-specific probabilities of inter-area group migration for the non-Indigenous population are presented in Figure 3. These probabilities were roughly similar to those exhibited by the Indigenous population, although the magnitudes were quite different. It is worth noting that for non-Indigenous migration from major cities to regional areas, there was a noticeable pre-retirement peak at around age 55, which is not observed in the other cases. The probabilities of remaining in remote

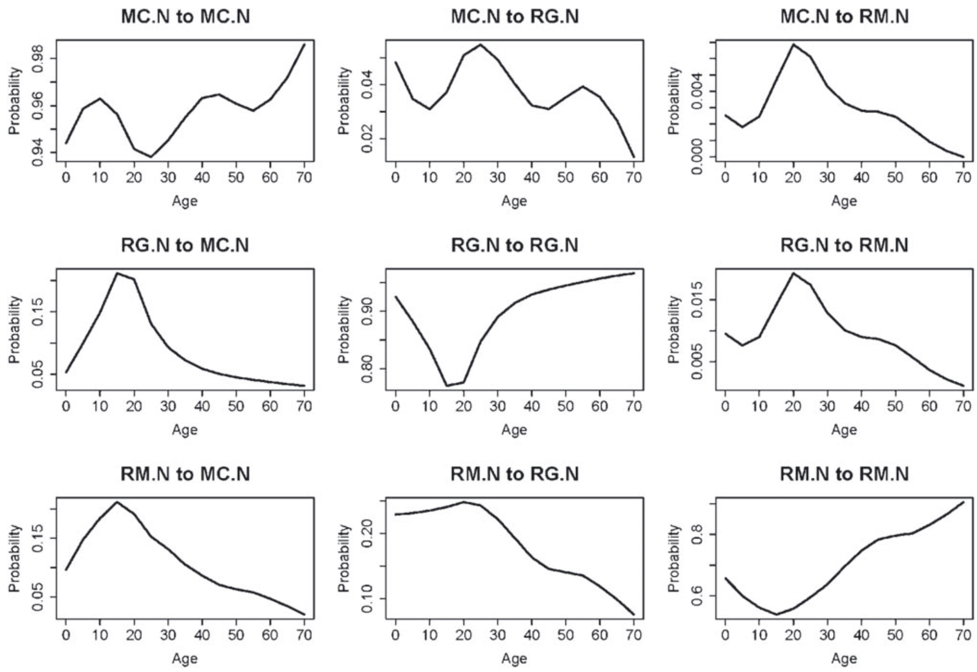
Figure 2:
Estimated age-specific probabilities of inter-area group migration for the Indigenous population, 2006–2011



areas (lower-left figure) were also much lower than the probabilities of remaining in major cities and regional areas.

The estimated age-specific probabilities of inter-area group migration for the non-Indigenous population who changed their identification to Indigenous are presented in Figure 4. The corresponding probabilities for the Indigenous people who changed their identification to non-Indigenous are presented in Figure 5. In both figures, we find similar patterns, albeit with very different magnitudes. For instance, all population groups had higher probabilities in the childhood years, and most had low or decreasing trends with increasing age. The exceptions are the probabilities associated with living in remote areas at the beginning of the time interval (bottom panels), where there appear to be labour force peaks. We also see that those who changed their identification but remained in major cities and regional areas exhibited increasing age-specific probabilities after age 20. Finally, using the smoothed probabilities presented in Figures 2 to 5, we regenerate the census counts via $\tilde{n}^c_{iajbxy} = \hat{n}^c_{iaxy}\tilde{s}_{iajbxy}$, where the tilde symbol denotes the corresponding smoothed values.

Figure 3:
Estimated age-specific probabilities of inter-area group migration for the non-Indigenous population, 2006–2011

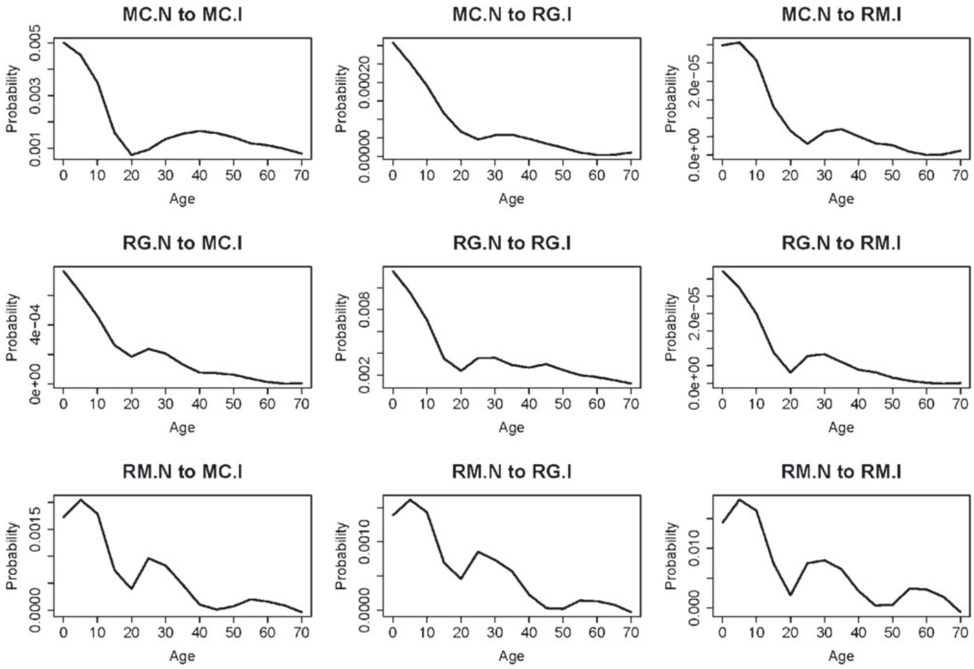


3.3.2 Area group mortality rates

Age- and sex-specific mortality rates for the six populations were needed to construct the multistate survival ratios. Using the 2010–12 Indigenous life tables provided by the ABS (2013d), we calculated age- and sex-specific mortality rates at the national level for both the Indigenous and the non-Indigenous populations. The area group life tables were then estimated by proportionating the 2011 age-specific death rates by the age-standardised death rates for major cities, regional areas, and remote areas. For instance, the Indigenous mortality rates in major cities equalled the national rates times 0.798, which represents the ratio of standardised death rates per 1000 people of major cities to the nation (i.e., 7.9/9.9). The corresponding ratio for the non-Indigenous mortality was 0.965 (i.e., 5.5/5.7).

The log age-specific death rates for females of the six population groups are plotted in Figure 6. The corresponding plots for males appear to be similar to those for females, albeit with somewhat higher rates. The estimated mortality rates for the non-Indigenous population were lower than those of the Indigenous population in all three areas. Moreover, since the mortality rates of Indigenous and non-Indigenous

Figure 4:
Estimated age-specific probabilities of inter-area group migration for the non-Indigenous population who became Indigenous, 2006–2011



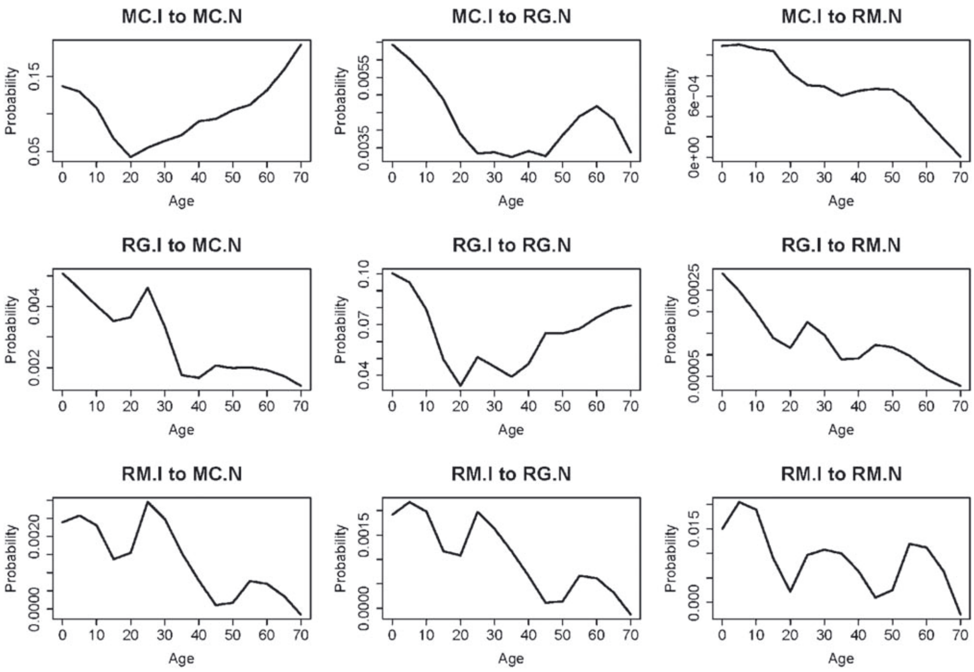
persons in major cities, regional areas, and remote areas were proportioned as described above, they have the same shape, but different magnitudes. Remote areas were estimated to have the highest mortality rates, and major cities were estimated to have the lowest mortality rates.

3.3.3 Births and fertility rates

The age-specific fertility rates used in the projection are plotted in Figure 7. The rates reached their maximum at the 20–24 age group for Indigenous women and at the 25-29 age group for non-Indigenous women. Among the six population groups, the maximum rate was exhibited by 20–24-year-old Indigenous women in remote areas. For the non-Indigenous population, the maximum rate was reached in the 25–29 age group living in regional areas. It is worth noting that the fertility rates for the mothers aged 40 or older were relatively high for those living in major cities, although the magnitudes were quite small.

As both Indigenous and non-Indigenous women could give birth to Indigenous and non-Indigenous babies, the new births could not be directly projected using

Figure 5:
Estimated age-specific probabilities of inter-area group migration for the Indigenous population who became non-Indigenous, 2006–2011



Equation 1. Information was obtained from the ABS to estimate the probabilities of having Indigenous babies by identification status of the women at risk of having births, area group, and age, denoted as p_{iax}. The identification statuses of females and babies were extracted from the 2011 census data, along with the usual residence addresses. To smooth random variations in the observed data, the following logistic regression was used:

$$\ln(p_{iax}/(1 - p_{iax})) = I_i + O_a + A_x, \tag{3}$$

where, as before, I, O, and A denote identification status, area group of residence, and age (of females), respectively. In addition, we considered all of the three two-way interactions of the three factors, and used the stepwise algorithm based on AIC[5] to select the final model.

[5] To implement the stepwise algorithm, we start from a full model (with all two-way interactions). At each step, we first do a backward selection by removing a variable so that the lowest AIC is obtained. We then do a forward selection by adding back a variable so that the lowest AIC is obtained. We continue this process until no more variables can be removed or added back to obtain a smaller AIC.

Figure 6:
Female age-specific death rates (log) by identification status and area group, 2011

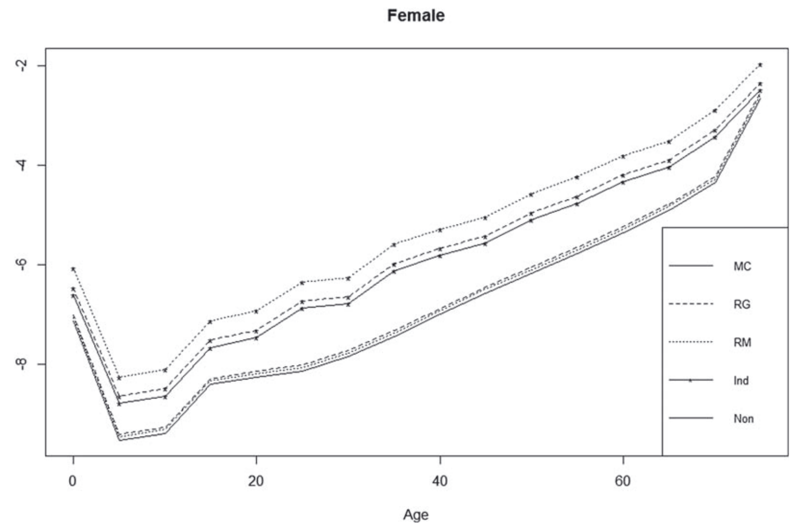
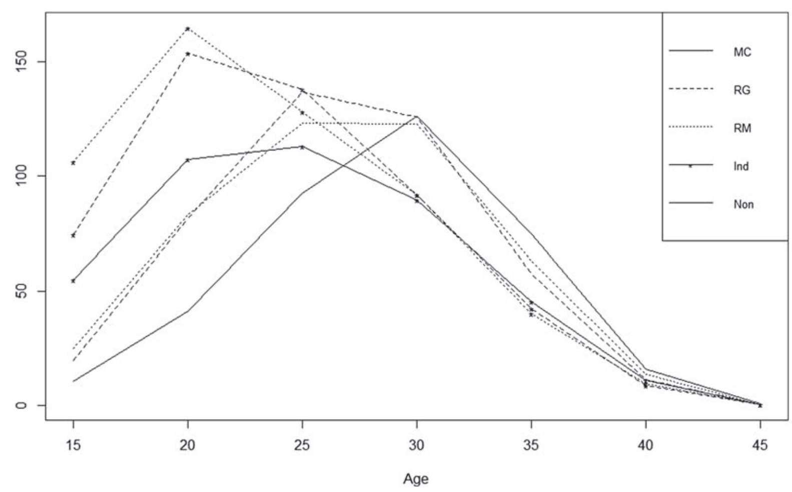


Figure 7:
Age-specific fertility rates per 1000 people by identification status and age group, 2011



The estimated probabilities of giving birth to Indigenous babies, $\hat{p}_{iax}$, are tabulated in Table 2. Both Indigenous and non-Indigenous mothers who lived in

Table 2:
Probabilities of births being Indigenous by identification status and age group of the female population: Major Cities, Regional Areas, and Remote Areas

	Indigenous			Non-Indigenous		
Age group	Major Cities	Regional Areas	Remote Areas	Major Cities	Regional Areas	Remote Areas
15–19	1.0000	1.0000	1.0000	0.0446	0.1024	0.1515
20-24	0.9522	0.9626	1.0000	0.0220	0.0520	0.0791
25–29	0.9351	0.9489	1.0000	0.0116	0.0279	0.0430
30–34	0.9369	0.9503	1.0000	0.0062	0.0150	0.0233
35–39	0.9728	0.9788	1.0000	0.0044	0.0107	0.0166
40–44	0.9501	0.9609	1.0000	0.0063	0.0152	0.0236
45–49	1.0000	1.0000	1.0000	0.0162	0.0388	0.0594

remote areas were more likely to give birth to Indigenous babies. For the non-Indigenous female population, these probabilities were larger for the very young and the oldest reproductive age groups, and were smallest for the 35–39 age group. For Indigenous women, however, no clear differences were found among the age groups.

Finally, for the projection of births, let K_{0a0} and K_{1a0} denote the number of Indigenous and non-Indigenous births, respectively, by area group a. Following Rogers (1995), the projected number of Indigenous births in area group a (K_{1a0}) is equal to $\sum_{x=15}^{x=49}[K_{0ax}B_{0ax}\hat{p}_{0ax} + K_{1ax}B_{1ax}\hat{p}_{1ax}]$, where in this case K refers to the female population only, B is the fertility rate of this particular female population group, and $x = 15\text{–}19,\ 20\text{–}24, \ldots, 45\text{–}49$ years. The projected number of non-Indigenous births (K_{0a0}) is simply $\sum_{x=15}^{x=49}[K_{0ax}B_{0ax}(1 - \hat{p}_{0ax}) + K_{1ax}B_{1ax}(1 - \hat{p}_{1ax})]$. For the distribution of these births by sex, we assume the sex ratio at birth is 1.05 (male to female) for all three area groups and both identification statuses. That is, there is a $1.05/(1 + 1.05)$ proportion of K_{0a0} and K_{1a0} being male, and $1/(1 + 1.05)$ proportion being female.

3.3.4 Net international migration totals

For the projected growth of the non-Indigenous population, net international migration is an important demographic component. Because of the flows between the two populations described above, non-Indigenous projections are also needed as an input for the Indigenous population projections.

In our model, we include age- and sex-specific net international migration as a source of growth for the non-Indigenous population, with the assumption that the levels will continue to increase by 45 percent per five-year interval. This assumption is consistent with the growth in net immigration observed between 1981 and 2011. The shares of net international migration in each of the three area groups are assumed to be proportional to the foreign-born populations residing in these areas, as measured in the 2011 census. This assumption is based on the close relationship often found between migrant stocks and migration flows (see, e.g., Bauer et al. (2007)).

Of the approximately 1.2 million people who were overseas five years prior to the 2011 census, only 1377 (or 0.4%) identified as Indigenous. This equates to 0.3% of the total Indigenous population in 2011 (including those aged 0–4). Of the non-Indigenous population, 6% were overseas five years prior to the 2011 census. Since the proportion was so small for the Indigenous population, we assumed zero net international migration for the Indigenous population projections.

4 Results

In this section, our focus is on analysing the transitions between residing in one of the three area groups and identification status, and how these transitions contribute to current and future population change. Multistate population projections based on the 2011 Estimated Resident Populations are also used to identify the relative sources of growth for the Indigenous population in major cities, regional areas, and remote areas for Australia.

4.1 Area group residence and identification status transitions

The aggregated smoothed census counts grouped by the usual residence and identification status in 2006 (t) and in 2011 ($t + 5$) are presented in Table 3. As the identification statuses are estimated by combining data from the ACLD data and 2011 census, the observations in Table 3 and Table 1 are consistent in the 2011 (column sum) margins with some minor differences (less than 0.01 per cent) due to the smoothing and the application of the estimated age-specific probabilities.

From the two off-diagonal panels of Table 3, we can see that only 0.27 per cent (i.e., (23,537 + 19,935 + 1980)/16,828,654) of the total non-Indigenous population transitioned to Indigenous status during the 2006–2011 period, compared with 6.80 per cent (i.e., (14,002 + 12,725 + 1243)/411,596) for the Indigenous population. For the Indigenous people who were living in the three area groups and changed their identification to non-Indigenous, the percentages were 10.15 per cent (i.e., (13,208 + 644 + 119)/137,579) for major cities, 7.17 per cent (619 + 11,944 + 30)/175,673) for regional areas, and 1.43 per cent (175 + 137 + 1094)/98,345) for remote areas. The corresponding percentages for the non-Indigenous people transitioning to Indigenous status were 0.20 per cent, 0.42 per cent and 0.77 per cent, respectively. In terms of the population counts, there were 26,245 Indigenous individuals who changed their identification status to non-Indigenous, but stayed in

Table 3:
Estimated flows of identification status change and migration for area groups in Australia, 2006–2011

	Status 2011						
	Indigenous			Non-Indigenous			
Status 2006	MC	RG	RM	MC	RG	RM	Total
A. Indigenous							
MC	114,398	8,208	1,003	13,208	644	119	137,579
RG	9,816	149,526	3,736	619	11,944	30	175,673
RM	1,903	7,084	87,951	175	137	1,094	98,345
Subtotal	126,117	164,818	92,690	14,002	12,725	1,243	411,596
B. Non-Indigenous							
MC	22,354	1,000	110	11,317,286	446,100	35,823	11,822,673
RG	992	18,768	39	401,510	4,256,231	42,322	4,719,861
RM	191	167	1,831	31,092	53,102	199,737	286,119
Subtotal	23,537	19,935	1,980	11,749,887	4,755,433	277,882	16,828,654
Total	149,654	184,753	94,670	11,763,890	4,768,158	279,125	17,240,250

Note: MC = Major Cities, RG = Regional Areas, RM = Remote Areas.

their area group of residence. The number of Indigenous people who changed their identification and moved to a different area group was 1725, or about 6.2 per cent of this group. For non-Indigenous people, the corresponding numbers were 42,953 who changed their identification but remained, and 2498 (5.5 per cent) who changed their identification and moved.

Both identification change and internal migration contributed to population change in each of the three areas. Major cities gained 9535 Indigenous people through identification change (i.e., 22,354 – 13,208), and another 2509 people through internal migration (i.e., 9816 + 1903 – 8208 – 1003). Regional areas also experienced net gains in Indigenous population through both identification change (18,768 – 11,944 = 6824 persons) and internal migration (8208 + 7084 – 9816 – 3736 = 1740 persons). However, the Indigenous population in remote areas declined because of a large negative net internal migration of 4248 people, which was substantially more than the 737 individuals gained through identification change.

As suggested by Figures 2 to 5, and as shown in previous individual-level modelling (Biddle and Crawford 2015), the interaction between inter-area group migration and identification status change is significant. To further explore this interaction, we present the ratio of the odds of people changing their identification and migrating to the odds of people changing identification (but not migrating) in Table 4. For example, consider the odds ratio of 7.41 for those changing their status from Indigenous and living in remote areas to non-Indigenous and living in major cities. This odds ratio is calculated from the counts presented in Table 3

Table 4:
Odds ratios of people changing their identification and migrating to people changing their identification and not migrating, 2006–2011

	Destination		
Origin	**MC**	**RG**	**RM**
A. Indigenous to non-Indigenous			
MC	1.00	0.68	1.03
RG	0.79	1.00	0.10
RM	7.41	1.56	1.00
B. Non-Indigenous to Indigenous			
MC	1.00	1.13	1.55
RG	0.56	1.00	0.21
RM	0.67	0.34	1.00

and represents: the ratio of (i) the odds of moving from remote areas to major cities and changing identification to non-Indigenous moving from remote areas to major cities and not changing identification (i.e., 175/1903 = 0.092) to (ii) the odds of changing identification to non-Indigenous to those remaining Indigenous (i.e., 1094/87,951 = 0.012). These types of moves clearly had strong and important effects on identification change.

Table 4 contains very useful information regarding the relationships between migration between different area groups and identification change. Like Indigenous people who were moving from remote areas to major cities, Indigenous people who were moving from remote areas to regional areas were more likely than those who were not moving to change their identification, albeit with a smaller odds ratio of 1.56. However, Indigenous people who were undertaking most of the other kinds of moves retained their status at much higher rates than those who did not move. This was particularly true for Indigenous people who were moving from regional areas to remote areas, for whom the odds ratio was 0.10.

Among the non-Indigenous population, those who moved from major cities to regional areas and remote areas exhibited odds ratios of 1.13 and 1.55, respectively; indicating positive relationships between these moves and identification change. The other moves had the opposite effect: i.e., the non-Indigenous people who moved from regional areas and remote areas were much less likely to change their identification to Indigenous.

4.2 Projected sources of growth: 2011–2031

Assuming fixed values for fertility, mortality, and inter-area group migration components, the 2011–2031 projected populations for the three areas and the corresponding sources of growth are presented in Table 5. Comparing the 2011 Estimated Resident Populations and the 2016 projection, we see that the Indigenous population was projected to have increased by 37,730 (16.2 per cent) in major cities, by 40,777 (13.9 per cent) in regional areas, and by 7792 (5.5 per cent) in remote areas. The most important projected source of growth was natural increase (i.e., births - deaths). For major cities and regional areas, the second-most important projected source of growth was net identification change. For remote areas, however, the second-most important source of growth was (negative) net internal migration.

Over two-thirds of the negative net migration of Indigenous persons in remote areas was added to major cities. Identification change contributed positively to Indigenous population growth in all three areas, but especially in major cities. The contributions of people changing both their identification status and their area of residence represented only a small share of the overall population change.

Comparing the projected sources of growth during the 2016–2021, 2021–2026, and 2026–2031 periods, we see that most of the above observations hold, albeit with some noticeable differences. First, levels of natural increase grow steadily over time, from 28,000 to 40,000 for major cities, from 36,000 to 44,000 for regional areas, and from 12,000 to 13,000 for remote areas. Second, levels of net internal migration decrease over time for major cities and remote areas, but increase slightly for regional areas. Third, net identification change to Indigenous status is positive across all three area groups and projection periods, but the levels fluctuate for major cities, decline for regional areas, and increase for remote areas. The net migration and identification changes are relatively small and contribute very little to overall growth, albeit with consistent negative growth for major cities and remote areas and positive growth for regional areas. Overall, we expect Indigenous populations to continue growing in all three area groups in Australia. Between the 2011–2016 and 2026–2031 periods, growth is projected to increase by around 32 per cent for major cities (from 38,000 to 50,000) and remote areas (from 8000 to 10,000). For regional areas, growth is projected to increase by 18 per cent.

4.3 Multistate population projections

We now proceed to describe the multistate projections to 2031 holding the 2006–2011 rates constant. The age-sex compositions of the 2011 Estimated Resident Population (dark shaded bars) and projected 2031 population (diagonal shaded bars) for the Indigenous population are presented for the three areas in Figure 8. There are two conclusions we can draw from these percentage plots and the corresponding plots of population counts (not shown). First, consistent with our observation in Section 4.1, growth is occurring in all area groups and age groups, but particularly

Table 5:
Sources of Indigenous population change

Component of change	Major cities	Regional areas	Remote areas
2011–2016			
Natural increase	28,048	36,185	11,996
Net internal migration	3,500	1,368	−4,868
Net identification change	6,210	2,916	743
Net internal migration & identification change	−28	308	−79
Total	37,730	40,777	7,792
2016–2021			
Natural increase	30,977	38,363	12,649
Net internal migration	3,243	1,284	−4,527
Net identification change	5,669	2,003	838
Net internal migration & identification change	−127	282	−90
Total	39,762	41,933	8,870
2021–2026			
Natural increase	35,533	41,639	12,786
Net internal migration	2,697	1,464	−4,161
Net identification change	5,966	1,419	1,045
Net internal migration & identification change	−225	327	−96
Total	43,971	44,849	9,574
2026–2031			
Natural increase	40,299	44,496	12,814
Net internal migration	2,119	1,682	−3,801
Net identification change	7,579	1,467	1,410
Net internal migration & identification change	−271	407	−95
Total	49,725	48,052	10,328

in major cities and regional areas. Second, ageing is occurring faster in major cities and regional areas, even though the 'pyramid' shape remains more or less the same.

We demonstrated in Section 4.1 that identification change contributes greatly to Indigenous population growth in all three areas. To further verify this point, we compare in Figure 9 three projections of the Indigenous population using our multistate model and a single state model that includes no identification change and fixed net internal migration levels for the years 2011 to 2031. We find that the multistate projection results in larger Indigenous populations in all areas due to the inclusion of identification change. The corresponding ABS projections (not shown) were between the multistate and single state models for major cities, close to the

Figure 8:
Age–sex composition (percentage) of the Indigenous population: 2011 estimated resident population (grey shade) and 2031 projection (diagonal line)

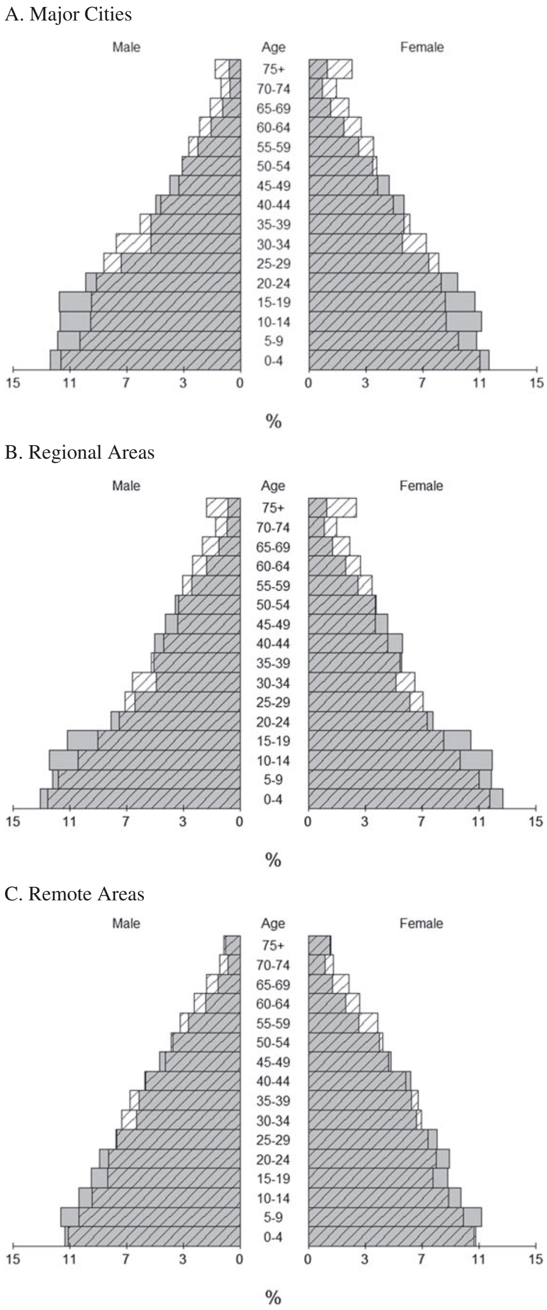
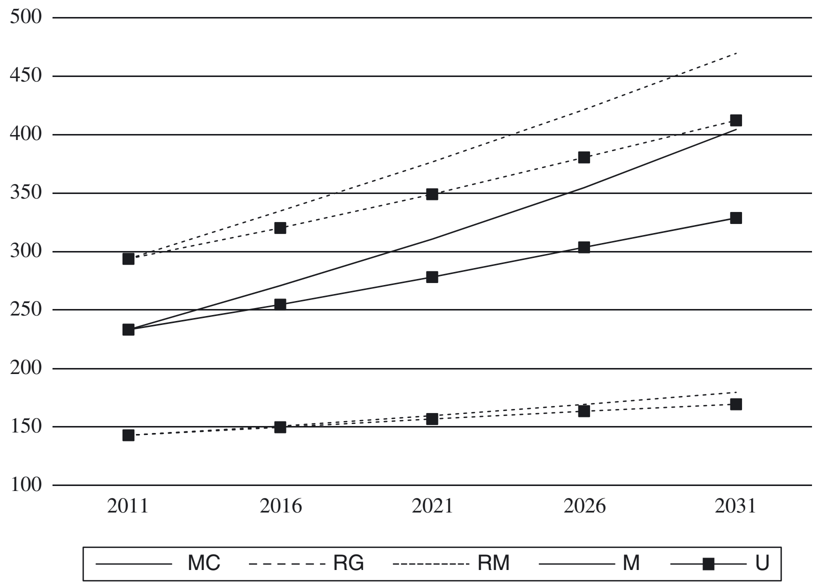


Figure 9:
Multistate and single state Indigenous population projections by area group, 2011 to 2031 (in thousands)



Note: MC = Major Cities, RG = Regional Areas, RM = Remote Areas, M = multistate, U = single state.

multistate model for regional areas, and below the single state projection for remote areas.

5 Conclusion

The Australian Aboriginal and Torres Islander (Indigenous) peoples are socially identified. Unlike in some other comparable countries, there are no widespread registries of the Indigenous population in Australia, which means that many people living Australia can and do change their identification at different points in time. This identification change is driven by a number of factors, including social conditions, life course events, and the context in which the identification takes place.

In this paper, we explored the relationships between internal migration and identification change among the Indigenous population in Australia. Our analysis involved combining and smoothing data from the 2011 census and the Australian Census Longitudinal Dataset and developing a multistate population projection model that included births, deaths, internal migration, and identification change. We showed that even though natural population increase made up the greatest component of net population change, identification change was an important additional contributor to the growth in the Indigenous population. The interaction between identification change and internal migration also led to a small but important projected spatial realignment of the population, predominantly from more to less remote parts of the country. These results provide important insights into the forces that are driving Indigenous population change in Australia.

By taking advantage of these additional data, and of our improved access to the existing data, we were able to gain a richer understanding of Indigenous population change. Having access to unit-record ACLD data would allow us to develop an even richer model of identification change that could include an interaction between the structural geography used in this paper and administrative boundaries. When results from the 2016 census are linked to the 2006–2011 ACLD (creating three waves of data), we will be able to obtain more stable estimates of identification changes and their relationship with population mobility. Moreover, having access to this expanded linked dataset will enable researchers to investigate whether people who change their identification over one intercensal period have a higher (or lower) probability of changing their status over the subsequent period.

There are other demographic processes that could be analysed alongside identification change. By linking data from the ACLD to births or deaths registries, it would be possible to test whether the newly identified population is subject to other demographic processes that are more akin to those of the rest of the Indigenous population or the rest of the non-Indigenous population.

The model could be extended by identifying two separate non-Indigenous populations. The first population, defined as those at relatively high risk of identification change, would include individuals listed in the census who were born in Australia and had at least one parent born in Australia. The second population, defined as those at relatively low risk of identification change, would include individuals listed in the census who were born overseas, had two parents who were born overseas, or were added to the population through projected international migration beyond the base year. Distinguishing between these two populations in both the calculation and the application of rates of identification change would likely improve the accuracy of projections of future population change.

While extensions of the model and the use of new data sources are possible, we have shown in this paper that careful analysis of identification change and its interactions with internal migration has the potential to increase our understanding of future Indigenous population developments, and to enable both government and community organisations to adopt more effective and forward-looking approaches to policy design.

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The end of population aging in high-income countries

Warren C. Sanderson, Sergei Scherbov and Patrick Gerland*

Abstract

Will the population of today's high-income countries continue to age throughout the remainder of the century? We answer this question by combining two methodologies, Bayesian hierarchical probabilistic population forecasting and the use of prospective ages, which are chronological ages adjusted for changes in life expectancy. We distinguish two variants of measures of aging: those that depend on fixed chronological ages and those that use prospective ages. Conventional measures do not, for example, distinguish between 65-year-olds in 2000 and 65-year-olds in 2100. In making forecasts of population aging over long periods of time, ignoring changes in the characteristics of people can lead to misleading results. It is preferable to use measures based on prospective ages in which expected changes in life expectancy are taken into account. We present probabilistic forecasts of population aging that use conventional and prospective measures for high-income countries as a group. The probabilistic forecasts based on conventional measures of aging show that the probability that aging will continue throughout the century is essentially one. In contrast, the probabilistic forecasts based on prospective measures of population aging show that population aging will almost certainly come to end well before the end of the century. Using prospective measures of population aging, we show that aging in high-income countries is likely a transitory phenomenon.

* Warren C. Sanderson (corresponding author), Department of Economics, Stony Brook University, Stony Brook 11794-4384, New York, USA
Email: warren.sanderson@stonybrook.edu

Sergei Scherbov, Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW, WU), International Institute for Applied Systems Analysis, Schlossplatz 1, 2361 Laxenburg, Austria

Patrick Gerland, United Nations Organization, Department of Economic and Social Affairs (DESA), Population Division, Two UN Plaza, Room DC2-1934, New York, NY 10017, USA

These authors contributed equally to this work.

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1 Introduction

What is the likely future of the population aging trends observed in today's high-income and high middle-income countries? Will the populations of these countries grow older continuously? If the answer is 'yes', then policy-makers should think about how to adjust to this continuous aging process, perhaps by adjusting regulations with respect to migration. But if the answer is 'no', then such adjustments may not be necessary. High-income and high middle-income countries are home to more than half of the world's population, and are the places where the challenges associated with population aging are now the greatest.

The effects of population ageing differ widely by country, as they depend on each country's specific demographic history and policy environment. Our focus in this paper is on providing background information for use in policy discussions, rather than on proposing policies for specific countries. Here, we investigate whether the current aging trends in today's wealthier countries are likely to continue throughout the century using probabilistic population forecasts (Raftery et al. 2012), and examine new measures of population aging that are adjusted for changes in life expectancy (Sanderson and Scherbov 2017, 2013, 2010; Lutz, Sanderson and Scherbov 2008). Our data come from UN (2015b). Previously in Lutz, Sanderson and Scherbov (2008, supplementary material), we presented forecasts of new measures of population aging for the world and its regions without associated probabilities. In Sanderson, Scherbov and Gerland (2017), we presented examples of Bayesian hierarchical probabilistic forecasts of new and conventional measures of population aging, but for four countries only: China, Germany, Iran, and the US.

2 Materials and methods

2.1 Definitions of measures of population aging

Population aging is frequently measured using changes in the proportion of the population categorized as old and changes in the median age. The *conventional proportion of the population categorized as old* is measured as the proportion of people who are above a fixed chronological age. Here, we use age 65 as the conventional old-age threshold. The *prospective proportion of the population categorized as old* is the proportion of people with less than a fixed remaining life expectancy. Here, we use a fixed remaining life expectancy of 15 years (Sanderson and Scherbov 2005; Lutz, Sanderson and Scherbov 2008; Sanderson and Scherbov 2010, 2013).

The conventional median age of a population is the age that divides the population into two subgroups of equal size. The *prospective median age* is defined as the age in the life table of a standard year in which people have the same remaining life expectancy as they have at the median age of the population in the current year. A mathematical description of how the prospective median age is computed is given Appendix A.1. Both the prospective proportion of the population categorized as old and the prospective median age are specific examples of measures of aging that take the characteristics of people into account. The general framework for the study of characteristic-related ages has been presented in Sanderson and Scherbov (2013, 2017). The conventional median age of the population depends solely on the age structure of the population. Half of the people in the population are older than the conventional median age. But it is also the case that half of the people in the population are older than the prospective median age, when their ages are adjusted to reflect changes in life expectancy. In Sanderson and Scherbov (2005, 2013, 2017), we have shown that when life expectancy increases, the prospective median age could decrease even if the conventional median age has increased.

2.2 Definitions of high-income and upper middle-income countries

Future distributions of conventional and prospective median ages and the conventional and prospective proportions of the population categorized as old were computed from 1,000 stochastic trajectories of population age structures and associated life tables over the 2015-2100 period for high-income countries and upper middle-income countries, as defined by the World Bank. These trajectories were provided by the UN's Population Division (UN 2015b).

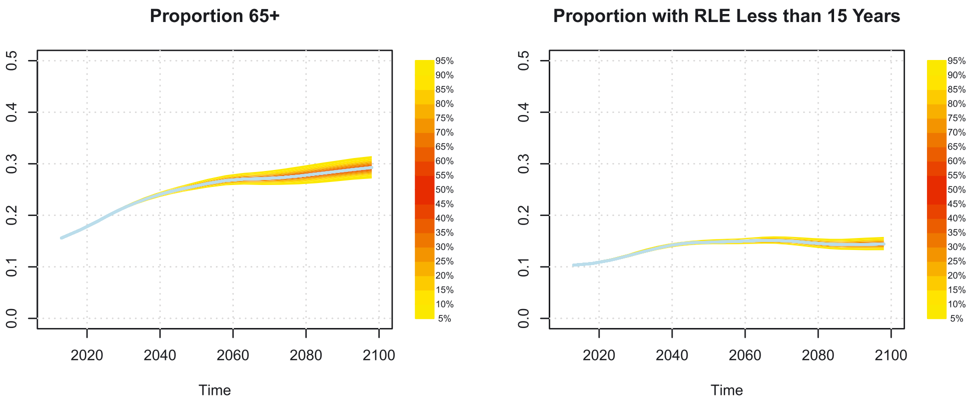
The high-income countries are the 89 countries and territories with the highest levels of Gross National Income per capita in 2014, as measured by the World Bank. In 2015, these countries accounted for 19 percent of the world's population. The upper middle-income countries are the 56 countries with the highest Gross National Income per capita after the high-income countries. That group includes China and the Russian Federation, as well as Albania, Botswana, Iraq, Mexico, Romania, and South Africa. In 2015, these countries accounted for 33 percent of the world's population. The UN mortality trajectories assume that life expectancy at older ages will generally increase throughout the century.

3 Results

3.1 Proportions of populations categorized as old

In Figure 1, we show the evolution over time of the probability distributions of the conventional proportion of the population who are counted as old, and its prospective analog for high-income countries. In 2015, the conventional proportion of the population categorized as old in these countries was 16.3 percent. The median forecast of this proportion rises to 25.8 percent in 2050, with a 90 percent prediction interval of 25.1 to 26.6 percent. The forecasts indicate that the increase in the conventional proportion of old people in the population will slow between 2060 and

Figure 1:
Proportions aged 65+ and proportions with remaining life expectancy (RLE) of 15 years or less. Evolution of probability distributions of the conventional proportion of the population counted as old and its prospective analog, World Bank high-income countries, 2015–2100



Source: 1,000 trajectories from UN (2015b) and authors' calculations.
Note: The thick line in the middle indicates the median of the distribution, and the legend to the right of the chart indicates percentiles.

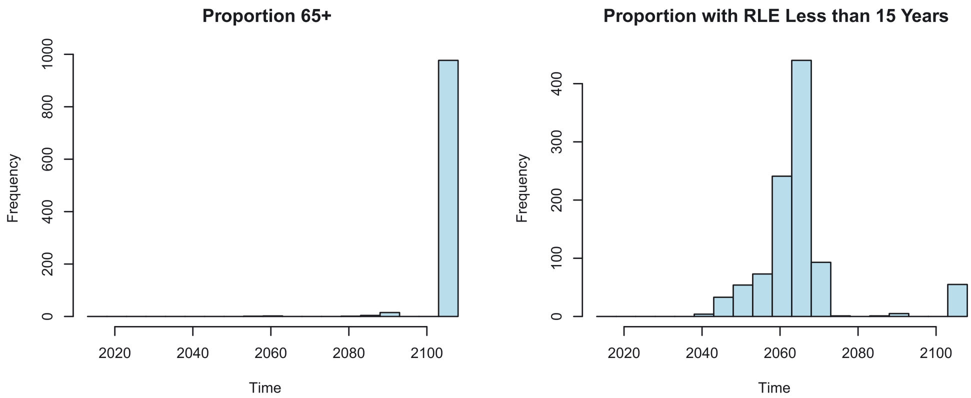
2080, and will then speed up again. By 2100, the median forecast of the proportion of the population categorized as old is 29.4 percent, with a 90 percent prediction interval of 27.2 to 31.6.

The median forecast of the prospective proportion of the population counted as old is around 10.4 percent in 2015. This proportion increases to around 14.6 percent in 2045, with a 90 percent prediction interval of 14.2 to 15.1; and is roughly stable for the following three decades. The median forecast of this proportion is 15.1 in 2070, with a 90 percent prediction interval of 14.4 to 15.9 percent; and falls to 14.5 in 2100, with a 90 percent prediction interval of 13.3 to 15.8.

In Figure 2, we show the histograms of the dates at which the conventional and prospective proportions of the population reach their maxima. Over 95 percent of the stochastic trajectories of the conventional proportion of the population counted as old peak in 2095 or beyond. In contrast, around eight percent of the stochastic trajectories of the prospective proportion of the population counted as old peak after 2070. The conventional proportion of the population categorized as old suggests that aging will likely continue throughout the century. In contrast, the prospective proportion of the population categorized as old indicates that aging will likely end well before the end of the century.

If the prospective old-age threshold was based on a remaining life expectancy of 10 years, the proportions of old people in the populations of high-income countries would peak later, with almost all trajectories reaching a maximum by 2075. If the

Figure 2:
Histograms of dates of reaching a maximum. Histograms of the dates at which the conventional and the prospective proportions of populations counted as old (with remaining life expectancy (RLE) of 15 years or less) reach their maximum, World Bank high-income countries, 2015–2100



Source: 1,000 trajectories from UN (2015b) and authors' calculations.

prospective old-age threshold was based on a remaining life expectancy of 20 years, the maxima would be reached slightly earlier. Regardless of which prospective old-age threshold is used, the proportion of trajectories peaking beyond 2095 in high-income countries never exceeds one percent. We present these findings in more detail in Appendix A.2.

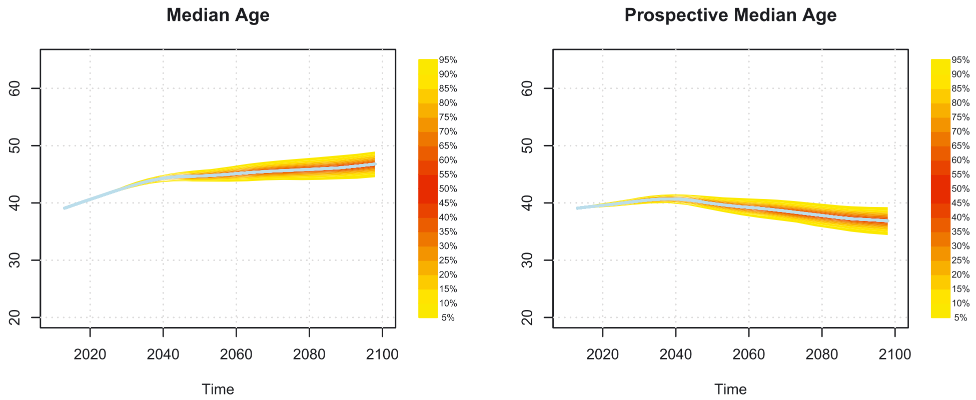
In Appendix A.3, we provide the analogs to Figures 1 and 2 for upper middle-income countries. We show that in these countries, the prospective proportions of the population categorized as old also generally peak before the end of the century.

3.2 Median ages

In Figure 3, we show the probability distributions of the conventional and the prospective median ages for high-income countries. We compute the prospective median ages as the ages in the life table of 2015, in which people have the same remaining life expectancy as at the median age in specific years (see Appendix A.1 for a mathematical exposition). The 2015 life table was interpolated on the basis of the UN life tables for 2010–15 and 2015–20 (UN 2015b).

In 2015, the conventional and the prospective median ages were both 39.6 years. The median forecast of the conventional median age is 44.7 for 2050, with a 90 percent prediction interval of 43.7 to 45.7; and is 47.0 in 2100, with a 90 percent prediction interval of 44.8 to 49.3. The median probabilistic forecast of the conventional median age increases rapidly from 2015 to 2040, and the probability

Figure 3:
Conventional and prospective median ages. Evolution of the probability distributions of the conventional median age and its prospective analog, World Bank high-income countries, 2015–2100

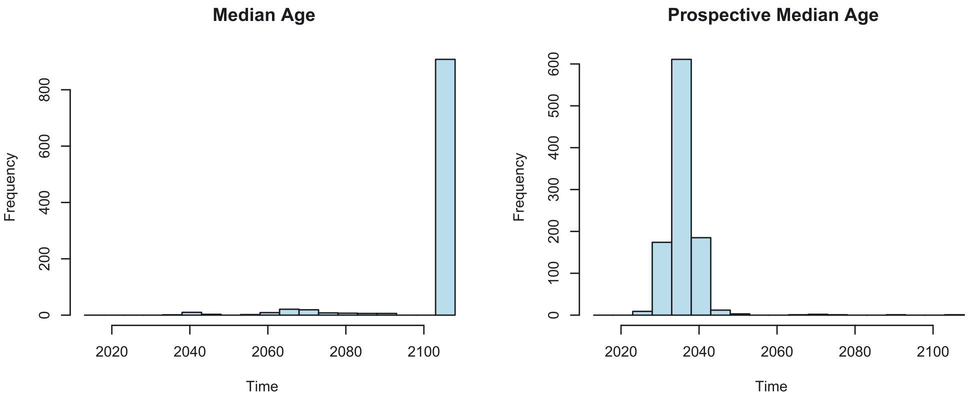


Source: 1,000 trajectories from UN (2015b) and authors' calculations.
Note: The thick line in the middle indicates the median of the distribution, and the legend to the right of the chart indicates percentiles.

that it would ever be lower than its 2015 value at any time during this century is essentially zero. The median forecast of the prospective median age also tends to increase between 2015 and 2040. In 2040, the median forecast of the prospective median age is 40.7, and the 90 percent prediction interval for the prospective median age is between 39.9 and 41.5. By 2100, the median forecast of the prospective median age is 36.7, and the 90 percent prediction interval is between 34.3 and 39.2. On the basis of the UN's probabilistic forecasts, it is highly unlikely that the prospective median age of the population of the high-income countries will be higher in 2100 than it was in 2015.

In Figure 4, we show the corresponding histograms of the years in which the conventional and the prospective median ages reach a peak in the high-income countries. In 89 percent of the stochastic trajectories, the peak of the conventional median age is reached in 2095 or beyond. The increases in the conventional median age do not suggest that population aging will come to a clear end in the high-income group during this century. The data for the prospective median age do, however, indicate that population aging will come to a clear end in these countries during this century. It is expected that by 2050, over 99 percent of the stochastic trajectories of prospective median ages will reach their peak. When measuring population aging using the prospective median age, the end of population aging in the high-income group is projected to be less than four decades away. It is also expected that the prospective median age in upper middle-income countries will peak well before the end the century. We present these findings in Appendix A.4.

Figure 4:
Histograms of dates of reaching maximum. Histograms of the dates at which the conventional and the prospective median ages reach their maximum, World Bank high-income countries, 2015–2100



Source: 1,000 trajectories from UN (2015b) and authors' calculations.

4 Conclusion

Changes in age structure measures in high-income and middle high-income countries are primarily driven by changes in fertility and mortality rates. In the long run, holding mortality and migration rates fixed, a decrease in fertility results in faster aging because it both increases the proportion of older people in the population and increases the population's median age. Moreover, in the long run, holding fertility and migration rates fixed, a decrease in mortality rates at older ages increases both the conventional proportion of the population who are old and the population's median age, but it decreases the prospective proportion of the population who are old and the population's prospective median age (Sanderson and Scherbov 2015).

The UN forecasts for high-income and upper middle-income countries generally assume nearly constant or slowly rising fertility. While past fertility declines will lead to increases in aging in the next few decades, fertility is generally forecast to change slowly after 2015. Conventional measures of aging indicate that aging will increase relatively rapidly in the short run because of past fertility declines, and then more slowly due to increases in life expectancy at older ages. While prospective measures of aging also show that aging will rise relatively rapidly in the short run because of past decreases in fertility, these measures project that aging will decrease in the long run due to increases in life expectancy at older ages.

In the high-income and upper middle high-income groups, some increases in the prospective proportion of the population who are old and in the prospective median age could occur after the middle of the century. However, almost all of the predicted increases in these measures will have occurred by then, as those regions are currently experiencing their most rapid periods of population aging.

We began by asking whether high-income countries as a whole will experience a century of population aging. When we use measures of aging that take changing life expectancy into account, the answer is that such a scenario is unlikely, as the application of these adjusted measures indicates that the speed of aging is currently at its peak. We have shown that in high-income countries, the pace of population aging will soon slow, and will very likely come to an end well before the end of the century. This does not mean that all of the problems associated with population aging will magically disappear. Adjusting to population aging will still be challenging, but there is no point in exaggerating the challenge through mis-measurement.

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Appendix

A.1 Formal definition of prospective median age

Let $e(a, t)$ be remaining life expectancy age a in year t, and let $a_m(t)$ be the median age of the population in year t. Using the life table of year t, life expectancy at age $a_m(t)$ is $e(a_m(t), t)$. It is possible to find the value of life expectancy at age $a_m(t)$ in other years as well. In year s, that life expectancy would be $e(a_m(t), s)$. For example, the median age in year t could be 40. In year t, life expectancy at age 40 could be 35. In this case, $e(a_m(t), t) = 35$. Now, we can also find life expectancy at age 40 in another year, denoted by s. Let us suppose that life expectancy at age 40 in year s is 37 years. In this case, $e(a_m(t), s) = 37$.

The prospective median age is the age in the standard year, denoted by s, where people have the same remaining life expectancy as at the median age in year t.

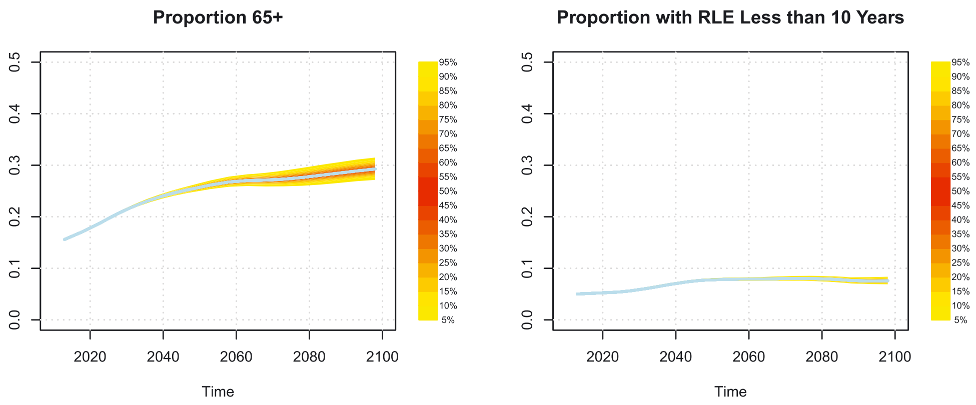
Formally, the prospective median age can be derived from the following equation:

$$e(pma(t, s), s) = e(a_m(t), t)$$

where $pma(t, s)$ is the prospective median age in year t using year s as a standard.

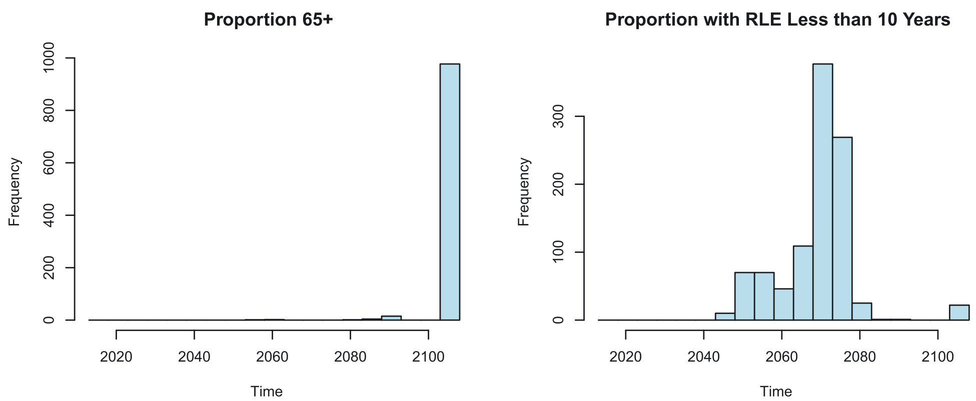
A.2 Sensitivity to the choice of the old-age threshold

Figure A.1:
Proportions aged 65+ and proportions with remaining life expectancy (RLE) of 10 years or less. Evolution of the probability distributions of the conventional proportion of the population counted as old and its prospective analog, World Bank high-income countries, 2015–2100



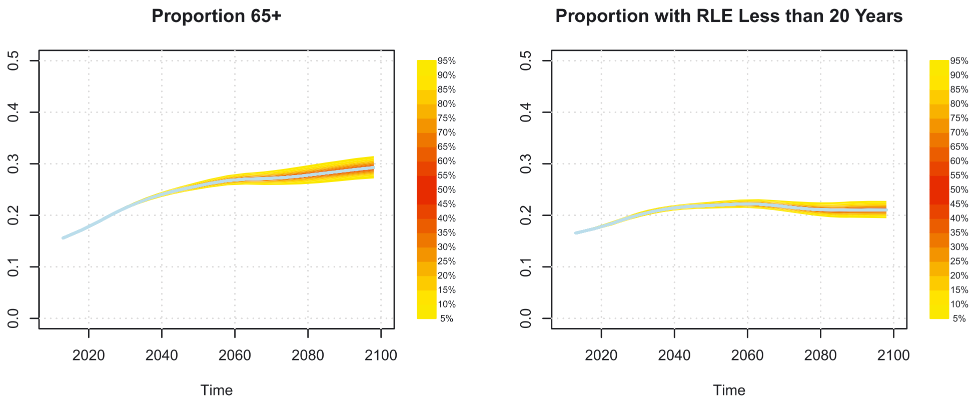
Source: 1,000 trajectories from UN World Population Prospects (UN 2015b) and authors' calculations.
Note: The thick line in the middle indicates the median of the distribution, and the legend to the right of the chart indicates percentiles.

Figure A.2:
Histograms of dates of reaching maximum. Histograms of the dates at which the conventional and the prospective proportions of populations counted as old reach (with remaining life expectancy (RLE) of 10 years or less) their maximum, World Bank high-income countries, 2015–2100



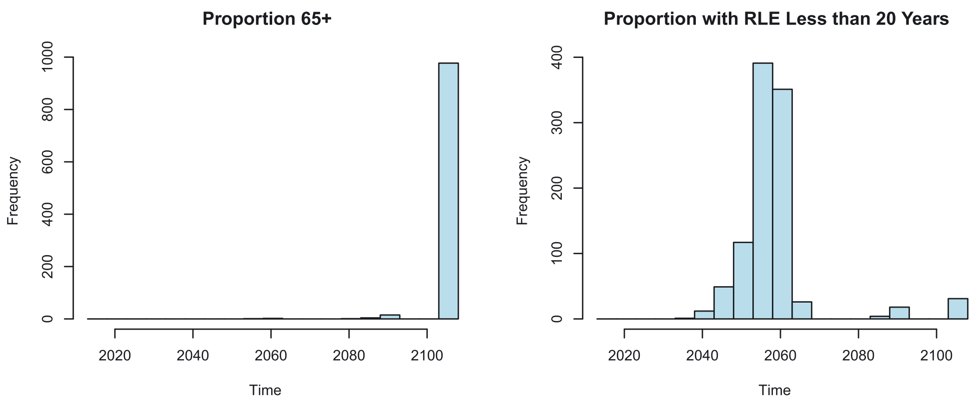
Source: 1,000 trajectories from UN World Population Prospects (UN 2015b) and authors' calculations.

Figure A.3:
Proportions aged 65+ and proportions with remaining life expectancy (RLE) of 20 years or less. Evolution of the probability distributions of the conventional proportion of the population counted as old and its prospective analog, World Bank high-income countries, 2015–2100



Source: 1,000 trajectories from UN World Population Prospects (UN 2015b) and authors' calculations.
Note: The thick line in the middle indicates the median of the distribution, and the legend to the right of the chart indicates percentiles.

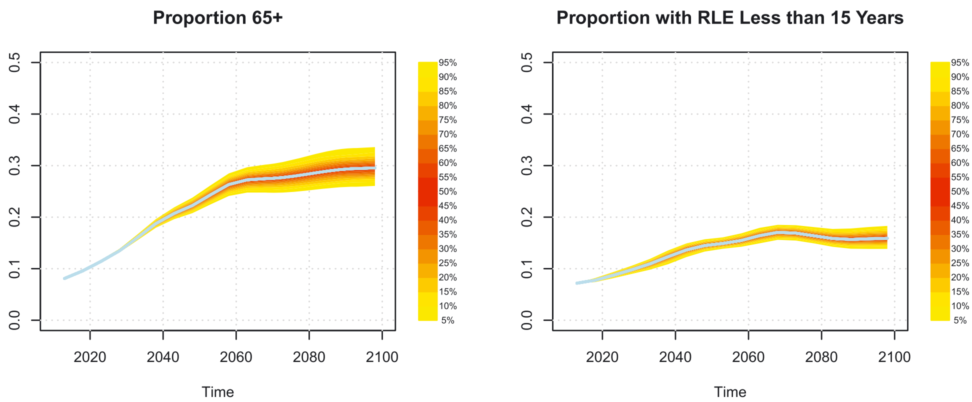
Figure A.4:
Histograms of dates of reaching maximum. Histograms of the dates at which the conventional and the prospective proportions of populations counted as old reach (with remaining life expectancy of 20 years or less) their maximum, World Bank high-income countries, 2015–2100



Source: 1,000 trajectories from UN World Population Prospects (UN 2015b) and authors' calculations.

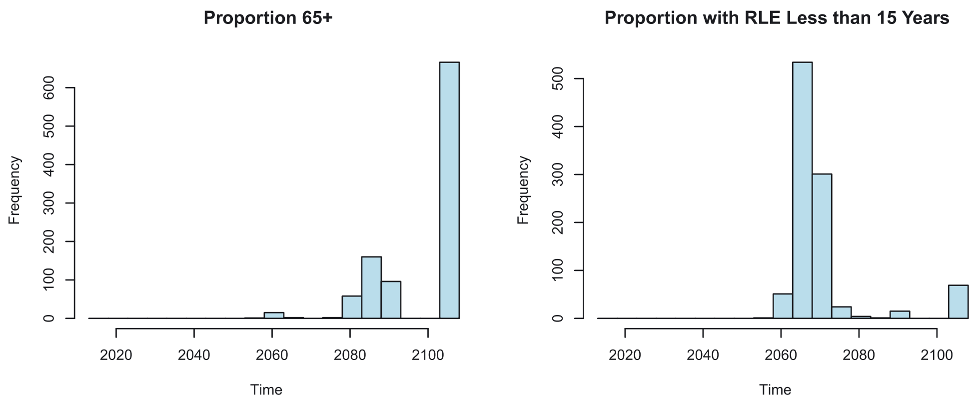
A.3 Conventional and prospective proportions of upper middle-income countries counted as old

Figure A.5:
Proportions aged 65+ and proportions with remaining life expectancy (RLE) of 15 years or less. Evolution of the probability distributions of the conventional proportion of the population counted as old and its prospective analog, World Bank upper middle-income countries, 2015–2100



Source: 1,000 trajectories from UN World Population Prospects (UN 2015b) and authors' calculations.
Note: The thick line in the middle indicates the median of the distribution, and the legend to the right of the chart indicates percentiles.

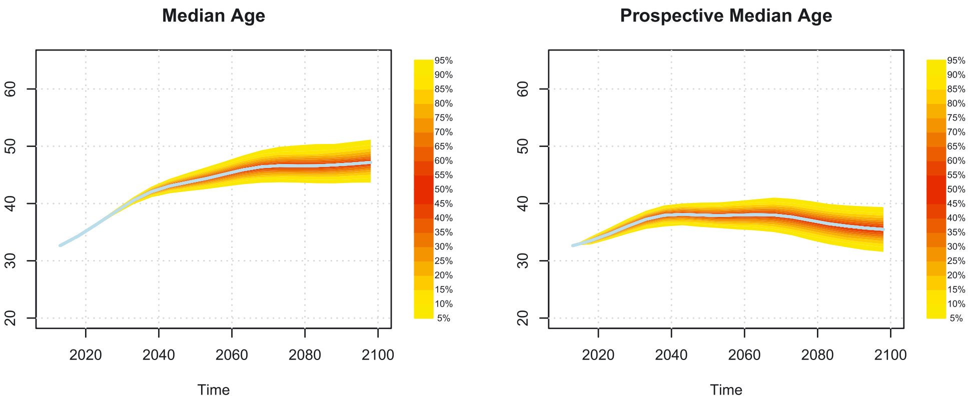
Figure A.6:
Histograms of dates of reaching maximum. Histograms of the dates at which the conventional and the prospective proportions of populations counted as old (with remaining life expectancy (RLE) of 15 years or less) reach their maximum, World Bank upper middle-income countries, 2015–2100



Source: 1,000 trajectories from UN World Population Prospects (UN 2015b) and authors' calculations.

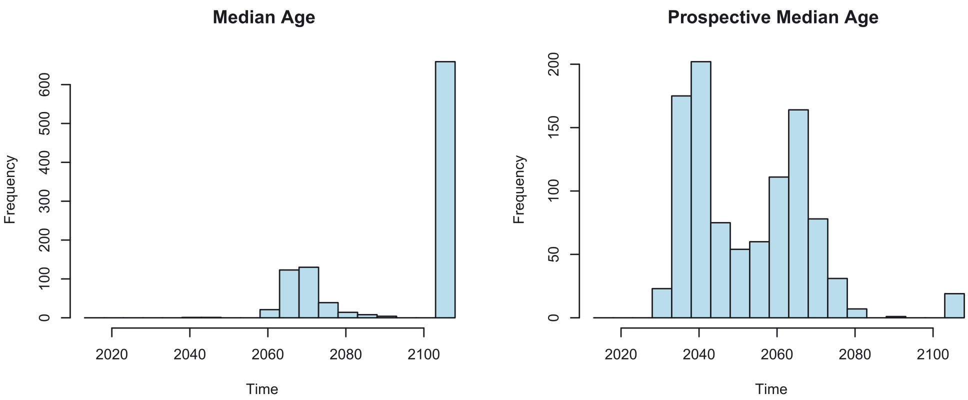
A.4 Conventional and prospective median ages of upper middle-income countries

Figure A.7:
Conventional and prospective median ages. Evolution of the probability distributions of the conventional median age and its prospective analog, World Bank upper middle-income countries, 2015–2100



Source: 1,000 trajectories from UN World Population Prospects (UN 2015b) and authors' calculations.
Note: The thick line in the middle indicates the median of the distribution, and the legend to the right of the chart indicates percentiles.

Figure A.8:
Histograms of dates of reaching maximum. Histograms of the dates at which the conventional and the prospective median ages reach their maximum, World Bank upper middle-income countries, 2015–2100



Source: 1,000 trajectories from UN World Population Prospects (UN 2015b) and authors' calculations.

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From intentions to births: paths of realisation in a multi-dimensional life course

Maria Rita Testa and Francesco Rampazzo*

Abstract

The adult lives of women and men are shaped by a wide range of choices and events pertaining to different life domains. In the literature, however, pregnancy intentions are typically studied in isolation from other life course intentions. We investigate the correspondence of birth intentions and outcomes in a life course cross-domain perspective that includes partnership, education, work, and housing. Using longitudinal data from the Generations and Gender Surveys, we examine the matching processes of individuals' birth intentions with subsequent outcomes in Austria, Bulgaria, France, Hungary, and Lithuania. The results show that the intention to change residence is directly correlated with having a child among men and women living in a union, and that the intention to enter a partnership is correlated with childbearing among single men, but not among single women. Furthermore, we find that the intention to change jobs is inversely correlated with an intended childbirth, while it is directly correlated with an unintended childbirth. These findings suggest that the transition paths from birth intentions to birth outcomes should encompass a multi-dimensional life course perspective.

1 Introduction

The interplay of individual life paths is a key dimension for understanding why couples do not always achieve their previously stated childbearing goals. With a few exceptions (e.g., Barber 2001; Philipov 2009), the link between fertility intentions and outcomes has been assessed in the literature in isolation from intentions and analogous links in other life course domains. With the aim of filling this gap,

* Maria Rita Testa (corresponding author), Wittgenstein Centre (IIASA, VID/ÖAW, WU), Vienna Institute of Demography/Austrian Academy of Sciences, Welthandelsplatz 2, 1020 Vienna, Austria
E-mail: maria.rita.testa@oeaw.ac.at

Francesco Rampazzo, University of Southampton, UK

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we study in this paper the link between birth intentions and outcomes using a multidimensional perspective, and following adult individuals in several areas of life, including partnership, education, work, and housing. These domains are closely interrelated, and all of them influence the family formation process.

The incompatibilities or conflicts between the roles of parent, student, and worker have contributed considerably to the decline in and the postponement of fertility observed in all developed countries (Gauthier 2007). In many countries, the traditional sequence of family events has been replaced by a de-standardisation of the life course, which means that patterns of family formation are becoming increasingly heterogeneous, and do not follow a predefined sequence. In the de-standardisation process, biographies become open and dependent upon decision-making, and are removed from the traditional precepts and certainties, as well as from external controls and general moral laws (Beck and Beck-Gernsheim 1995). This process goes hand-in-hand with the increased number of options that individuals are able to choose from, and that they expect to make decisions about. To study the increasingly complex sequencing of family life courses, approaches that encompass a multidimensional life course perspective are needed (Berrington et al. 2015).

We address this challenge and expand the existing literature on reproductive intentions by studying the intention-behaviour link within the framework of a number of different life intentions of adult individuals. Our research question is as follows: How does a multidimensional life course plan affect the translation of birth intentions into birth outcomes? Which of the life course intentions other than childbearing ease or hinder the realisation of birth intentions? We focus on a set of alternative intentions for which cross-national longitudinal data are available: education, partnership, work, and housing. These intentions are interrelated with the childbearing sphere of life, and thus influence the family formation process.

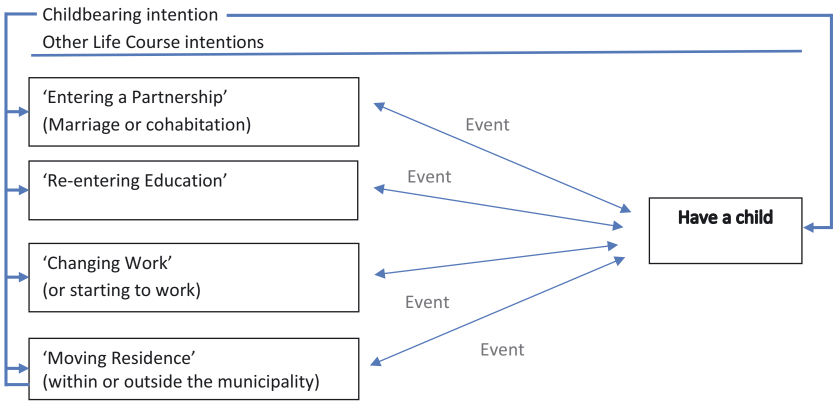
2 Theoretical background

From a life course perspective, a biography can be seen as a sequence of biographical transitions in different domains that are interdependent. Individuals decide on which activities they will perform in different life course domains on the basis of their goal-related aspirations and expectations. Raising children, being employed, getting an education, and owning a house are interrelated lifetime goals that positively contribute to a person's subjective well-being. In this range of options, fertility is a goal-seeking behaviour over the life course, while parenthood is either an ultimate or an intermediate goal that is expected to improve the individual's social well-being through the affection and the social approval that arises from the parent-child relationship (Huinink and Kohli 2014).

The life course approach is based on several principles, including those of situational imperatives, linked lives, agency, and life stage (Elder et al. 2003). The principle of agency refers to a subject constructing her/his life course and biography as a self-monitored actor within the particular opportunities and constraints s/he faces. For example, two or more persons who have the same socio-economic background may nonetheless follow different residential move and occupational career paths. Social scientists usually refer to the concept of agency as the intrinsic human capacity to make choices and act (Giddens 1984), or as the personal resources that are brought to bear when taking action. In this latter definition, agency can be measured empirically and operationalised by psychological concepts like self-efficacy (Bandura 1997). The concept of agency is crucial in life course research because the process of individualisation, accelerated social change, and the uncertainty of the modern 'risk society' (Beck 1992) have made status passages increasingly conditional, and thus impose agentic behaviour upon the individual. People do not merely follow institutionally prescribed pathways; but actively participate in societal domains like education, the labour market, and family. Thus, a subject constructs her/his life course as a self-monitored actor within historical socio-economic circumstances. Heinz (1996) has argued that individuals are biographical actors, and as such they do not simply follow social norms, or engage in subjective utility-maximising behaviour, but pursue their own goals and biographical plans while evaluating structural opportunities and institutional constraints.

To put the principle of agency to work in empirical research, the rational choice theory or any other theory of action may be applied. One theory that is commonly cited in the study of reproductive decision-making is the theory of planned behaviour (Billari et al. 2009; Ajzen and Klobas 2013; Dommermuth et al. 2011; Mencarini et al. 2014). According to this model, intentions are the result of three groups of factors: attitudes towards the behaviour; the perceived norms formed under the influence of social pressure; and the perceived behavioural control, or the extent to which individuals think they can exercise control over factors that have a major influence on their behaviour. This last group of factors is close to the concept of self-efficacy proposed by Bandura (1997). Within the framework of the TPB theory, some scholars have studied attitudes towards goals that compete with childbearing, such as educational attainment, professional career development, and consumer spending (Barber 2001; Barber et al. 2002; Barber and Axinn 2005). Using US longitudinal data, Barber (2001) provided evidence that attitudes towards alternative behaviours are background factors that influence the three blocks of determinants of childbearing intentions in the TPB. Similarly, Philipov (2009) showed that in Bulgaria, the intention to pursue higher education competes with childbearing; whereas the intention to enter employment, or the status of actually being employed, facilitates the realisation of childbearing intentions. The studies by Barber (2001) and Philipov (2009) both predicted that competing life domains would influence the paths through which childbearing intentions are translated into actual behaviour. The first study (Barber 2001) assumed, however, that the mechanism of influence works mainly through the formation of new attitudes affecting childbearing intentions, while the second study (Philipov 2009) posited that competing intentions have a direct influence on both birth intentions and the

Scheme 1:
Intentions in several life course domains and their influence on childbearing



Note: The effects of life course intentions on the likelihood of having a child is twofold: one is merely due to the cross-domain intentions and the other is due to the corresponding cross-domain events. Because of a lack of accurate data, we restrict the analysis to the effects exerted by life course intentions.

realisation of birth intentions. In this paper, we concentrate on the cross-domain influence of other life course intentions on births. We do not deny that life course intentions may have an effect on birth intentions as well. But given the constraints on the available data, we prefer to restrict the empirical analysis to the effects of life course intentions on childbirth.

When two events in different life domains compete with each other and cannot be realised at the same time, the individual may decide to either give up definitively on one of them, or establish a temporal order of the events over the life course. The conflict between the events can sometimes resolve itself spontaneously over the course of life. For example, being enrolled in education may conflict with the formation and the realisation of a woman's pregnancy intentions at early reproductive ages; but later on, after the woman has already made the transition to parenthood, her intention to return to education can be complementary with her birth intentions and birth outcomes. In the life course theory, the different domains of life and the decision-making processes that govern transitions to different life states are assumed to be interrelated. Education, partnership, childbearing, work, and housing are examples of different 'careers' that are simultaneously present in a person's life. Each of these careers consists of a number of transitions, or changes of state, and the durations (length of time) between these transitions will vary (Elder 1985; Elder et al. 2003). Events in one career can hinder, enable, delay, or anticipate events in others; a phenomenon known as 'interdependencies of parallel careers' (Dykstra and van Wissen 1999). The organisation of one's own life course implies the existence of a complex decision-making process (Blossfeld et al. 2005) in which intentions are a main component. In this paper, we study such decisions before they are implemented in the form of a behavioural outcome by looking at the relationship between birth and other life course intentions on the one hand, and birth intentions and birth outcomes on the other (Scheme 1).

3 Research hypotheses

Over the life course, individuals often have a large number of competing life goals (Blossfeld et al. 2005). The wide range of available choices make the decision-making process complex and the paths to realisation highly heterogeneous. The multiple roles individuals occupy simultaneously can make it challenging for them to fulfil their reproductive intentions. Understanding the impact of these intentions on childbearing requires the formulation of specific research hypotheses for each life course domain.

Being in a partnership is a precondition for having children (Schoen et al. 1999), regardless of whether the partnership is formalised through marriage. Hence, we expect to find that *the intention to enter a union is positively correlated with the birth of a child among single men and women* (Hypothesis 1a). Moreover, since being married indicates that the partners have a higher level of reciprocal commitment (Hiekel and Castro-Martin 2014), we anticipate that *the intention to marry is positively correlated with the birth of a child among cohabiting men and women* (Hypothesis 1b).

There is ample literature on the conflict between enrolment in education and childbearing. Previous studies have found that the tasks associated with these life domains cannot be easily reconciled (Blossfeld and Huinink 1991; Billari and Philipov 2004). We extend these findings to the case of the return to education.[1] We therefore expect to find that *the intention to return to education reduces the likelihood of having a child for both singles and couples* (Hypothesis 2).

Work competes with childbearing because of opportunity costs, which are normally higher for women than for men, as in most couples and societies mothers perform most of the household and childcare duties (Thomson and Brandreth 1995). Similarly, a job change might be associated with individual aspirations for career advancement, which could negatively influence childbearing (Philipov 2009). Based on the dominant age norm, young adults (ages 18–39) in particular may be expected to prioritise pursuing a working career over childbearing. Hence, we anticipate that *the intention to start working or to change jobs is inversely correlated with childbearing for both singles and couples* (Hypothesis 3).

[1] Only a very tiny percentage of our available sample (3%) consisted of individuals who were still in education and exposed to (the intention to) complete their studies. For this reason, we focused on the intention to return to education.

A move to another municipality, or to another dwelling within the same municipality, is often associated with an attempt to improve one's socio-economic status. Individuals frequently move because they want to live in a bigger flat or house, which is in turn likely to create suitable conditions for childbearing. Alternatively, individuals may move because they plan to expand their family; i.e., the move may be an anticipatory relocation to adapt to a growing household size (Vidal et al. 2017). Hence, we expect to find that *the intention to change residence is positively associated with childbearing for both singles and individuals living in a union* (Hypothesis 4).

4 Data, measures, and models

We used two follow-up waves of the Generations and Gender Surveys (GGS) for five European countries, including Austria, Bulgaria, France, Hungary, and Lithuania. As the Generations and Gender surveys are part of an international programme that uses an international questionnaire, GGS data are suitable for cross-national comparative analyses (Vikat et al. 2007). It should be noted, however, that the extent to which the country questionnaires have been harmonised, and the overall quality of each national survey dataset, can vary (Fokkema et al. 2016).

The national surveys were conducted in different years within the 2003–2013 period. The intervals between survey waves were three years in France, Lithuania, and Bulgaria and four years in Austria and Hungary.[2] We selected only men and women of reproductive ages (ages 18–49) who provided valid answers to the questions on short-term fertility intentions at the first round of the survey, which resulted in a sample of 14,439 respondents, including 3,129 single men and women and 11,310 individuals living in a union. In the paper, the analysis refers to the pooled country dataset. Within this sample, Bulgaria and Hungary have the largest sample sizes, while Austria and France have medium sample sizes, and Lithuania has the smallest sample size (Table 1).

The birth of a child is the outcome variable. Respondents who were re-interviewed at the second wave were asked whether they had a child during the period between the surveys ('Did you have a child in the last three years?'). The consistency of this variable has been cross-checked with information coming from the household grid questionnaire items from which we recovered the date of birth of each family member. Female respondents who were already pregnant at the time of the first survey (748 in the pooled country dataset) were excluded from the analysis because it was not clear whether their answers referred to the child they were currently expecting or to the next child; thus, the intended births included in

[2] Sensitivity analysis showed that the different time spans between the two survey waves in the different countries did not have a statistically significant effect on the likelihood of having a child.

the analysis are expected to occur at least nine months after the date of the first survey.

The intention to have a child, as measured at the time of the first survey, is the key explanatory variable. The survey question reads: "Do you intend to have a child in the next three years?" The item has four response options: *definitely yes*, *probably yes*, *probably not*, and *definitely not*. The same options were included in the questions regarding the other intentions. The question about the intention to return to education is phrased as follows: "Do you intend to return to education in the next three years?" The intention items pertaining to the partnership domain are: "Do you intend to start living with a partner in the next three years?" or "Do you intend to marry in the next three years?" The intention items pertaining to the work domain are: "Do you intend to change companies or start a business in the next three years?" or "Do you intend to take a job or start a business in the next three years?" Finally, the intention to change residence is measured with the following question: "Do you intend to move in the next three years?" In this item, a move refers to a general change of residence, regardless of whether it is in the same municipality.

For the sake of simplicity, birth intentions were computed on a binary scale that groups together the probably and definitely yes answers and the probably and definitely not answers. This approach was necessary because some countries, like Hungary, coded childbearing intentions on a binary scale, rather than on a four-category scale. Individuals with missing information for births or any of the other life course intentions variables were excluded from the analysis. Missing records accounted for 12% of the country pooled dataset, and were almost evenly distributed across countries.[3]

Life course intentions other than those related to education were coded as dichotomous variables. The intention to return to education was computed by contrasting those individuals who intended to experience the event with a category that groups together those individuals who had not been asked because they had not been exposed to the event (e.g., those who were enrolled in education could not return to education) with those individuals who reported a negative answer. This latter group was retained as a separate dummy in the models only if the related effect was statistically significantly. To measure the intention to change jobs, we merged together the binary variable indicating a job change (for those individuals who were already employed) and the binary variable indicating the transition from unemployed/inactive to employed (for those individuals who were not employed). This approach enabled us to deal with the problem that some individuals were not exposed to the risk of experiencing the event of interest. The intention to change residence can be experienced by all individuals regardless of their characteristics; thus, a simple dichotomous variable indicating the change has been computed for this life domain.

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[3] Sensitivity analysis did not show a noticeable selection effect based on this reduction of the initial target sample.

The control variables include age, gender, educational attainment (partner's educational attainment), marital status, and employment status (partner's employment status). All of the variables were considered as measured at the time of the first survey. The country dummies estimated the cross-national variance in the probability of having a birth. Summary statistics for model covariates (also broken by parity) can be reviewed in Table 1.

Woman's age, the only numeric variable, was centred on the rounded mean values of 29 and 31 among single men and women, and of 37 and 35 among men and women living in a union. The level of education was a three-category variable, with low, medium, and high levels corresponding to levels 0–2, 3–4, and 5–6 of the International Standard Qualification of Education. The intention to marry was included in the models run on couples; while the intention to enter a relationship, either marriage or cohabitation, was included in the models run on singles. Employment status had the following four categories: employed, unemployed, not active, enrolled in education, and retired or other. The sub-sample of singles was evenly distributed across men and women. The men and women in this sub-sample were similarly likely to have a high level of education level (62% of men and 57% of women) and to be employed (about 58% of men and women). However, 33% of single women, but just 11% of single men, already had a child. Around three out of four individuals living in a union were married (78%), two out of three were highly educated, and more than half had a partner with a medium level of education (55% of men and 64% of women). Finally, majorities of both men and women in a couple were employed (86% of men and 67% of women) and had a partner who was employed (64% of men and 86% of women) (Table 1).

Logistic regression models were performed separately on singles and individuals living in a union because the two categories referred to different stages of each individual's life course, and thus required different sets of predictor variables. Because we did not want to reduce the already stratified sample sizes, we pooled together individuals at different parity statuses, even though the marked differences between the transition to parenthood and the transition to a higher-order birth would have required us to perform a separate analysis. This methodological choice enabled us avoid ending up with a fragmented analysis based on very small sample sizes, which would have generated weak empirical results.

5 Results

5.1 Birth and other life course intentions

Around 70% of men and women expressing an intention to have a child had other life course intentions as well: 34% had one other intention, 27% had two other intentions, and 15% had three or more other intentions. It is thus clear that for the adults in the sample, decision-making was often multidimensional. Figure 1

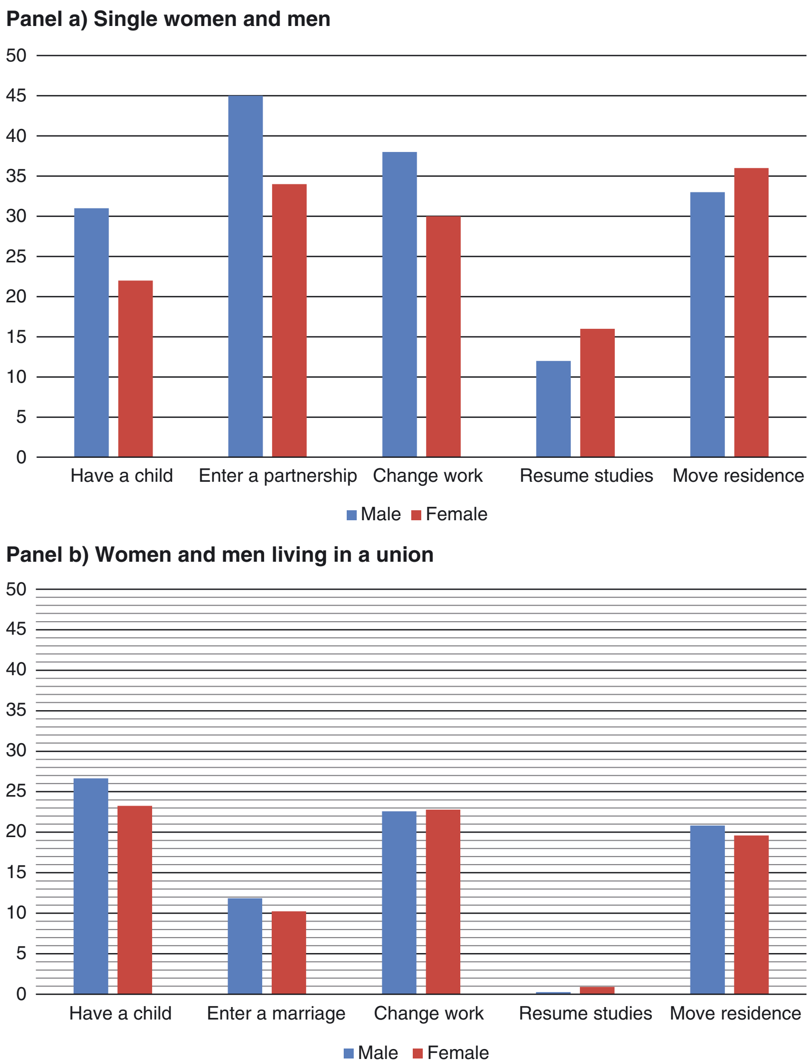
Table 1:
Distribution of the control variables used in the regression analysis. Per cent values

		Singles		Couples	
Control variables		**Male**	**Female**	**Male**	**Female**
Age	Age (mean)	29.09	30.71	37.00	35.24
Gender	Female	49.86	50.14	41.78	58.22
	Male	50.14	49.86	58.22	41.78
Parity	No child	98.78	77.56	14.15	12.92
	One or more children	11.22	32.44	85.85	87.08
Relationship status	Cohabiting			21.91	21.12
	Married			78.09	78.88
Educational attainment	Low level	22.63	32.12	18.09	18.73
	Medium level	15.64	10.96	11.13	11.16
	High level	61.73	56.92	69.97	69.25
Partner's educ. attainment	Low level			5.63	4.57
	Medium level			55.39	63.47
	High level			38.98	31.97
Employment status	Employed	58.01	58.64	85.75	66.67
	Unemployed	20.06	13.19	9.87	10.66
	Housework	0.06	2.68	0.45	18.94
	Student	16.28	22.43	0.5	1.35
	Other	5.58	3.06	3.42	2.38
Partner's employment status	Employed			64.36	86.11
	Unemployed			10.52	9.11
	Housework			21.07	0.22
	Student			1.56	0.57
	Other			2.49	3.93
Countries	Austria	24.10	25.81	16.67	18.91
	Bulgaria	55.38	44.3	27.85	32.15
	France	20.51	29.89	17.15	17.37
	Hungary			31.88	26.79
	Lithuania			6.45	4.77
Sample size		*1560*	*1569*	*4618*	*6435*

Note: In Hungary and Lithuania, singles were not interviewed.

displays the univariate distribution of each of these life course intentions by gender, and separately for singles and couples. The intention to have a child was reported by 31% of single men and 22% of single women (Figure 1, panel a). This was not

Figure 1:
Birth intentions and other life course intentions by gender. Pooled country dataset



the most frequently expressed intention, as individuals were more likely to report having intentions in the education, work, and housing domains: 45% of men and 34% of women said they intend to enter a partnership, 37% of men and 30% of women said they intend to change jobs, and 33% of men and 36% of women said they intend to move house. Finally, 12% of men and 16% of women said they intend to return to education. Intentions to make changes in the work and partnership domains were more common among men, while intentions to make changes in the housing and educational domains were more common among women. Birth intentions were more common among men than among women (Figure 1, panel a).

Individuals living in a couple were most likely to express an intention to make a transition to a different status in the domains of childbearing, work, and housing. The gender differences were very small in this sub-group: 26% of men and 24% of women said they intend to have a child, 23% of men and 24% of women said they intend to change job, 21% of men and 19% of women said they intend to move house, and 12% of men and 10% of women said they intend to marry. The intention to return to education was expressed by less than 1% of the individuals living in a union (Figure 1, panel b).

In order to estimate the effects of all of the intentions studied – including of birth and other life course intentions – on the probability of having a child, we ran a logistic regression analysis that included the various life course intention variables, as well as a set of variables that controlled for the socio-demographic characteristics of adult individuals. We present the outcomes of the analysis in the next section.

5.2 Realisation of birth intentions

In the models for single men and women, none of the other life course intention variables was significant, with the exception of 'enter a partnership', which was positively associated with a childbirth. Age was negatively correlated with childbearing, but having already had at least one child was positively correlated with further childbearing. Highly educated men were less likely than medium educated men to have a child. Single men and women living in Austria were more likely to have a child than their counterparts living in Bulgaria (Table 2, panel a). Lithuania and Hungary could not be included in this analysis because questions about these intentions were posed only to respondents living in a union.

The outcomes of the models for individuals living in a union suggest that the intention to change residence increased the likelihood of having a child (Table 2, panel b). This result was robust across all three models. None of the other life course intention variables had a significant influence on the likelihood of having a child. Childbirth was negatively correlated with age and parity: the older an individual was, the less likely s/he was to have a child; and the more children the individual had, the less likely s/he was to have another child. Women were less likely than men to have a child. Furthermore, the birth of a child was negatively associated with a high educational level among men, but not among women. The partner's educational level displayed a U-shaped pattern, whereby the probability of having a child was highest for individuals with a partner in the low or in the high educational level category. Being a housewife increased the chances of having a child among women. Being unemployed increased the likelihood of having a child among men only. Men and women in Austria and in Hungary were more likely to have a child than their counterparts in Bulgaria. The results were similar for France,

Table 2:
Panel a) Logistic regression on having a child for singles. Beta coefficients

Variables	Labels	All	Male	Female
Intentions variables				
Childbearing	Have a child, yes	0.917***	0.707**	1.035***
		(0.202)	(0.284)	(0.291)
Partnership	Enter a partnership, yes	0.278	0.647**	−0.0772
		(0.198)	(0.291)	(0.281)
Education	Return to education, yes	−0.225	−1.324	0.379
		(0.604)	(−1.010)	(0.808)
Work	Change jobs, yes	−0.112	−0.413	0.123
		(0.223)	(0.323)	(0.321)
Residence	Move house, yes	0.278	0.249	0.323
		(0.179)	(0.257)	(0.255)
Control variables				
Age	Age	−0.063***	−0.038*	−0.090***
		(0.0166)	(0.0228)	(0.0254)
	Age squared	−0.008***	−0.007**	−0.009***
		(0.002)	(0.003)	(0.003)
Gender	Female	0.0834		
(ref. Male)		(0.181)		
Parity	At least one child	0.763***	1.006***	0.683*
(ref. No child)		(0.264)	(0.388)	(0.358)
Education	Low level	0.0952	0.471	−0.0474
(ref. Medium level)		(0.469)	(0.638)	(0.716)
	High level	−0.584**	−0.607*	−0.562
		(0.243)	(0.329)	(0.365)
Employment	Unemployed	0.008	−0.134	0.203
(ref. Employed)		(0.268)	(0.389)	(0.379)
	Housework	0.416		0.584
		(0.569)		(0.717)
Country	France	−0.584	−1.210*	−0.219
(ref. Bulgaria)		(0.479)	(0.692)	(0.698)
	Austria	0.636***	0.323	0.929***
		(0.206)	(0.296)	(0.299)
Constant		−4.065***	−3.386***	−4.380***
		(0.760)	(0.970)	(1.052)
Sample size		3,129	1,560	1,569

Note: Standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 2:
Panel b) Logistic regression on having a child for couples. Beta coefficients

Variables	Labels	All	Male	Female
Intentions variables				
Childbearing	Have a child, yes	1.943***	1.821***	1.998***
		(0.073)	(0.106)	(0.101)
Partnership	Get married, yes	0.0636	−0.0269	0.197
		(0.121)	(0.179)	(0.164)
Education	Return to education, yes	0.532	−1.210	(a)
		(0.895)	(−1.235)	
Work	Change jobs, yes	−0.0115	−0.0946	0.0894
		(0.093)	(0.132)	(0.132)
Residence	Move house, yes	0.263***	0.328***	0.210**
		(0.074)	(0.107)	(0.102)
Control variables				
Age	Age	−0.246***	−0.177***	−0.506***
		(0.023)	(0.025)	(0.051)
	Age squared	−0.005***	−0.004***	−0.013***
		(0.001)	(0.001)	(0.002)
Gender	Female	−0.275***		
(ref. Male)		(0.0803)		
Parity	At least one child	−0.325***	−0.353***	−0.273**
(ref. No child)		(0.093)	(0.135)	(0.130)
Education	Low level	0.355	0.225	0.535
(ref. Medium level)		(0.250)	(0.357)	(0.357)
	High level	−0.224*	−0.355**	−0.213
		(0.118)	(0.169)	(0.169)
P Education	Low level	0.372**	0.399*	0.312
(ref. Medium level)		(0.164)	(0.229)	(0.240)
	High level	0.216***	0.270**	0.195*
		(0.073)	(0.109)	(0.101)
Employment	Unemployed	0.350**	0.549***	0.147
(ref. Employed)		(0.139)	(0.205)	(0.193)
	Housework	0.442***		0.258
		(0.130)		(0.163)
	Enrolled	−0.182	1.545	−0.511
		(0.493)	(0.985)	(0.340)

Continued

Table 2:
Panel b) Continued

Variables	Labels	All	Male	Female
P. employment				
(ref. Employed)	Unemployed	−0.090	−0.194	−0.019
		(0.135)	(0.202)	(0.185)
	Housework	0.521***	0.555***	
		(0.116)	(0.124)	
	Enrolled	−0.162	0.0295	−0.403
		(0.252)	(0.307)	(0.448)
Country	France	0.424*	0.366	0.371
(ref. Bulgaria)		(0.253)	(0.365)	(0.357)
	Hungary	0.982***	0.946***	0.991***
		(0.105)	(0.155)	(0.144)
	Austria	1.220***	1.226***	1.254***
		(0.112)	(0.170)	(0.153)
	Lithuania	0.221	0.197	0.250
		(0.179)	(0.256)	(0.251)
Constant		−5.772***	−5.687***	−7.818***
		(1.000)	(1.429)	(0.450)
Sample size		11,310	4,900	6,410

Note: Standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.
(a) The variables were dropped from the regression because the cell size was too small.

but in this case, statistical significance was reached in the pooled gender models only (Table 2, panel b). Interestingly, among cohabiting couples, the intention to get married did not significantly influence the likelihood of having a child (Table 2, panel b). Childbearing was conditioned on being in a union, irrespective of whether the union took the form of cohabitation or marriage.

Our observation period was relatively short (i.e., three years). As the life course intentions (i.e., intentions related to partnership, education, work, and housing) of individuals who intend to have (more) children might be strongly interrelated, endogeneity issues arise. To minimise the risk of endogeneity, we conducted a supplementary analysis of cross-domain intentions; the results of which are displayed in the appendix (Table A.1 panel (a) and panel (b)). In this analytical setting, the chances of birth occurrences were modelled conditionally to the sign of birth intentions, or to whether they are positive or negative. This methodological approach was chosen based on the distinctive and primary role of the intention to have a child in the transition path to a birth outcome. Indeed, women and men who do not intend to have children, but have other life course intentions, have already prioritised other life goals over childbearing, and will necessarily have a lower risk of having a child. The results of this analysis show that among singles who said they intend to have a child, only age, parity, and education significantly influenced their chances of having a child, with age having a negative effect and education and parity having positive effects. If an individual did not intend to have a child, having the intention to move house and living in Austria also positively influenced the likelihood of having a child. Among individuals who were living in a union, the intention to change jobs negatively affected their chances of having a child if they had planned to have a child, and it positively affected their chances of having a child if they had not planned to have a child. Furthermore, the intention to move house was statistically significant and positively correlated with childbearing. Among the control variables, parity status lost its significance if the birth was not planned, which means that whether an individual had a child did not depend on whether there were already children in the family.

6 Concluding remarks

Most of the studies on the correspondence between birth intentions and birth outcomes have considered this link in isolation from intention-behavioural links pertaining to other life course domains. In this paper, we examined for the first time the matching process between birth intentions and birth outcomes in a cross-domain context including partnership, education, work, and housing. All four of these domains contribute to the family formation process. Key to our analysis was the study of the intersection of the different life course domains through the link between life course intentions in education, partnership, work, and housing on the one hand; and childbearing on the other. The argument for using this approach is that the interdependence across life domains affects not only the observed events, but the preceding corresponding intentions. For each selected life course domain, we tested whether the corresponding life course intention facilitated or competed with the realisation of the birth intention using a longitudinal dataset derived from the Generations and Gender Surveys (GGS). The study included data from Austria, Bulgaria, France, Hungary, and Lithuania. Consistent with previous literature (Steele and Ermisch 2016), we found that intending to change residence was closely correlated with the realisation of childbirth. Hypothesis four is, however, only partially supported, because the result applied only to men and women living in a union. This finding might indicate that moving house plays a role only if the family is already consolidated in a stable relationship, and that the quantity or the quality of the living space only matters if the size of the family is expanding through the birth of a child. This empirical finding is in line with those of previous studies, according to which individuals with children are more likely than childless individuals to relocate (Vidal et al. 2017). In addition, the GGS data provided evidence that the intention to enter a partnership was correlated with the intention to have a child. However, this result held for single men, but not for single women. Hence, hypothesis one is only partially supported by the data. A possible explanation for this gender difference is that compared to men, women might want to wait longer to have a child after starting a union, or they might simply plan the events of entering a partnership and having a child more independently of each other. On the other hand, the results did not show that the intention to get married had any significant effect on childbearing, which implies that the precondition for childbearing was living in a union, regardless of whether the union was formalised through marriage. This result is consistent with only some of the existing literature. While it has been shown that marriage is a relevant predictor of the realisation of birth intentions (Schoen et al. 1999), a study conducted in France found no differences between cohabiting and married unions in the realisation of birth intentions (Testa and Toulemon 2006). Cross-national variations could be related to cross-country differences in the meaning of cohabitation (Hiekel and Castro-Martín 2014), but we were not able to test this claim in this paper because of the small national sample sizes.[4]

Finally, we could not find empirical evidence in support of hypothesis two regarding the intention to return to education, or for hypothesis three regarding the intention to change job. Both variables were found to be negatively correlated with childbearing among men and positively correlated with childbearing among women. We could speculate that changes in these life domains complement the realisation of birth intentions for women, but compete with the realisation of birth intentions for men. As this result was not statistically significant, further investigation in this direction should be pursued once more longitudinal data become available. Interestingly, our findings indicate that the effect of the intention to change jobs on having a child was conditioned on whether the birth intention was positive or negative. If the birth intention was positive, changing jobs conflicted with childbearing; whereas if the birth intention was negative, changing jobs was complementary with childbearing (see the results of the supplementary analysis reported in the appendix).

The analysis conducted in this paper contains some suggestions for further research in the field. In particular, we hope that our approach will eventually be expanded to additional countries and over time. In this paper, each country's specific institutional, economic, and normative characteristics have merely been treated as control variables. However, taking these dimensions into account is important for understanding the heterogeneity in cross-domains intentions. For example, the degree of competition between work and family choices depends on the options people have to combine these spheres of life in different institutional settings (Gauthier et al. 2016). Hence, observing a larger set of countries that also includes some Southern and Northern European countries could help to clarify the effects of institutional factors on childbearing. In addition, studying a larger number of groups (i.e., countries) could allow for the combination of micro- and macro-level analysis in a unitary (multi-level) framework. Using a longer period of observation could

[4] Our finding that the interaction terms 'intention to marry * country' were not statistically significant might be due to the small national sample sizes.

help to shed light on the conditional structure of multiple life course intentions, and to determine the differences in the chances of realisation depending on the temporal priority of each life goal in a single individual's life. Moreover, using a longer period would make it possible to study the cross-domain effect of the events, rather than just those of the intentions. Over a longer time period, a larger number of links between life course intentions and outcomes would emerge, and these links could be ordered temporally in relation to births and other life course domains.

Our contribution to the literature is twofold. First, we extended previous studies on childbearing intentions to a broader set of alternative life course intentions, and emphasised that some intentions do not compete with, but rather facilitate the realisation of childbearing intentions (e.g., moving house). Second, by studying the influence of cross-domain intentions on the realisation of childbearing intentions, we provided an original interpretation of the mismatch between birth intentions and birth outcomes, and urged the inclusion of several life course intentions in studies on the predictive power of birth intentions. Despite the limits of this research, we have shown that various life course intentions – and especially the intention to enter a partnership and the intention to move house – matter, and need to be considered in the analysis of childbearing and the family life course.

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Appendix tables are on the following pages.

Appendix

Table A.1:
Panel a) Logistic regression on having a child for singles with and without the intention to have a child. Beta coefficients

Variables		**Intended to have a child**	**Did not intend to have a child**
Intentions variables			
Partnership	Enter a partnership, yes	0.332	0.391
		(0.266)	(0.318)
Education	Return to education, yes	−0.712	−0.0126
		(0.774)	−1,168
Work	Change jobs, yes	−0.0784	−0.108
		(0.320)	(0.317)
Residence	Move house, yes	0.110	0.482*
		(0.266)	(0.254)
Control variables			
Age	Age	−0.0739***	−0.0475**
		(0.0242)	(0.0242)
	Age squared	−0.00916***	−0.00594*
		(0.00271)	(0.00323)
Gender (ref. Male)	Female	0.234	−0.0173
		(0.262)	(0.257)
Parity (ref. No child)	At least one child	0.608*	0.834**
		(0.368)	(0.391)
Education (ref. Medium)	Low level	−0.138	0.311
		(0.699)	(0.662)
	High level	−0.613*	−0.580
		(0.327)	(0.382)
Employment (ref. Employed)	Unemployed	−0.115	0.171
		(0.370)	(0.396)
	Housework	−0.107	1,107
		(0.747)	(0.969)
Country (ref. Bulgaria)	France	−0.618	−0.528
		(0.722)	(0.676)
	Austria	0.0391	1.286***
		(0.284)	(0.316)
Constant		−4.448***	−2.570*
		(0.971)	(1.383)
Sample size		2,294	835

Note: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.1:
Panel b) Logistic regression on having a child for couples with and without the intention to have a child. Beta coefficients

Variables	Labels	Intended to have a child	Did not intend to have a child
Intentions variables			
Partnership	Get married, yes	0.0964	0.103
		(0.148)	(0.209)
Education	Return to education, yes	1,027	−0.0183
		−1,294	−1,231
Work	Change jobs, yes	−0.217*	0.330**
		(0.112)	(0.162)
Residence	Move house, yes	0.184**	0.260**
		(0.0905)	(0.126)
Control variables			
Age	Age	−0.137***	−0.303***
		(0.0280)	(0.0380)
	Age squared	−0.00272**	−0.00552***
		(0.00107)	(0.00148)
Gender	Female	−0.0373	−0.669***
(ref. Male)		(0.0983)	(0.145)
Parity	At least one child	−0.396***	−0.136
(ref. No child)		(0.105)	(0.200)
Education	Low level	0.115	0.393
(ref. Medium level)		(0.387)	(0.313)
	High level	0.141	−0.380**
		(0.178)	(0.156)
P Education	Low level	0.263	0.508**
(ref. Medium level)		(0.225)	(0.254)
	High level	0.176*	0.231*
		(0.0908)	(0.128)
Employment	Unemployed	0.459**	0.0687
(ref. Employed)		(0.180)	(0.219)
	Housework	0.437***	0.377*
		(0.169)	(0.210)
	Enrolled	−0.263	−0.138
		(0.625)	(0.691)
P. employment	Unemployed	−0.908**	0.140
(ref. Employed)		(0.386)	(0.337)
	Housework	−0.140	−0.0308
		(0.179)	(0.197)
	Enrolled	0.490***	0.354**
		(0.153)	(0.179)

Continued

Table A.1:
Panel b) Continued

Variables	Labels	Intended to have a child	Did not intend to have a child
Country	France	1.238***	−0.462
(ref. Bulgaria)		(0.381)	(0.353)
	Hungary	0.755***	1.137***
		(0.132)	(0.167)
	Austria	1.355***	0.835***
		(0.139)	(0.198)
	Lithuania	0.215	0.205
		(0.213)	(0.328)
Constant		−3.748***	−5.585***
		(1.416)	(1.323)
Sample size		2,727	8,583

Note: Standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

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Towards causal forecasting of international migration

Frans Willekens*

Abstract

International migration is difficult to predict because of uncertainties. The identification of sources of uncertainty and the measurement and modelling of uncertainties are necessary, but they are not sufficient. Uncertainties should be reduced by accounting for the heterogeneity of migrants, the reasons why some people leave their country while most stay, and the causal mechanisms that lead to those choices. International migration takes place within a context of globalisation, technological change, growing interest in migration governance, and the emergence of a migration industry. Young people are more likely than older people to respond to these contextual factors, as they are better informed, have greater self-efficacy, and are more likely to have a social network abroad than previous generations. My aim in this paper is to present ideas for the causal forecasting of migration. Wolfgang Lutz's demographic theory of socioeconomic change is a good point of departure. The cohort-replacement mechanism, which is central to Lutz's theory, is extended to account for cohort heterogeneity, life-cycle transitions, and learning. I close the paper by concluding that the time has come to explore the causal mechanisms underlying migration, and to make optimal use of that knowledge to improve migration forecasts.

1 Introduction

In 2015, approximately 244 million people, or 3.4% of the world's population, were living in a country other than their country of birth (United Nations Department of Economic and Social Affairs, Population Division 2016). While less than 1% of the

* Frans Willekens, Netherlands Interdisciplinary Demographic Institute (NIDI), Lange Houtstraat 19, NL-2511 CV The Hague, The Netherlands
Email: willekens@nidi.nl

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world's population emigrate in a given year (Abel and Sander 2014), the share of people who express a desire to emigrate is much larger. A worldwide Gallup survey conducted in 2005 found that 14% of the world's population aged 15+ (630 million people) would like to move permanently to another country if they had a chance to do so, but that only 3% had started making preparations to leave (Esipova et al. 2011). Thus, while many people express a desire to leave their country, very few actually make such a move.

Forecasting international migration is a huge challenge. According to Bijak and Wiśniowski (2010, 793), international migration is difficult to predict for the following reasons:

a. There is no comprehensive migration theory. The existing theories on migration are partial, addressing only certain aspects of a hugely complex phenomenon.
b. A coherent and harmonised definition of migration across countries and time does not exist, and standardised procedures for measuring migration are lacking.
c. Data on migration are missing, incomplete, or defective. For example, a time series of observations typically includes a few time points only. Moreover, the existing data are not comparable across countries, and the existing information on the causal mechanisms that trigger migration flows is rudimentary.
d. The processes governing migration are inherently random, and are susceptible to factors that are difficult to predict. In addition, a wide range of actors can help to shape international migration flows.

The classical approach to international migration forecasting is to identify regularities in migration trends and to use that knowledge to forecast migration. That approach produces reliable forecasts if the future is a continuation of the past. Forecasters emphasise the need to quantify uncertainties (using probability theory) and to reduce uncertainties by combining data from different sources, including expert judgments on trends. Wolfgang Lutz and colleagues were among the first to introduce expert judgments (Lutz et al. 1998; Lutz and Goldstein 2004) and to quantify the underlying narrative in argument-based scenarios (Lutz and Scherbov 2003). In recent years, the Bayesian approach has become the leading paradigm in probabilistic forecasting (see, e.g., Bijak (2011); Bijak and Wiśniowski (2010); Azose and Raftery (2015); Billari et al. (2014); Disney et al. (2015); Bijak et al. (2016)). It offers a coherent framework for combining data from different sources, and for assessing the multiple uncertainties in forecasting.

Collecting expert knowledge on modelling and prediction is a first step towards developing a knowledge-based forecasting approach. While commenting on population forecasting in general, Keyfitz (1982) expressed scepticism that more demographic knowledge could improve forecasts because the theories of population growth were developed to *explain* population change, not to support forecasting. A decade and a half later, Sanderson expressed optimism when he wrote: "Yes, knowledge can improve forecasts" (Sanderson 1998, 88). Sanderson observed that in the forecasting models he had reviewed, knowledge was incorporated as statistical associations between the time series of the demographic variables to be predicted and the time series of the factors that are known to influence these variables. This *prediction by association* approach makes no reference to the behaviours of individuals, families, and institutions. Keyfitz (1982, 747) noted that this approach circumvents the need for causal understanding. He envisaged a behavioural approach to forecasting in which causal mechanisms are incorporated into forecasting models (Keyfitz 1982, 747). A similar argument was made more recently by Bijak (2015), who asserted that the relatively weak theoretical foundations of demography, and especially the lack of theoretical micro-foundations, make forecasts more uncertain. Mechanism-based forecasting and the predictive validity of demographic theories have occupied demographers ever since Keyfitz asked the question: "Can knowledge improve forecasts?" (for an overview, see Willekens (1992) and Booth (2006)). Progress in mechanism-based forecasting has been slow because (a) the theories were developed to explain, not to predict; and (b) the existing projection models are ill-suited to incorporating causal mechanisms. That situation is changing with the emergence in demography of behavioural theories and actor-based or agent-based models.

My purpose in this paper is to contribute to the development of a projection model that incorporates the causal mechanisms of migration. The presentation of such a model, which requires the operationalisation of the mechanisms in mathematical equations, is beyond the scope of this paper. These mechanisms operate at multiple levels (micro, meso, and macro), and involve a multitude of actors, from individuals to international organisations. These actors operate within institutional and historical contexts. At the highest level, migration is embedded in mega-trends, including globalisation, demographic change, technological change, socio-cultural and political shifts, and climate change (see, e.g., Castles (2010)). The diversity of the actors and the factors that contribute to these trends increases the degree of uncertainty and makes it difficult to produce reliable migration forecasts, particularly during periods of discontinuity.

The paper is structured as follows. In Section 2, I explain why international migration is difficult to predict. The complexity of migration is attributed to (a) the multiplicity of reasons for migration and of the types of migration that result from these diverse motivations; (b) the multiplicity of factors that influence the migration decision-making process; (c) the multiplicity of actors and actions that encourage or facilitate, or discourage or constrain, migration; (d) the politicisation and securitisation of migration; and (e) the absence of harmonised definitions and standardised measurements of migration. I present the main features of the migration forecasting model in Section 3. The point of departure is Wolfgang Lutz's (2012) theory of demographic metabolism, which posits that cohort replacement is the central mechanism of demographic and social change. According to this theory, each new cohort provides an opportunity for social transformation because young people are more likely than older people to adopt new technologies and values. For instance, successive cohorts are increasingly mobile-minded and less nationally oriented (see Striessnig and Lutz (2016)). Providing a detailed description of the model and an assessment of the predictive performance of the model relative to existing migration forecasting models is beyond the scope of this paper. For an operationalisation of some of the mechanisms covered in this paper, the reader is referred to Klabunde et al. (2017). In Section 4, I present my conclusions.

2 Why is international migration forecasting so difficult?

Migration is difficult to predict for the following reasons:

a. There are many motives for migration.
b. Migration is sometimes hard to distinguish from other forms of mobility.
c. A wide range of actors influence migration.
d. Migration is being politicised and securitised.
e. Migration is difficult to measure.

I discuss each of these reasons in this section. Because they introduce major uncertainties, these issues should be considered in migration forecasting. In addition, these challenges should be studied further to identify key processes that can be modelled and incorporated into existing models as mechanisms that help shape international migration.

2.1 Multiple motives for migration

Migration is a possible response to the drive to meet two universal basic needs: security and proximity. The need for security is more than simply the need for safety or the absence of threat. For people to feel secure, they require access to food, water, shelter, income, and health care. They also need access to education, which in turn creates the human capital required to secure access to food and other basic necessities. People's security needs further extend to protection from sudden major losses. To obtain such protection, people must have access to risk management tools, particularly tools for diversifying and sharing risk. People may also migrate to be close to jobs, schools, and other opportunities that are not available at home, but that exist or are perceived to exist elsewhere. Migration is not an end in itself, but a means to an end: i.e., migration is instrumental for gaining access to jobs and other income-generating activities, schools, health facilities, and safety and security.

The reasons for migration, and how these motivations vary over the life course, have been studied extensively (see, e.g., Castles et al. (2014)). But the reasons for migration are changing. Two reasons for migration that have become increasingly important in recent years are gang violence and food insecurity. Gang violence has become a major push factor in Central America's 'Northern Triangle' (El Salvador, Guatemala, and Honduras) (Cantor and Serna 2017).[1] According to a recent study by the UN World Food Programme, food insecurity resulting from climate change, military conflict, population growth, and cash crop dependencies is becoming a push factor worldwide (World Food Programme 2017). Migration is a risk management strategy in situations in which other risk management tools are non-existent. For instance, families may see the migration of one or more family members as a way to diversify sources of income and to create safety valves that can be activated to escape threats that may arise in the future (Stark 1991).

People also migrate to be close to loved ones (proximity). Marriage migration and family reunification are examples of migration in response to proximity needs.

The reasons for migration are diverse, and tend to change over the life course. Thus, migration forecasts need to account for these shifts in the reasons for migration, including over the life course. De Beer (2008) made a strong argument for distinguishing between the main types of migrants and reasons for migration in migration forecasting; asserting that at a minimum, forecasts should differentiate between labour migration, family-related migration, and asylum-seeking. De Beer also advocated differentiating between nationals and foreigners because members of these groups have very different propensities to migrate across national borders. According to De Beer, the number of migrant categories that should be created and the reasons for migration that should be distinguished depend on the purpose of the forecast. For example, different migrant categories may be identified depending on whether the purpose of the forecast is projecting population or providing information to policy-makers. Migrants may have multiple motives, or may be more likely to report the motive they believe increases their chances of (im)migrating successfully (Kusa 2015). Migrants' motives for moving may also vary depending on their living conditions; and certain living conditions may influence some motives more than other. For instance, in order to anticipate the impact of climate change on migration, it is essential to assess the likely impact of climate change on migration motives (The Government Office for Science 2011).

Gaining insight into migration motives can improve forecasts, but it cannot explain why most people who want to emigrate do not actually leave their home country. Answering this question would require us to gain a better understanding of the migration decision-making process, which is often complex and lengthy. A wide range of variables and actors influence the decision to migrate, such as the availability of resources and the existence of a support network. Moreover, even the people who ultimately leave their home country may find that they are unable to settle in the country of their choice, and need to stay in a transit country.

[1] Gang members include US immigrants who joined gangs in US cities, like Los Angeles, and were later deported.

2.2 Multiple forms of mobility

Migration is often not necessary to meet the basic needs of security and proximity. Opportunities to undertake frequent short-term stays abroad and/or to use communication technology may reduce the desire to migrate. As travel and border crossing have become easier, many people are participating in activities and social networks in different countries, and are traveling frequently or periodically. These transnationals, as they are called, identify with groups in different countries. They may have multiple identities, and some have multiple citizenships. There are different kinds of transnationals, including expatriates, people with residences and/or jobs in multiple countries, and irregular migrants.

Some people relocate to gain access to services and opportunities, while others try to gain access without relocating. The growth of telework, crowdsourcing, outsourcing, and the gig economy are developments that are changing the traditional link between physical presence and job access. The availability of distance learning means that people no longer need to migrate to get access to education. Trends in migration and other forms of geographical mobility cannot be understood or predicted without reference to the type of access being pursued, or to the roles of the intermediaries (migration brokers, smugglers, etc.) who facilitate access (Alpes 2017).

Long-term relocation and short-term relocation are part of a continuum encompassing different types of mobility with varying durations of stay. As a result of technological change and reductions in travel costs, people are much more mobile today than they were in the past (Zelinsky 1971). Migration, or a permanent change in a person's usual residence, is an extreme form of mobility that is increasingly being replaced by short-term relocations. Individuals and governments often prefer a sequence of short-term relocations to a long-term relocation, but when repeat migrations (circular migration) are made difficult, people are likely to settle for a long-term relocation (Massey and Pren 2012; Czaika and de Haas 2013). The traditional definition of migration as a relocation for an extended period of time (more than 12 months), which was introduced by the United Nations in 1998 to enhance the international comparability of migration statistics (United Nations 1998), is becoming outdated. Meanwhile, the duration of stay (actual and intended) is becoming increasingly important.

2.3 Multiple actors

To be successful, an emigrant requires support from a wide range of individuals and institutions. These actors may be informal or formal; public or private; and based in the country of origin, of transit, or of destination. The decision to emigrate is often made not by an isolated individual, but by families and households (Stark 1991). Some of these actors might inhibit migration (Massey et al. 1993). People with a wealth of social capital are likely to get informal support, whereas people with sufficient financial means may be able to purchase support or a permanent residence permit.[2] Migration is much more likely if the prospective migrant has a support infrastructure in place, even if using the infrastructure is very costly. The most obvious type of social infrastructure migrants can tap into is offered by family and friends in the countries of origin, transit, and destination. Migration leads to the development of transnational social networks that can in turn trigger and channel new migration flows. In labour-exporting countries, such as the Philippines and Bangladesh, governments offer assistance for migration.

In addition to these informal and public support systems, a migration industry has emerged to support or discourage migrants in the origin, transit, and destination countries; to implement policies, including border controls; to transfer remittances; and to help migrants integrate into the country of destination. Castles et al. (2014, 235) has described the migration industry as a broad spectrum of individuals and institutions who have an interest in migration or earn their livelihood by organising migratory movements. Such actors include travel agents, labour recruiters, brokers, interpreters, immigration lawyers, money transfer agencies, border control agencies, and human smugglers. These actors may, for example, (i) facilitate migration; (ii) assist migrants before departure, during travel, and/or at arrival; (iii) assist governments in managing border security by verifying (biometrically or otherwise) the identities of individuals at border crossings, or by detaining and deporting people who are not authorised to cross the border or stay in the country; or (iv) assist immigrants in transmitting remittances. The authors argued that over time, the migration industry could become the primary motivating force in migratory movements, which would make migration very difficult to control and forecast (see also Gammeltoft-Hansen and Nyberg Sorensen (2013); Cranston et al. (2017)). These actors may pursue different goals, including goals that reflect an individual's ideology or self-interest. Although the roles of such actors have been addressed in the literature, they are largely missing from migration theory (Massey 2015). Europol has estimated that 90% of the more than one million migrants who reached the European Union in 2015 used facilitation services, mostly provided by migrant smugglers (Europol and Interpol 2016).[3] According to Europol and Interpol, most smuggling networks are loosely coordinated along a given route, and manage activities locally through personal contacts and opportunistic low-level facilitators. This observation is consistent with reports from journalists and scientists who have investigated network operations. Research has shown that smugglers are not always involved in organised crime, but sometimes belong to the migrants' own

2 In the US, the EB-5 visa allows applicants to obtain a US green card and permanent residency through an investment that results in at least 10 full-time jobs for US workers for at least two years. Several European countries offer residency and even citizenship in exchange for investment, including investment in residential properties (http://www.eb5investors.com/european-investment-immigration and http://www.eb5investors.com/eb5-basics/international-immigrant-investor-programs)

3 Globally, the criminal migration industry is worth US$35 billion a year (Horwood and Reitano 2016).

social networks and local communities. Users of these operations have reported that law enforcement officers, border guards, and state officials are also involved in smuggling (see, e.g., Kingsley (2016); Crawley et al. (2016)). Smuggling arises from a mismatch between global migration intentions and opportunities for legal immigration. Van Liempt (2016, 6) asserted that there are only few smuggling cases in which it has been proven that organised crime was involved, and concluded that "[t]hese policies of blaming smugglers divert attention away from the fact that smuggling is first of all a reaction to the militarisation of border controls, not the cause of irregular migration" (Van Liempt 2016, 7). For a recent review of research on migrant smuggling, see Sanchez (2017), who argued that "the processes leading to clandestine or irregular migration are not merely the domain of criminal groups. Rather, they also involve a series of complex mechanisms of protection . . . as attempts to reduce the vulnerabilities known to be inherent to clandestine journeys" (Sanchez 2017, 10).

Migration is difficult to predict without understanding the many individual and institutional actors that influence and shape international migration flows.

2.4 Politicisation and securitisation

In destination countries, two perspectives on migration dominate the public debate, and may have far-reaching consequences for the future of migration. The first perspective emphasises the contributions of immigration to economic growth and a sustainable welfare state, and thus describes migration as an opportunity. The second perspective sees immigration as a threat to the national identity, safety, social cohesion and the nation state.

International migration is tied to the concept of the nation state, and that concept is evolving. A government's views on immigration will depend to a large extent on its views on the nation state. The concept of the nation state originated in 1648 with the Peace Treaty of Westphalia (Germany). The Treaty ended the European wars of religion (the Thirty Years' War, 1618-1648, between the Habsburgs and their Catholic allies and the Protestants and their allies; and the Eighty Years' War, 1568-1648, between Spain and the Dutch Republic). The Treaty established a system of political order in Europe based on the concept of co-existing sovereign nation states. As European influence spread across the globe, the concept of sovereign states became central to the prevailing world order. The concept is upheld in the UN Charter. Countries did not control immigration until relatively recently. The British Empire introduced immigration control with the Aliens Act of 1905. The United States introduced immigration control with the Chinese Exclusion Act of 1882.

The concept of nation states legitimates the limitations national governments place on human mobility, both arrivals and departures. Global and transnational forces limit the ability of national governments to enact migration policies and to control migration flows (Sager 2016). The recent growth of transnational networks and multiple citizenship has challenged the sovereignty of nation states (Betts 2011), and that challenge helps explain the unease some people feel about immigration. That feeling becomes stronger when in the sending and the receiving countries controversies arise about the dual loyalty of transnationals who identify with both the country of origin and the country of residence, or about the diaspora engagement policies of some sending countries. In several nation states, people have expressed considerable doubt about the government's ability to control migration flows because of (a) the implications of international agreements (e.g., Schengen; ASEAN countries seeking a single-visa policy similar to that of the Schengen countries; the 1951 Refugee Convention and the 1967 Protocol); (b) the limited effectiveness of authentication and authorisation schemes intended to prevent illegal entries and stays; and (c) threats made by sending and transit countries to use mass migration as an instrument to persuade target countries to change their policies or make concessions (Greenhill 2010, 2016). In response to these developments, many people have come to perceive immigration as a threat to their national sovereignty and national security (securitisation of immigration). These perceptions have major consequences for international agreements. For instance, in 2017 the United Kingdom decided to withdraw from the European Union (Brexit) in 2019, largely in order to 'regain control over immigration'. Several countries responded to the inflow of refugees in 2015 by replacing the long-term humanitarian protections guaranteed by the 1951 Refugee Convention with temporary protections under the 1949 Geneva Convention.

2.5 Migration measurement

The main source of migration data is the population census. Some countries (mostly in Europe) also have population registers. In addition, some countries use sample surveys (border surveys, labour force surveys, household surveys) to measure migration (for an overview, see Willekens et al. 2017b). There is no universal and harmonised definition of migration that all countries in the world use, and there is no standardised measurement of migration. To make census data on migration globally comparable, the United Nations (1998) introduced in 1998 the concepts of long-term migrant (12 months or more) and short-term migrant (between three and 12 months). Only a few countries have adopted the UN definitions of migration. In Europe, the UN definition of long-term migrant was officially adopted in the EU Regulation 862 of 2007. In 2009, the Member States started to publish migration data that are consistent with the UN definition.

The population census and sample surveys usually measure immigration by comparing each respondent's country of current residence and country of residence at some previous point in time, usually at his or her date of birth or at a date one or five years prior to the census. The census does not yield data on emigration. Emigration can be measured by cross-classifying immigration data for all countries of the world. Since such data are not available, the measurement of emigration is considerably more challenging than the measurement of immigration (Dumont and

Lemaitre 2005). Countries with a population register usually rely on administrative data to measure immigration and emigration. A register system requires individuals to report immigration and emigration. When people leave the country without deregistering, emigrants are undercounted and net migration is overestimated. In some countries, such as Poland, residents who migrate to another country do not need to deregister unless they intend to stay abroad permanently. In the 2002–2007 period, Poland registered an annual average of 22,306 emigrants to the 18 EU and EFTA countries considered by de Beer et al. (2010); whereas the destination countries registered a total of 217,977 immigrants from Poland. The 2011 census revealed that 1.9 million residents of Poland (5% of the population) had been living abroad for more than three months (Wiśniowski 2017).

3 Response: demographic metabolism and causal forecasting of migration

In this section, I augment the cohort replacement mechanism, which is the central causal mechanism in Wolfgang Lutz's theory of socioeconomic change, with other mechanisms that should be considered in mechanism-based migration forecasting. The extension accounts for (a) the heterogeneity of cohorts and (b) the changes in personal attributes over the individual life course. Lutz acknowledged these mechanisms (see, e.g., Lutz (2012, 283)), but did not elaborate on them. To accommodate the extensions, the cohort-component model is modified in three directions. First, cohort biographies are replaced by individual biographies. Second, it is assumed that individuals have agency; i.e., the capacity to make choices and to act accordingly. Choices are outcomes of decision processes, which are cognitive processes that vary individually (Willekens et al. 2017a). Third, it is assumed that individual actors are influenced by other actors: e.g., members of the actors' social networks, individual brokers/intermediaries, and private and public institutions and organisations. To accommodate the diversity of actors, individuals are replaced by actors (agents). Actors interact with other actors. These interactions lead to the transmission of resources, information, values, and norms. In turn, these interactions result in a social diffusion mechanism causing social change.

Any model of these actions and interactions is fully consistent with Lutz's theory of socioeconomic change and with the cohort-component model. The cohort-component model, which describes the cohort-replacement mechanism, is the most common demographic forecasting model. The model describes individual mechanisms (e.g., decision processes) and social mechanisms (e.g., social influence and social diffusion).

3.1 Demographic metabolism: from cohorts to individuals

A population changes because the personal attributes of its members change from one generation to the next, and over the life course of each individual (Lutz

2012, 283). A few attributes are fixed (e.g., sex, date, and country of birth), but most change during the life course (e.g., level of education, level of income, and family composition). When personal attributes are fixed at a young age, personal characteristics remain stable throughout the life course, and social change is caused entirely by new cohorts replacing old cohorts (cohort effects). In that case, the cohort-component model is sufficient to predict social change.[4] According to the theory of demographic metabolism, cohorts are "heterogeneous in measurable ways while their characteristics are persistent along cohort lines" (Lutz 2012, 285–286).

Personal attributes influence the propensity to migrate. When attributes are fixed over a lifetime, changes occur when new cohorts replace old cohorts. In such cases, understanding the cohort replacement mechanism is sufficient to assess the impact of personal attributes on migration. Since most personal attributes change during the life course, their effects on migration change. The ages at which these attributes change need to be predicted to determine their effects on migration. For instance, getting married, having a child, and securing a stable job tend to reduce an individual's propensity to migrate. The effects of these events on migration are larger if they occur early in life, when the propensity to migrate is high. While individual differences between cohort members and personal attributes that change in the life course cannot be easily accommodated in population-based models, such as the cohort-component model, they can be easily accommodated in individual-based models (Railsback and Grimm 2012) and micro-simulation models (see Billari and Prskawetz (2003); Willekens (2011); Bélanger and Sabourin (2017)). Individual-based models extend the concept of cohort biography introduced by Ryder (1965, 847). Cohort replacement remains the key driver of change, but cohort members differ and their personal attributes are not stable throughout the life course.

Linking population-based models, such as the cohort-component model and individual-based models, was previously proposed by Keyfitz and Caswell (2005). They observed that formal demographic models provide the framework within which micro-level individual phenomena can be interpreted; concluding that the vital rates and other parameters of demographic models "are, in the end, properties of individuals" (Keyfitz and Caswell 2005, 511). The authors called for new models that relate the vital rates to their determinants "through often complicated causal pathways" (Keyfitz and Caswell 2005, 512). Thus, Keyfitz and Caswell were calling for models that describe causal mechanisms.

To predict cohort biographies *and* individual biographies, multistate models are generally used. They describe the life course in terms of states and transitions between states (Willekens 2005).

[4] Striessnig and Lutz (2016, 310) found strong cohort effects in national and regional (European) identities even during periods of major change, which confirms the predictive power of cohort replacement even during turbulent times.

3.2 Causal forecasting: focus on mechanisms

The call for *causal forecasting* is not new. For many years, scholars have voiced concerns that demographic forecasting models disregard substantive scientific knowledge on the drivers of mortality, fertility, and migration; and on the mechanisms linking drivers and outcomes (Keyfitz 1982; Willekens 1992; Sanderson 1998; de Beer 2000; Bijak 2011, 82ff; Lutz and Goldstein 2004, 3; Wilson and Rees 2005; Booth 2006). According to Herbert Simon, "Without a knowledge of these mechanisms, we cannot predict how variables will co-vary when the structure of the system under study is altered, either experimentally or by changes in the world around us" (Simon 1979, 79). Simon's statement, which applies to both causal analysis and forecasting, is as important today as it was in 1979.

The first call for causal forecasting was probably made by Euler in 1760 (Euler 1970 (1760)). He was the first to establish the causal mechanism that links population structure and the components of change (fertility and mortality). He also distinguished between cohorts in population projections. Euler's work was rediscovered by Sharpe and Lotka (1911), which led to the development of the stable population theory. The cohort-component model and the Lotka equation, which describes a trajectory of births in terms of surviving women, are causal models. They describe the mechanism linking drivers (fertility and mortality) and output (population and births).

Causal models are generative models; they describe the mechanisms through which causes operate and generate effects (see Russo (2009, 19 and 160)). Interest in causal modelling has increased significantly in recent years, as exemplified by the rise of generative social science (Epstein 2007) and analytical sociology (Hedström and Ylikoski 2010; Goldthorpe 2016); and by the growing interest in the micro-level underpinnings of demographic phenomena at the population level (Billari 2015; Courgeau et al. 2017). Sanderson (1998, 88) has advocated the formulation of causal forecasts (Sanderson 1998, 88), while Booth (2006) has called for the development of theory-informed forecasts. The models Sanderson and Booth have described are not causal or generative models in the sense that they represent the mechanisms that generate phenomena at the population level; they are regression models that describe statistical associations between population change and socioeconomic determinants.

Three causal mechanisms should be considered in migration forecasting. The first is the cohort replacement mechanism. The second is the cognitive process of decision-making, with the outcome being the decision to migrate (by country of destination) or the decision to stay. The decision-making process consists of multiple stages. Each stage lasts a certain amount of time to allow the individual to accumulate the information necessary to proceed to the next stage. During each stage, conditions may change or events may occur that cause the individual to reassess the benefits and the costs of migration. A decision to migrate does not automatically lead to a migration event, because intervening factors (e.g., a lack of resources) and actors (e.g., a border control agency) may prevent the person from implementing his or her choice and taking the desired action. In several existing models of migration, migration decision-making is implemented (for a review, see Klabunde and Willekens (2016)). Most models are based on relatively simple behavioural theories (decision theories or action theories). Klabunde et al. (2017) and Willekens (2017) recently used the theory of planned behaviour (Fishbein and Ajzen 2010) to model the migration decision-making process. For a discussion of decision mechanisms and decision theories in the context of individual-based generative models, see Willekens et al. (2017a).

The third causal mechanism that should be considered in migration forecasting is the mechanism that generates and governs interactions between actors and the diffusion processes that may result. Encounters may be random, but whether they result in some type of bonding (ties) depends on individual decision-making processes (Prskawetz 2017). Interactions usually involve the transmission of information (communication) and a transaction (exchange of goods and services). Communication and exchange are easier when the actors are close (geographically) or are similar (socially and/or culturally). Interactions may trigger a diffusion process. Diffusion mechanisms should be considered when seeking to determine the macro-level (population-level) effects of micro-level actions and interactions (Billari 2015; Casterline 2001; Caswell and John 1992; Klüsener et al. 2017).

Actors that influence migration operate at different levels of aggregation, from the individual to the international level (e.g., International Organisation for Migration and UNHCR). Causal models need to incorporate mechanisms at different levels that interact with processes at other levels. Therefore, a causal model is necessarily a multilevel model (Billari 2015; Courgeau et al. 2017). Warnke et al. (2017) proposed a new computer language that facilitates the multilevel causal modelling of demographic phenomena. They applied the language in implementing the computer model of international migration developed by Klabunde et al. (2017).

3.3 Towards a causal forecasting model

A causal forecasting model of migration should, at minimum, have the following characteristics:

1. The model should be an individual-based or micro-demographic model.
2. The actors (agents) should be individuals and institutions/organisations.
3. The actors should have multiple attributes. Changes in attributes imply transitions between states. The traditional cohort-component model distinguishes three transitions only: childbirth, migration, and death. The multistate cohort-component model considers additional attributes and transitions.
4. The actors should have life histories that are operationalised as sequences of states and transitions between states.
5. The individuals should be members of a birth cohort. Cohorts are heterogeneous. The cohort biography should be obtained by aggregating individual life histories, while accounting for the influence on individual life

histories of interactions between the individual and other individuals and institutions.

6. The life courses of identical individuals should differ stochastically. Caswell (2009) called the random difference between individuals *individual stochasticity*. This type of difference should be distinguished from *individual heterogeneity*, which reflects differences in latent or unobserved attributes.
7. The life course of an individual should consist of multiple careers, one for each time-varying attribute. Each career is a sequence of states and transitions between states. In the fertility career, a state represents parity. In the migration career, a state represents a country of residence. Different dependencies between careers may be distinguished (Willekens 1991; Blossfeld 2009).
8. A career should be modelled as an outcome of a stochastic process; more specifically, as a continuous-time Markov process. The parameters should be transition rates. Courgeau (2012, 197 and 253) referred to a group of individuals whose life courses are described by the same probability model as the life course of a *statistical individual*. The life courses should differ only stochastically.
9. Two approaches should be distinguished to determine (in the stochastic process model) the occurrence and the timing of migration and other events in the individual life course. The first approach uses transition rates estimated from empirical data. Transition rates are estimated by relating event counts to the population at risk, weighted by the duration of exposure (Aalen et al. 2008; Willekens 2014). The estimates are maximum-likelihood estimates. The second approach does not use transition rates, but transition rules. These rules are more or less complex heuristics based on decision/action theories and theories of social interaction and diffusion.
10. Time matters. Time should be a continuous variable, and two time scales should be distinguished: age to mark the location of transitions in the individual life course, and calendar time to mark the location of transitions in historical time. Calendar time may be used to account for the historical context early in life and its effect on the life course (cohort effect).
11. In principle, all of the variables in the forecasting model are random. Their values follow probability distributions. The distributions are usually based on a combination of beliefs and empirical evidence. For combining beliefs and evidence, the Bayesian approach is the most appropriate (Azose and Raftery 2015; Bijak 2011). This approach also provides a way of formalising the process of learning; i.e., of updating beliefs in light of new evidence.
12. The forecasting model should acknowledge the different sources of uncertainty, including the model specification, measurement, parameter estimation, heuristics, and exogenous variables used (see, e.g., Bijak (2011, 23ff)).

4 Conclusion

Migration forecasting is extremely difficult because of the diversity of reasons for migration, the possibility that migration will be substituted by other forms of mobility, the multiplicity of actors influencing migration, the politicisation and securitisation of migration, and the conceptual and measurement issues surrounding migration. Most models of migration in use today identify patterns in time series of migration data (usually net migration), and use that knowledge to project migration. However, future migration patterns are likely to be quite different from those in the past because of the challenges mentioned above, and in light of ongoing social transformations, technological changes, and demographic changes. In this paper, I have argued for the use of causal forecasting, which emphasises the causal mechanisms that generate migration. The starting point of this approach is the demographic theory of socioeconomic change proposed by Wolfgang Lutz (2012). While cohort replacement is an important facilitator of change, cohorts are not homogeneous, and personal attributes do not remain fixed throughout the life course. To accommodate these shifts, cohort biographies are replaced by individual biographies of the members of a cohort. By focusing on individual biographies, the interaction between migration and other demographic events in the life course can be modelled relatively easily. In addition, interactions between individuals and between individuals and institutions can be incorporated into the model.

Individual life histories are modelled as continuous-time Markov processes, like in the modelling of cohort biographies. To accommodate the actors who affect migration and to model their influence on potential migrants, the parameters of the Markov model (transition rates) are replaced by individual decision rules or behavioural rules. If these rules are based on migration theory, they can provide a vehicle for the integration of theoretical insights into migration forecasting models. The resulting model is a causal forecasting model that is rooted in Lutz's demographic theory of socioeconomic change, but that extends the existing theory, which operates at the macro (cohort) level, to construct a new theory, which combines the macro level and the individual level. The full specification of a causal forecasting model is beyond the scope of this paper. Several characteristics of such a model have been listed. The ultimate model is an actor-based or agent-based model with multiple levels, in which individuals have agency and make decisions in a stochastic environment, and in which other individuals and institutions influence individual decisions and actions.

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DATA & TRENDS

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Summary of *'Demographic and human capital scenarios for the 21st century: 2018 assessment for 201 countries'*

*Nicholas Gailey and Wolfgang Lutz**

Abstract

In 2016, the Joint Research Centre (JRC) of the European Commission and the International Institute for Applied Systems Analysis (IIASA) agreed to form a partnership, establishing the Centre of Expertise on Population and Migration (CEPAM). The work presented here summarises the first results published by CEPAM. The results reveal clear momentum towards population ageing, and how migration has limited ability to influence the population structure of the EU, especially in the long-run. On the other hand, boosting labour force participation can nullify expected rises in the dependency ratio from population ageing. Globally, the findings show the future of population growth and socio-economic development will be determined by the expansion of education, particularly among girls in Africa. Scenarios of either rapid or stalled development illustrate a large range of possible futures for world population by 2100.

1 Introduction

Any meaningful understanding of the future world hinges on informed projections of how current demographic trends could unfold. In that spirit, the Centre of Expertise on Population and Migration (CEPAM) has developed contrasting scenarios based on the most recent demographic data, analyses, and trajectories

* Nicholas Gailey (corresponding author), Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW, WU), International Institute for Applied Systems Analysis, Schlossplatz 1, 2361 Laxenburg, Austria
Email: gailey@iiasa.ac.at

Wolfgang Lutz, Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW, WU), Vienna, Austria

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for 201 countries. The scenarios cover key population and human capital measures, looking as far into the future as the century's end.

By considering not only age and sex structures, but also educational attainment (in all countries) and labour force participation (in EU member states), this CEPAM volume goes beyond the more limited ambitions of conventional population projections. The results account for key drivers of change and thus help to paint a more complete demographic picture. Ultimately, the purpose of CEPAM's contrasting scenarios is to inform policy-focused assessments of migration flows into the European Union.

This volume serves as an update to the population projections presented in *World population and human capital in the 21st century* (Lutz et al. 2014), which provides a comprehensive summary of scientific arguments about assumptions for future fertility, mortality, migration, and education based on input from more than 550 population experts. The baseline population numbers used in this CEPAM volume incorporate new censuses and survey data up through 2015.

In terms of migration, three rough scenarios are defined – zero migration, constant migration rates taken from the past 60-year average, and double the constant migration rate. The three strongly differing pathways were combined with medium fertility and mortality assumptions to help focus on the sensitivity of population trends to varying migration intensities. These divergent futures also serve as the basis for an expanded set of more detailed scenarios.

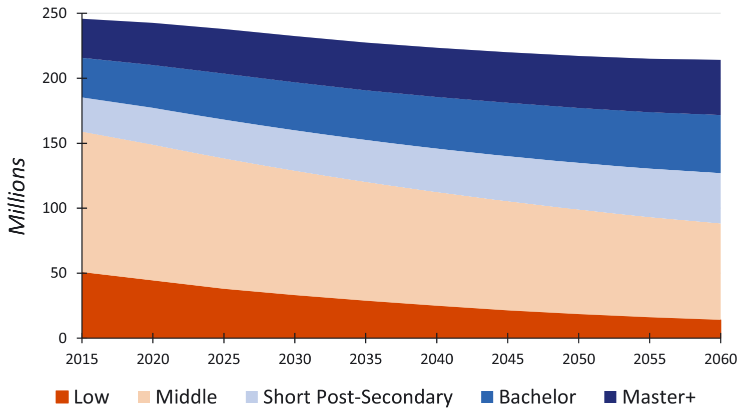
To project populations under varying degrees of socio-economic development, this volume also uses three 'Shared Socioeconomic Pathways', or SSPs. The SSPs compare a world of rapid social development (high education, low mortality, and low fertility) with one of stalled social development (low education, high mortality, and high fertility), and a medium variant between the two.

Almost every country in the world is now moving towards lower fertility, increasing longevity, and higher educational levels. The resulting population ageing will remain largely unavoidable for the EU, regardless of possible changes in migration or fertility. However, developments in labour force participation rates, more productive working lives, and the ongoing automation of labour all suggest a diminishing threat from population ageing. Integrating such understanding into the policy-making process is important for envisioning judicious and realistic policy goals for the future.

In this summary, CEPAM's results are presented under the following sections: *EU Member States and their Future Labour Forces, Projected EU Population Size and Age Composition, and Global Population Futures.*

Lastly, for abbreviated samples of the appendix tables that cover all countries (457 pages of tables in the full volume), we include Nigeria as the most populous African country, and India as the soon-to-be largest country in both Asia and the world.

Figure 1:
Total labour force by education level in the European Union, according to constant participation – CEPAM Medium (SSP2) scenario, 2015–2060



Source: Loichinger and Marois (2018).

2 EU member states and their future labour forces

2.1 A smaller, higher educated labour force

While the absolute size of the EU workforce is expected to be smaller in the coming decades, it is also likely to be more highly educated. As Figure 1 illustrates, the total size of the workforce is projected (under the CEPAM Medium scenario, SSP2[1]) to change from 245.8 million to 214.1 million over the next four decades. The *decline is solely attributable to fewer workers with educational levels of 'upper secondary' and 'lower secondary or below'*. Projected decreases in the size of the labour force come from the population with education levels of low (from 50.7 to 14.0 million) and upper secondary (from 108.2 to 74.2 million).

At the same time, the numbers of workers with a master's degree or higher, a bachelor's degree, or a shorter form of post-secondary education (e.g., technical training) are all projected to increase not only in their proportions of the labour force, but also in absolute terms. Significantly, these *post-secondary groups are expected to grow by almost half (+45%) over the next 40 years*.

National differences exist in the levels and rates of educational increases, but the general trend holds true across all EU countries. Irrespective of various changes to the age structure and labour force size in individual member states, it is anticipated

[1] SSP2 and other Shared Socioeconomic Pathways (SSPs) are detailed in 'Global Population Futures', section 4.

that the human capital of future workers (measured by the highest level of education attainment) will be higher at every age because younger cohorts are spending more years in education than previous generations.

Looking at regional trends within the EU, we see that several eastern member states – the Czech Republic, Slovakia, Poland, Latvia, and Croatia – currently register the highest levels of post-secondary educational attainment. While CEPAM projects that all EU member states will continue moving towards higher educational attainment, Southern member states that currently have the lowest levels – i.e., Portugal, Spain, Italy, and Greece – will make the fastest gains.

In the scenario with constant participation rates, the labour force size remains stable for many western member states, due in part to the movement of working-age citizens from eastern member states. As a result of these same migration trends, the labour force size decreases in the 13 new member states (EU13). However, the labour force dependency ratios in these states would remain at intermediary levels because, on average, their populations have lower life expectancy or fewer unproductive years at older ages than their western counterparts.

Whether either population age-structures shifting towards higher ages or reductions in the working-age populations do in fact produce a smaller labour supply, depends on how age-specific labour force participation rates – particularly of women and people aged between 50 and 70 – develop in the coming decades. The extent of any economic implications also depends on labour demand, which may fundamentally shift in the coming years amid automation and other factors.

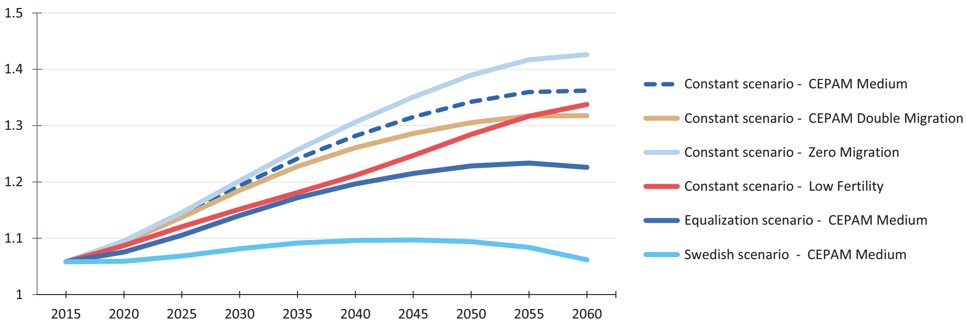
When considering future labour force size and composition, it is important not to overlook the labour force dependency ratio. This measure, together with changing productivity, in large part determines the potential economic impact of population ageing. By comparing the economically inactive population to the economically active population, the ratio captures a population's composition both in terms of demographic structure and labour force participation.

2.2 Does Europe have a demographic need for migration?

A recurring theme in Europe's public discussions of migration describes an unmet, ongoing demographic need that can be filled by migrants. Apprehensions revolve around the size of the future workforce and how the system might function with fewer workers. However, largely absent from such discussions are (1) considerations of existing differentials in workforce participation rates between the EU member states, specifically, important variations in female participation rates; and (2) analyses of how migration could influence the labour force dependency ratio, rather than simply the labour force size.

As can be seen in Figure 2, increasing female participation rates leads to the lowest ratio of non-workers to workers among the scenarios considered. This scenario uses observed Swedish workforce participation rates as a focal point, projecting a slow convergence of other member states towards Sweden's age- and

Figure 2:
Six scenarios for the labour force dependency ratio of the EU, 2015–2060



NB: *Constant, Equalisation* and *Swedish* scenarios refer to different participation assumptions. *Medium, Zero Migration, Double Migration* and *Low Fertility* refer to the population scenarios used throughout the CEPAM volume, which were combined with constant participation assumptions to compare them with two scenarios of changing participation.

Source: Loichinger and Marois (2018).

education-specific participation rates over the course of the next 45 years. CEPAM research shows how such a gradual development would *wholly counterbalance* the expected rise in the dependency ratio due to population ageing.

The next-lowest dependency ratio is produced by the *Equalisation* scenario, in which the female labour force participation rates reach current country-specific male levels by 2060. In this situation, the expected climb in the dependency ratio would be significantly slowed, stabilising at around 1.2 dependents per worker. This amounts to about only *half the increase* compared to the constant scenario, arriving at nearly 1.4 dependents.

In contrast, even in the double scenario, migration leads to only a minimal decrease in the dependency ratio. CEPAM projection results show that doubling migration, despite increasing the overall population (and labour force) size, would only slightly improve the labour force dependency ratio, without altering the broader momentum towards rising levels.

Therefore, increased migration flows – particularly of migrants with low education and low labour force participation prospects – are unlikely to alleviate the economic consequences of population ageing. Although political discourse often refers to migration as a tool for easing the consequences of population ageing, demographers agree that while immigration can affect population size, it generally has little impact on the ratio of non-working to working people. Furthermore, the human capital levels of natives and migrants matter greatly for any potential improvements in productivity, and how societies will or will not cope with the consequences of automation of work processes.

3 Projected EU population size and age composition

CEPAM's *Medium* scenario foresees the end of rapid growth in the EU-28, with the population remaining largely unchanged from the current 507.5 million to 508.3 million by the year 2060. Table 1 displays members state-specific results for population change in different scenarios.

For historical context, the population of the current EU member states (EU-28) has expanded by 128 million inhabitants since 1950. The CEPAM *Zero Migration* scenario finds that the rate of natural decline from low fertility brings the EU-28 population to 461 million by 2060, or back to the size observed in the 1980s.

3.1 Fertility growth and convergence

Fertility in the EU-28 varies between 1.35 children per women in Portugal and two children per woman in France and Ireland (standard deviation around 0.2), with the average total fertility rate standing at 1.61. Western members have had higher fertility levels than those in southern and eastern member states, although fertility rates appear to be slowly converging across Europe as fertility falls in the west and rebounds in the east.

According to the CEPAM *Medium* scenario, average period fertility in the EU will rise from the current 1.61 children per woman to 1.67 in 2030, and then to 1.71 children by 2060. In addition to higher EU-wide fertility, CEPAM *Medium* predicts the continuation of converging fertility behaviours across member states into the future.

3.2 Moving west, over time – population changes from intra-EU movement

Over time, EU internal mobility has the potential to strikingly change the demographic makeup of many member states depending on whether intensities of south- and east-to-west movements lessen, remain the same, or grow further. In some cases, net internal flows significantly impact the overall size of a sending country's population.

Particularly in eastern EU member states (Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia, and Romania) smaller populations seem inevitable, primarily due to high net movement to western economies. Without out-migration, the populations of the eastern member states would naturally only shrink 11–25% by 2060, similar to the natural rates of decrease in many other European countries.

If EU internal mobility continues without stabilising at lower levels, CEPAM results indicate that the most extensive population decreases reach −38.0% for Bulgaria and −34.3% for Romania by 2060. In a double migration future, the populations of many eastern member states would fall even more dramatically, including Bulgaria (−48.6%) and Romania (−46.8%).

As for the proportion of people aged 65+ in the population, higher volumes of internal mobility generally reduce age-dependency rates in western Europe and increases them in eastern Europe. If current trends continue, a particularly dynamic process will be observed in the eastern member states where lower fertility is accompanied by high volumes of movement to other EU member states, accelerating ageing.

3.3 International migration driving population expansion in the EU

Aside from internal movement, western member states will continue to see expanding populations if current flows of international migration either remain at constant levels or double. Such inflows would be significant enough to increase the number of people living in the EU as a whole.

Only seven countries are unlikely to naturally decreases in population size without migration (in all presented scenarios, including those of Eurostat (2015) and national projections), mostly because they have relatively high fertility: Ireland, Denmark, France, Sweden, and the UK (TFRs around 1.8−2.0 in 2015), or an age structure in which a large share of the population is of reproductive ages: Luxembourg (median age of 39.3 years) and Cyprus (35.0 years).

All CEPAM scenarios show a decrease in the populations aged 0−14 and 15−64, and an increase in the population aged 65+. No migration leads to a reduction in the population aged 0–69, but also to a more moderate increase in the population aged 70+, shown in Figure 3. Whereas higher migration (CEPAM Double Migration) would reduce the magnitude of change for ages 0–69, it would also enlarge the populations aged 70+ by 67.8 million people in the long-run, as the migrant populations inevitably grow older.

4 Global population futures

4.1 The importance of education for fertility decline and longevity

Demographic changes are to a large extent pre-determined in the near term by population age structures that result from past fertility, mortality, and migration trends. But from the longer perspective, all components of demographic change can be influenced by policy and other initiatives.

CEPAM results demonstrate that aside from policies intending to influence fertility and mortality directly, efforts to enhance education can have important indirect consequences that lead to increases in longevity and reductions in high fertility as well. The effects of socio-economic development become clear when looking at Figure 4. The two extremes in possible global development pathways

Table 1:
Population change (in percent) in EU-28 countries from 2015–2060, by scenario

	CEPAM						
Country	**Zero migration**	**Medium**	**Double migration**	**SSP1**	**SSP3**	**Eurostat**	**National**
Austria	−13.1	8.5	27.3	3.3	−6.6	19.3	13.9
Belgium	−1.8	13.7	28.2	6.5	9.7	21.2	16.2
Bulgaria	−25.5	−37.9	−48.6	−37.0	−22.2	−27.4	−25.2
Croatia	−18.7	−19.7	−20.3	−20.2	−14.2	−16.4	−16.4*
Cyprus	4.2	23.7	40.9	21.6	13.8	19.5	19.5*
Czech Republic	−13.7	−8.7	−4.2	−12.6	−8.4	−2.2	−10.8
Denmark	1.8	13.9	25.4	5.7	15.2	19.4	15.0
Estonia	−14.5	−7.1	−1.3	−12.7	−6.0	−7.0	−9.2(a)
Finland	0.2	3.9	7.2	−3.2	12.8	3.3	8.9
France	6.1	18.3	29.1	9.6	18.8	13.7	13.2
Germany	−19.1	−2.6	12.3	−6.7	−12.7	−0.5	−6.9
Greece	−15.7	−3.5	7.2	−7.2	−10.0	−23.6	0.0(b)
Hungary	−22.7	−17.9	−13.6	−21.0	−18.6	−7.5	−19.3
Ireland	16.5	20.8	24.0	12.1	27.7	27.4	26.0(e)
Italy	−18.6	−10.4	−2.8	−13.1	−13.5	−6.3	−9.5
Latvia	−23.3	−19.7	−16.7	−20.9	−18.8	−28.2	−3.4(c)
Lithuania	−19.0	−27.8	−34.7	−28.3	−12.7	−37.1	−37.1*
Luxembourg	3.1	53.0	96.1	42.4	17.3	76.4	101.2
Malta	−10.4	−8.9	−7.8	−9.5	−5.6	20.9	20.9*
Netherlands	−2.2	8.6	18.4	2.2	8.4	14.3	5.9
Poland	−12.9	−16.8	−20.4	−20.3	−7.1	−13.6	−11.6(d)
Portugal	−17.8	−20.3	−22.4	−23.2	−13.9	−17.6	−17.2
Romania	−21.3	−35.1	−46.8	−34.1	−17.9	−21.0	−34.2
Slovakia	−10.7	−13.6	−16.3	−17.2	−5.8	−5.7	−1.9
Slovenia	−13.9	1.2	14.6	−3.7	−6.8	−3.0	−3.0
Spain	−13.4	2.6	17.8	−0.7	−7.7	6.7	−8.7
Sweden	7.4	27.0	45.2	17.6	20.0	36.3	30.2
United Kingdom	6.1	17.4	27.2	8.7	17.4	22.3	22.9
EU28	**−9.1**	**0.2**	**8.6**	**−4.8**	**−1.3**	**3.2**	**−0.9**

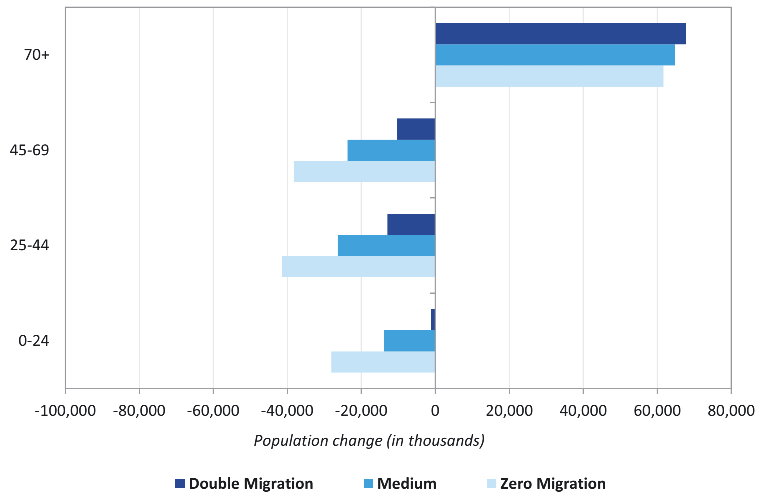
Note: (*) national authorities do not prepare own projections and use Eurostat numbers, (a) projection period 2015–2040, (b) 2015–2050, (c) 2015–2030, (d) 2015–2050, (e) 2015–2045.

SSP1 = Rapid Social Development and SSP3 = Stalled Social Development.

Source: Adapted from Stonawski (2018), Eurostat, and national statistical agencies.

lead to wildly different worlds, over 5.5 billion people apart. By the end of the century, these divergent trajectories reach 7.23 billion (Rapid development/SSP1) and 13.6 billion (Stalled development/SSP3).

Figure 3:
Change in the EU-28 population size (by age-groups) under zero, medium, and double migration conditions. * Uses in the SSP2 medium development scenario



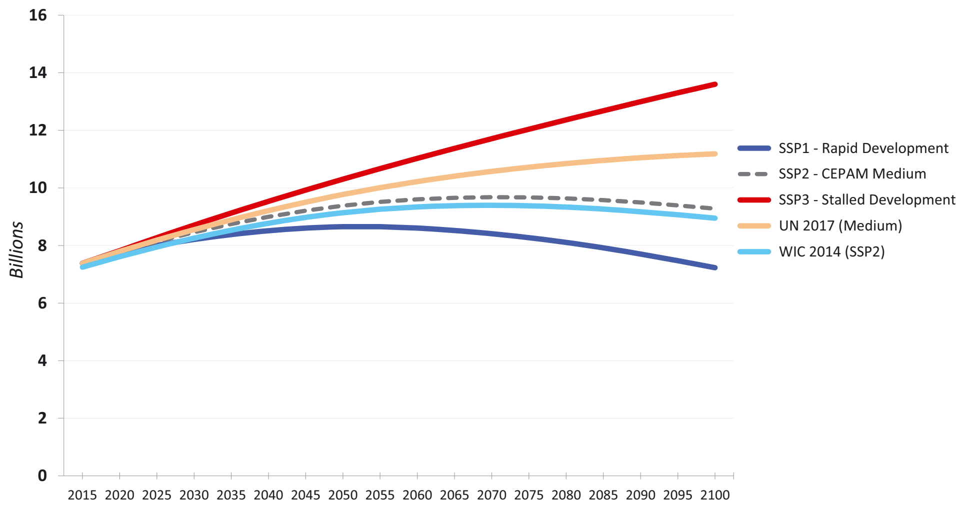
Source: Adapted from Stonawski (2018).

Shared Socioeconomic Pathways (SSPs)
SSP1 (Rapid Social Development): A sustainable and human wellbeing-focused path with an accelerated demographic transition and relatively low world population. High education, low mortality, and low fertility.
CEPAM Medium (SSP2): Middle-of-the-road scenario in which trends continue and development of low-income countries is uneven. Medium fertility, mortality, and education. For CEPAM migration projections these medium assumptions are combined with zero, medium, and double migration variants.
SSP3 (Stalled Social Development): A world separated into regions broadly characterised by rapidly growing populations. Low education, high mortality, and high fertility.

4.2 Global population ageing

Population ageing is not confined to East Asia, Europe, and North America. Under all scenarios the world population will get significantly older as a consequence of lowering fertility rates and rising life expectancy. In the CEPAM *Medium* (SSP2) scenario, the proportion of the population aged 65+ increases from the current 8.3%

Figure 4:
Comparison of different scenarios for world population growth over the 21st century



Source: Adapted from Lutz and KC (2018).

to 17% by mid-century, and to 29% by 2100. Moreover, the faster gains in life expectancy assumed by the Rapid Social Development (SSP1) scenario result in the proportion of 65+ reaching about 20% by mid-century, and 45% in 2100.

4.3 Regional trends: Sub-Saharan Africa

CEPAM projections for world population have been revised upwards from the estimates in *World population and human capital in the 21st century* (Lutz et al. 2014), primarily due to swifter declines in African mortality and slightly higher fertility rates than were previously assumed by other international assessments. In demographic terms, higher rates of child survival have the same effect as increasing fertility. Already by 2015, the population was markedly higher than had been foreseen using the 2010 baseline data.

Spread of mass education has been very slow (with moderate progress in recent years) across Sub-Saharan Africa. Although educational attainment is expected to increase steadily over time in all of Africa's sub-regions, it will still remain lower than other continents at the aggregate level according to the CEPAM *Medium* (SSP2) scenario. While the average amount of schooling for western, middle, and eastern Africa stood between 5.4 and 5.8 years in 2015, these sub-regions are projected to reach between 9.3 and 9.9 years by 2060.

If development slows or stalls (SSP3) and female education does not expand, world population already crosses the 10 billion mark around 2045 and then continues to grow over the rest of the century to 13.6 billion in 2100. For Africa, such a path would likely be associated with weak resilience to environmental changes, high mortality, and widespread poverty. Interruptions in the spread of education would in fact accelerate population growth due to differing fertility behaviours between education groups.

In this stalled development scenario, the combination of *high population growth with no further expansion of schooling results in African populations becoming less educated*. Schooling expansion must keep pace with the pressures from rapid population growth, otherwise CEPAM results show hardly any improvement in the proportion of people without any formal education even at the global level – from 10% in 2015 to 9% by the end of the century.

4.4 Regional trends: South Asia

South Asia is the least educated region of Asia with the adult population averaging 6.6 years of schooling in 2015, or slightly above the average for Sub-Saharan Africa. Younger cohorts of Indian women have notably risen their levels of educational attainment. However, for the adult population of India as a whole, the low educational attainment of previous cohorts still overshadows the gains made in recent decades.

All of the projections foresee India eclipsing China to become the world's most populous country. And although most South Asian countries send large numbers of emigrants to North America, the EU, and Gulf countries, these flows have a negligible effect on population growth of the region. Still, by 2060 the median age in South Asia is expected to rise to a point similar to that of East Asia in 2015, stabilising by mid-century.

4.5 Regional trends: East Asia

The Japanese population has achieved global leadership in both educational attainment (ages 25+ averaged 13 years of schooling in 2015) and longevity (87.2 years for women in 2015–20, expected to climb to an impressive 95.7 by 2055–60). Japan is also further along in the ageing process, with the world's highest share of population 65 and older. The current proportion of people aged 65+ in Japan is 7% higher than in the EU, and is expected to continue rising in the future as migration remains low and life expectancy increases.

China is rapidly catching up with the other highly educated East Asian countries after coming from far behind, and is predicted to reach 11.4 mean years of schooling in 2060. Over the same span of time, CEPAM results show China is expected to continue ageing to become 14% smaller compared to itself in 2015.

4.6 Differing paths for international development

Differences between CEPAM's projections make clear that changes in educational composition play a significant role in steering social development and population trends. The *SSP3* pathway illustrates a future in which minimal investments in education and continued high fertility in Africa and parts of South Asia could reinforce each other, locking the world into a cycle of very high population growth, poverty, and high vulnerability.

In stark contrast, the *SSP1* scenario shows how feedbacks between population, education, and development can alternatively result in further improvements in education and lower fertility. Many countries under this rapid development scenario would be well positioned to take advantage of the opportunities for broad economic and social advances that come from population structures shifting towards more workers and fewer dependents.

However, without sufficient education, the benefits of a maturing age structure are not guaranteed. To repeat the development successes seen in parts of East Asia and Latin America requires both prior investments in education and health infrastructure, along with positioning local enterprises to employ and retain the newfound potential of a more educated local labour force.

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Editors and authors of *Demographic and human capital scenarios for the 21st century: 2018 assessment for 201 countries*, the full volume: Wolfgang Lutz, Anne Goujon, Samir KC, Marcin Stonawski, and Nikolaos Stilianakis

Additional authors: Guy Abel, Bilal Barakat, Alain Bélanger, Alessandra Conte, Jakob Eder, Daniela Ghio, Erofili Grapsa, Sandra Jurasszovich, Elke Loichinger, Guillaume Marois, Michaela Potančoková, Patrick Sabourin, Tomáš Sobotka, Markus Speringer, Erich Striessnig, Marcus Wurzer, Dilek Yildiz, Sam Hyun Yoo and Kryštof Zeman

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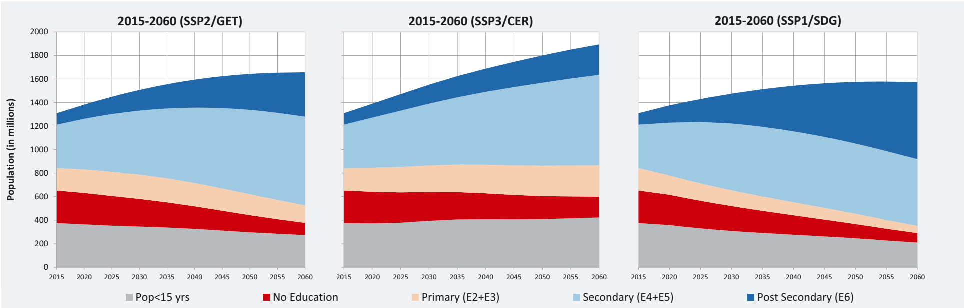
Appendix is on the following page.

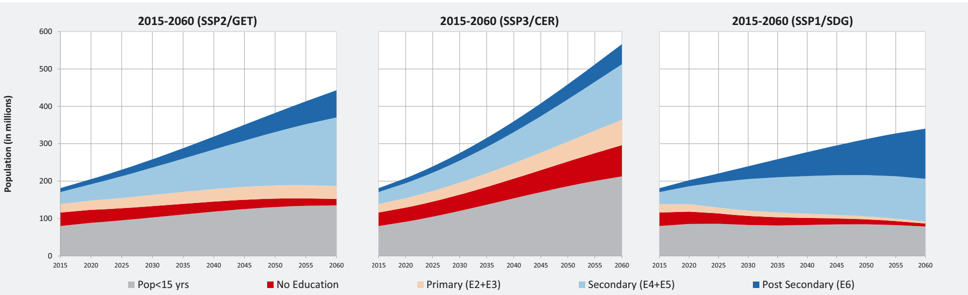
Appendix: Population tables for select countries

These snapshots of possible futures for India and Nigeria are taken as examples from a rich set of detailed projections. Interactive data accompanied by high-resolution colour graphs and population pyramids for all countries of the world can be found here: http://dataexplorer.wittgensteincentre.org/shiny/wic/

India



Nigeria



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‘Express transitioning’ as a special case of the demographic transition

Marc Luy and Bernhard Köppen*

Abstract

The theory of the ‘(first) demographic transition’ (DT) still has considerable practical relevance in the field of population research. For instance, the DT serves as a conceptual model that underlies the UN’s population projections, and is central to the discussion around the so-called ‘demographic dividend’. Although it was first described 90 years ago, several questions related to the DT remain open or need verification. In particular, there is debate about the question of what the indispensable triggers of the DT are. Assumptions regarding the primary causes include increased education for women and related changes in values, as well as economic development, urbanisation, migration, and the democratisation process. This paper aims to contribute to DT-related research using an innovative research approach. Our study covers all 102 countries with populations that have undergone the DT between 1950 and 2010. Among these countries, we identified 25 populations that passed through this process at an exceptionally high tempo. We refer to this process as ‘express transitioning’ (ET), and seek to identify its main determinants by comparing the ET populations with the populations of the other DT countries. The data we use are taken from the Wittgenstein Centre Data Explorer, the UN World Population Prospects, the UN World Urbanization Prospects, the World Bank Group, and the Center for Systematic Peace. Our analysis is based on rather descriptive methods, including ANOVA tests and bivariate correlations. We find that the urbanisation level and the education dynamics are most closely associated with ET, whereas other variables show no significant association with the ET process.

* Marc Luy (corresponding author), Vienna Institute of Demography of the Austrian Academy of Sciences, Welthandelsplatz 2/Level 2, 1020 Vienna, Austria
E-mail: mail@marcluy.eu

Bernhard Köppen, University of Koblenz-Landau, Universitätsstraße 1, 56070 Koblenz, Germany
E-mail: koeppen@uni-koblenz.de

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1 Introduction

The '(first) demographic transition' (DT) model holds a dominant position in population studies, and thus continues to be of considerable practical relevance. The model describes the demographic changes that occur in a society as it undergoes the process of industrialisation; i.e., as a society transitions from being a pre-modern regime with high fertility and mortality rates to being a post-modern regime in which the vital rates stabilise at lower levels (Thompson 1929; Landry 1934; Carr-Saunders 1936; Notestein 1945). In most cases, fertility does not decrease until the population has undergone a period of growth due to a decrease in mortality. Whereas today's industrialised countries experienced this transition between the 18th century and the beginning of the 20th century, the so-called 'developing countries' have started moving through this process only very recently (Reher 2004). As the DT provides us with a picture of past, present, and future developments across the global population, studying it has been called a 'recurrent task in demography' (Bocquier and Costa 2015, 1297). Furthermore, the DT has been characterised as "[...] one of the best-documented generalizations in social sciences" (Kirk 1996, 361), which has made a significant contribution to the scholarship generated in a field of science that is typically "short on theory, but rich in quantification" (ibid). Nonetheless, as Dyson (2011, 34) pointed out, "[...] demographers have made rather little out of the demographic transition", and have underestimated its "central role" for the "creation of the modern world" (Dyson 2001, 67). Instead, the use of follow-up conceptual-theoretical approaches has become increasingly popular in demography for explaining causalities (Caldwell 1976) or addressing demographic developments in post-industrialised societies. These models include the 'second demographic transition', which refers to the transition to below-replacement fertility (Van de Kaa 1987; Lesthaeghe 1995); and the controversial idea that shifts in migration and fertility trends are leading to the emergence of a 'third demographic transition', which is characterised by increasing proportions of people with foreign cultural backgrounds living in formerly ethnically homogenous societies (Coleman 2006).

Although the implied (but unproven) assumption in the model that there is a causal linkage between fertility and mortality has been criticised, the DT continues to be a highly relevant concept and a widely used tool for categorising and assessing populations around the world. Currently, the DT serves as a conceptual model that underlies the UN's population projections, as well as the 'demographic dividend' paradigm that informs development policy for the Global South (Bloom et al. 2003). However, even though the DT model has been the subject of numerous scientific investigations over many years, and continues to be important, the model's central explanatory factors remain vague or in need of verification. For example, the question of which factors are the decisive triggers of this process is still open. As we described above, the original DT model linked the stages of population growth rate cycles directly to the broader economic developments in a given population. But based on observations made in sub-Saharan Africa, where the DT process has taken place without the expected degree of economic development, it has been suggested that the underlying causes of fertility decline go beyond the state of a country's economy and wealth (Caldwell 1986; Caldwell and Caldwell 1987; Caldwell et al. 1992; Bongaarts 2008; Shapiro and Gebreselassie 2008; Ezeh et al. 2009; Bongaarts and Casterline 2012). The most commonly cited factors other than those directly related to economics are the education of women (e.g., Axinn and Barber 2001; Murtin 2012; Cuaresma et al. 2014) and its influence on (societal) values and roles (Mason 2001; Korotayev et al. 2016), urbanisation (Haggett 2001; Boquier et al. 2011; Dyson 2011), and shifts in migration regimes (Rees et al. 2016). Most recently, Wilson and Dyson (2017) proposed going beyond these rather conventional explanations to study the influence of a more comprehensive set of societal changes, including democratisation processes.

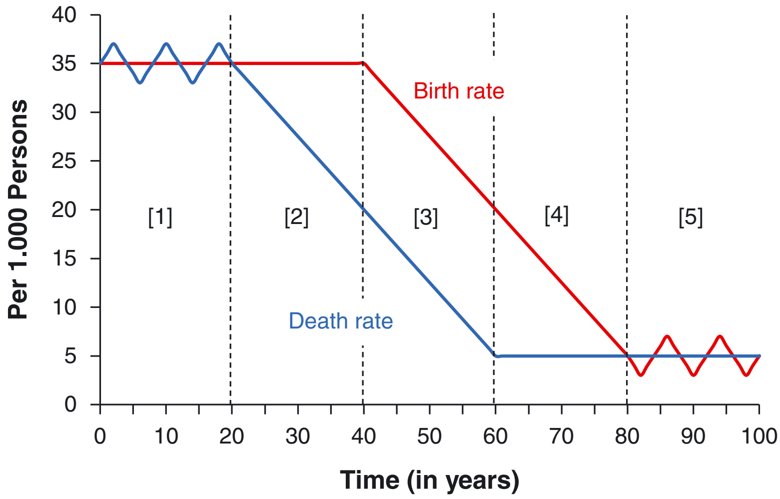
Because of restrictions in data availability and quality, most of the existing research on the DT has focused on larger spatial entities (such as whole continents or groups of countries), or it has been based on case studies for individual populations. This paper aims to contribute to DT-related research using an innovative, yet challenging research design with a global perspective. In a first step, we select all of the populations of the world that underwent the DT between 1950 and 2010, and identify those that underwent this process at an exceptionally fast pace. We refer to this process as 'express transitioning' (ET). Then, we try to find evidence of the main determinant(s) of this accelerated demographic development by comparing the ET populations with those of the other DT countries. Using recent as well as established scholarly findings, we create a set of indicators for our analyses that are broad, but also concise and experimental. These indicators include the standard explanatory factors: namely, the education of women, urbanisation, population density, and GDP per capita (as an economic indicator). In addition, we include information on migration flows and an assessment of the prevailing political system and its stability.

Besides providing new insights into the possible factors behind the accelerated transition process of the ET countries, this study can help to extend our understanding of the DT in general. Moreover, the approach and the results presented in this paper might also be helpful for the development of future population projections based on country-specific characteristics. In Section 2, we clarify our definition and assessment of the ET as a concept. In Section 3, we present the underlying data and the methods we use for our empirical investigation. The results of this analysis are presented in Section 4. Finally, in Section 5, we conclude the paper with a summary and a discussion of our main findings.

2 Definition and assessment of express transitioning

Our definition of express transitioning (ET) is rooted in the well-known 'phase model' of the DT, as introduced by Thompson (1929), Blacker (1947), and Notestein (1953). The original variant of this model identified four sequential and connected phases of the transition from a pre-modern demographic regime with

Figure 1:
The five-phase model of the demographic transition



Source: Authors' own.

high fertility and mortality levels to a post-modern pattern with low fertility and low mortality levels. However, an examination of empirical data for European populations showed that the subdivision of the DT into just four phases was too crude. The model has, therefore, been extended to five phases, with an additional phase placed in the middle of the transition process, as illustrated in Figure 1 (see, e.g., Haggett 2001). The five phases are as follows:

1. the 'high stationary' phase, during which birth and death rates are high, but the population is stable, with the population growth rate fluctuating at around zero;
2. the 'early transitional' or 'early expanding' phase, during which the birth rate remains high but the death rate starts to decline and the rate of population growth starts to increase;
3. the 'middle transitional' or 'middle transformative' phase, during which the death rate continues to decline and the birth rate starts to decrease as well, with the population growth rate reaching its maximum level around the middle of the phase, and starting to decrease thereafter;
4. the 'late transitional' or 'late expanding' phase, during which the death rate has stabilised while the birth rate is still declining, which keeps the total growth rate at a positive but decreasing level; and, finally,
5. the 'low stationary' phase, during which the birth and the death rates stabilise at low levels, and population growth returns to a zero or very low rate.

The third phase of the five-phase model is of crucial importance for our definition of ET. We define a population as having undergone ET if it moved through the middle transitional phase in five years or less. The identification of such populations depends on our ability to determine the DT stage of each of the countries in our study sample at any given time of observation. The classical phase model described above is problematic for this purpose because it is based on crude birth and death rates. Initially, these crude rates were seen as appropriate proxies for roughly characterising and comparing the demographic trends of populations that were predominantly agricultural or in the early stages of industrialisation. The countries experienced similar demographic conditions (high fertility and mortality rates with singular or temporary fluctuations) and inevitably developed comparable, pyramid-shaped population structures. Today, the age structures of countries differ considerably. As a consequence, crude birth and death rates, which are strongly affected by the age composition of the population, cannot be used for comparative studies.

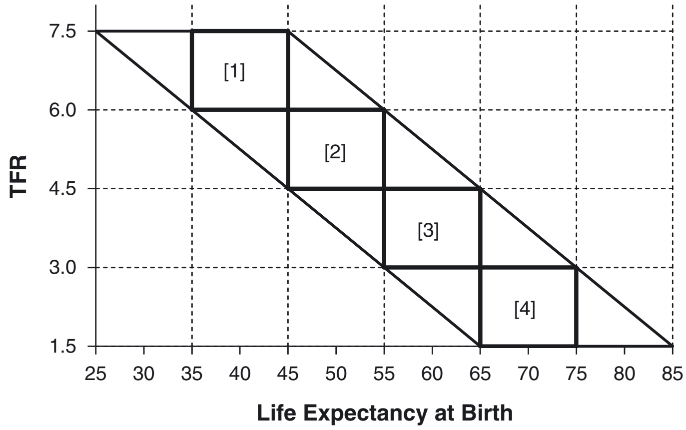
The United Nations (1989) addressed this problem by introducing an alternative 'stage model', which is based on the age-standardised parameters of life expectancy at birth (LE) and the total fertility rate (TFR). Compared to the phase model, this approach is more flexible for combining the trends in fertility and mortality, even though it again summarises the DT in only four stages. The stages are defined by ranges of LE levels and TFRs (see Fig. 2):

1. stage [1] covers LE below 45 years and TFRs above 6.0 children per woman;
2. stage [2] covers LE from 45–55 years and TFRs from 4.5 to 6.0;
3. stage [3] covers LE from 55–65 years and TFRs from 3.0 to 4.5; and
4. stage [4] covers LE above 65 years and TFRs below 3.0.

However, despite its advantages relative to the classic phase model, this approach also turned out to be problematic for the purposes of empirical application. Many populations exceed the hypothesised ranges of TFR and LE within a predefined stage. As Büttner (2000) has shown, these deviations can be so accentuated that some populations cannot be assigned to a specific DT stage with the UN stage model.

As an alternative approach for the systematic identification and assignment of phases, or stages, of the DT, we propose combining the classic five-phase approach with the UN stage model. In crafting our approach, we retain the logic of the five-phase model in terms of DT sequences, but use the TFRs and LE levels cited in the UN stage model for classifying countries and allocating them to a specific DT phase (Table 1). In our approach, the initial phase 1 is defined in accordance with UN stage [1]. The DT starts (phase 2) when LE increases to the stage [2] level of the UN model, while fertility remains in UN stage [1]. In line with the DT concept, the decline in mortality (i.e., the increase in LE) is the key element at this point. The decisive indicator for the identification of phases 3 to 5 is, by contrast, the fertility level. As soon as fertility falls below the level of the pre-modern DT stage [1] – i.e., when the TFR falls below 6.0 children per woman – the population is assigned to

Figure 2:
The stage model of the demographic transition



Source: United Nations (1989), slightly modified by the authors.

Table 1:
Classification of the DT phases according to the five-phase model on the basis of the indicators of the four-stage model

	4-stage model of the UN	
5-phase model	**TFR**	**LE**
Phase [1]	Stage [1]	Stage [1]
Phase [2]	Stage [1]	Stage [2]+
Phase [3]	Stage [2]	Stage [3]±
Phase [4]	Stage [3]	Stage [4]−
Phase [5]	Stage [4]	Stage [4]

Source: Authors' own.

DT phase 3. Phase 4 begins when the population's fertility decreases to the level of stage [3] of the UN model. Accordingly, the population has completed the DT process (phase 5) when its TFR has fallen below 3.0 children per women (UN stage [4]).

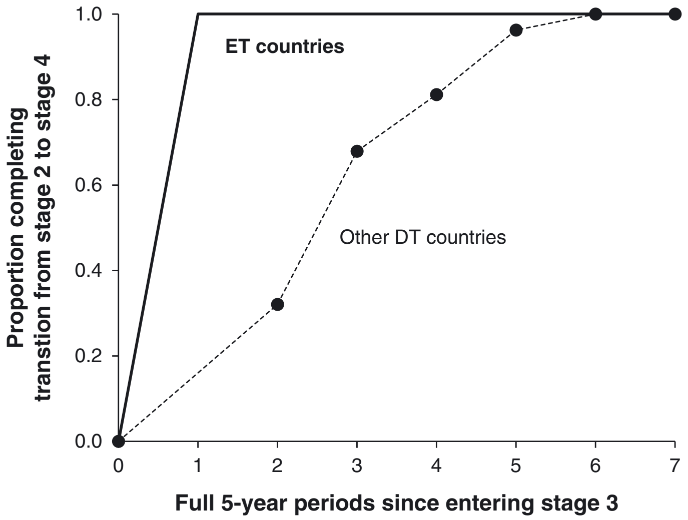
Note that LE is treated more flexibly than fertility in our approach. There are several reasons why we made this choice. During the 19th and 20th centuries, mortality declines were linked to significant changes (increases) in economic structure and wealth. However, the exportation via colonialism or 'foreign aid' programmes of scientific knowledge, health care infrastructure and know-how, foodstuffs, and other foreign goods to societies with a pre-modern demographic regime led to immediate and strong decreases in mortality in many populations that did not experience accompanying changes in their economy, culture, society, and wealth. Furthermore, in the so-called low and least developed countries, mortality can fluctuate significantly when conditions are changing (e.g., through famine, epidemics, military conflicts, or a lack of funding). LE is a less stable indicator than fertility in such vulnerable societies because it strongly depends on external factors. Fertility, by contrast, is related to a greater extent to individual decisions that are embedded in a larger social context. Therefore, fertility is usually not as volatile as mortality can be under certain circumstances.

Moreover, for technical reasons, it is reasonable to focus on fertility as the key indicator. In some populations, LE increased at a faster pace than the TFR decreased. This pattern led some of these populations to jump a mortality stage, but not a fertility stage, according to the logic of the UN model. In addition, the spread of the HIV/AIDS epidemic in sub-Saharan Africa resulted in such strong increases in mortality in some populations that these societies stepped backwards, following the logic of the UN stage model. But such mortality spikes would not represent a stage change, according to the logic of the DT concept (as long as fertility keeps declining). When we look at these populations over the long term, we see that sudden, but temporary, increases in mortality are a common phenomenon, because disasters – whether ‘natural’ or man-made (such as war and conflict) – are occurring with increasing frequency, especially in parts of Africa and the Near and Middle East. With our approach of treating mortality more flexibly than fertility, a population can only move forward along the phases, but it cannot fall back once the DT has started. This is in line with the basic assumptions of DT theory, and is not a limitation introduced by our phase assignment logic.

3 Data and methods

Considering that “demographers and others in search of causality are dealing with a very complex and highly interrelated structure of causation that at time seems nebulous” (Kirk 1996: 386), we tried to create a set of clearly arranged, meaningful indicators that would help us identify the possible drivers of the ET and DT processes in a more general way. These potential contributing factors include women’s education, urbanisation, population density, migration, the political system (as an indicator that is also related to societal change), and the economy. Naturally, there might be additional relevant determinants of the DT and ET processes. However, the range of available reliable longitudinal data with a time span of more than 20 years for every country in the world is very limited. The inclusion of a variable or a proxy reflecting culture and cultural change would have been highly desirable, but such variables are practically unavailable. While this is unsatisfactory given that culture and demographic change are related to each other, a general lack of quantifiable indicators and the often qualitative nature of research on culture make the use of quantitative approaches difficult or unfeasible. Consequently,

Figure 3:
Tempo of the demographic transition (DT) from phase 2 to phase 4 of the 'express transitioning' (ET) countries and the other countries that underwent the demographic transition between 1950 and 2010



Source: The authors' own analyses.

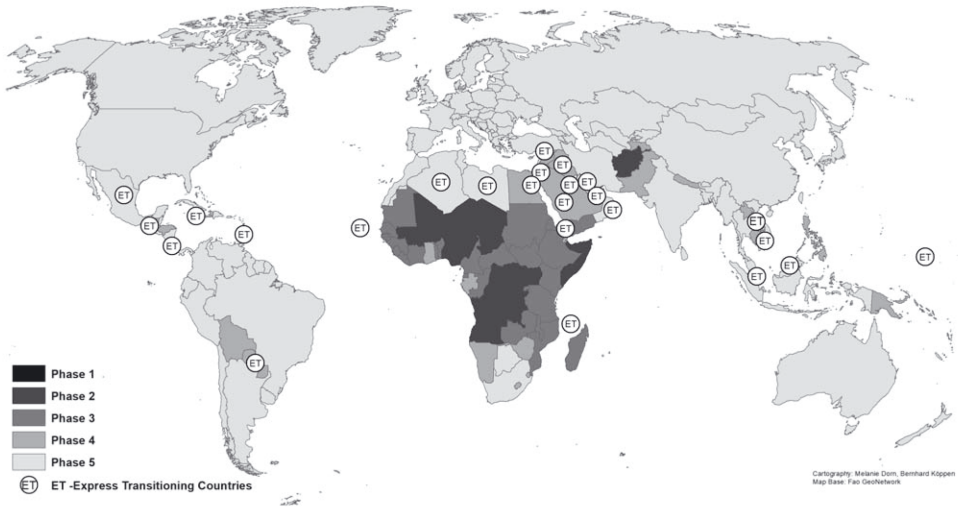
culture remains an under-researched and underestimated factor in demographic studies (see also Bachrach 2014).

Hence, the sampling and harmonisation of our database was an especially challenging undertaking that generated satisfactory, but not perfect, results. Nonetheless, even though meaningful longitudinal variables are (still) sparse, we believe that examining cases of countries that underwent ET will contribute to a better understanding of the complexity and multi-faced character of the DT. The empirical analysis presented in this paper is based on descriptive statistics for all study variables, presented separately for the ET and the other DT countries, with one-way ANOVA tests for the differences between the ET and the other DT countries. We are aware that further statistical analysis using more sophisticated methods is the next necessary step. But for our aim of introducing a new research approach to extend research on the DT process, the descriptive approach can be a suitable starting point.

3.1 Study populations

We used the LE and TFR data of the 2012 revision of the United Nations World Population Prospects (United Nations 2013) to identify the study populations

Figure 4:
The development stages (phases) in the demographic transition process of the world's countries in the period 2005–10, with the 'express transitioning' countries marked



Note: No country in DT phase 1.
Source: The authors' own analyses.

according to our classification system of DT phases (see Section 2). Following the logic of this system, we assigned to each country of the world a specific DT phase in 12 five-year periods from 1950–55 to 2005–10. Based on these data, we identified 102 populations that moved from phase 2 to a higher phase; i.e., that passed through the DT during the 60-year observation period. We refer to these populations as 'DT countries'. Among these DT countries we identified 25 cases of ET; i.e., countries that jumped over phase [3] in this series of five-year periods by entering phase [4] directly from phase [2]. Among the other 77 DT countries, 53 also completed phase 3 and reached phase 4, but at a slower pace. Figure 3 illustrates the difference between the ET and these other DT countries in terms of the speed with which they moved through DT phase 3. The graph visualises our concept of the ET process, which is applied in the empirical analysis. As most populations of the Northern hemisphere completed the DT before 1950, the ET countries are located primarily in a belt between the Tropic of Cancer and the Tropic of Capricorn. This pattern can be seen in Figure 4, which identifies the ET countries and shows the DT phases reached in all countries across the world during our last observation period of 2005–10. A detailed overview of the 25 ET countries and the 77 other DT countries, with their corresponding DT phases across the whole observation period, can be found in the appendix.

3.2 Study variables

We chose the following variables for our analyses:

Period *t*: last five-year calendar period in which a population was in DT phase 2.

Primary education at period *t*: percentage of women aged 20–39 with at least primary education; data downloaded from the Wittgenstein Centre Data Explorer;[1] if period *t* was earlier than 1970–74 (beginning of the available data in the Wittgenstein Centre Data Explorer), we used the data for 1970–74 as the primary education indicator for *t*.[2] We refrained from modelling the missing values because the use of 1970 data for our sample of only less and least developed populations would lead at most to a slight overestimation of education levels. Note that the level of education was still very low in all of the populations included in our analysis. Thus, because the education of women tends to be correlated with fertility (Cuaresma et al. 2014), the use of this approach appears to be more constructive than modelling values that might underestimate the role of education.

Primary education dynamics: change in the percentage of women aged 20–39 with at least primary education between periods $t-5$ and t (calculated as the difference between t and $t-5$ in absolute as well as in relative terms); data downloaded from the Wittgenstein Centre Data Explorer (see Footnote 1); if period *t* was 1970–74 (beginning of the available data in the Wittgenstein Centre Data Explorer) or earlier, we derived the indicator for the primary education dynamics from the difference between the periods 1975–79 and 1970–74.[3]

Average years of schooling at period *t*: average number of school years among women aged 20–39; data downloaded from the Wittgenstein Centre Data Explorer (see Footnote 1); if period *t* was earlier than 1970–74 (beginning of the available data in the Wittgenstein Centre Data Explorer), we used the data for 1970–74 as the average years of schooling indicator for *t* (see Footnote 2).

Average years of schooling dynamics: change in the average years of schooling among women aged 20–39 between periods $t-5$ and t (calculated as the difference between t and $t-5$ in absolute as well as in relative terms); data downloaded from

[1] Available at: http://www.wittgensteincentre.org/dataexplorer (accessed: 16 February 2017).

[2] This applies to Albania (t = 1955–59), Bahrain (t = 1965–69), Brazil (t = 1960–64), Colombia (t = 1965–69), Costa Rica (t = 1960–64), Dominican Republic (t = 1965–69), Ecuador (t = 1965–69), Egypt (t = 1965–69), El Salvador (t = 1965–69), French Polynesia (t = 1950–54), Malaysia (t = 1960–64), Myanmar (t = 1960–64), Paraguay (t = 1965–69), Republic of Korea (t = 1955–59), Réunion (t = 1960–64), Saint Lucia (t = 1965–69), Saint Vincent and the Grenadines (t = 1965–69), Singapore (t = 1955–59), South Africa (t = 1960–64), Suriname (t = 1960–64), Thailand (t = 1965–69), Tonga (1965–69), Turkey (t = 1960–64), and Venezuela (t = 1960–64).

[3] In addition to the cases given in Footnote 2, this applies to the following countries with t = 1970–74: Bolivia, Kuwait, Mexico, Morocco, Peru, Philippines, Tajikistan, Turkmenistan, United Arab Emirates, Vanuatu, and Vietnam.

the Wittgenstein Centre Data Explorer (see Footnote 1); if period t was 1970–74 (beginning of the available data in the Wittgenstein Centre Data Explorer) or earlier, we derived the indicator for primary education dynamics from the difference between the periods 1975–79 and 1970–74 (see Footnote 3).

Urbanisation at period *t*: percentage of population at period t residing in urban areas, averaged from mid-year data for the start years of the five-year periods; data downloaded from the United Nations World Urbanisation Prospects, 2014 revision.[4]

Urbanisation dynamics: change in the percentage of the population residing in urban areas between periods $t-5$ and t (calculated as the difference between t and $t-5$ in absolute as well as in relative terms); data downloaded from the United Nations World Urbanisation Prospects, 2014 revision (see Footnote 4).[5]

Population density at period *t*: persons per square kilometre at period t, averaged for five-year periods from data for single years; data downloaded from the United Nations World Population Prospects, 2015 revision.[6]

Population density dynamics: change in the number of persons per square kilometre between periods $t-5$ and t (calculated as the difference between t and $t-5$ in absolute as well as in relative terms); data downloaded from the United Nations World Population Prospects, 2015 revision (see Footnote 6).[7]

Net migration rate at period *t*: number of immigrants minus the number of emigrants during period t, divided by the person-years lived by the population of the receiving country over that period (expressed as the average annual net number of migrants per 1000 population); data downloaded from the United Nations World Population Prospects, 2015 revision (see Footnote 6).

Migration dynamics: change in the migration balance (number of immigrants minus the number of emigrants) between periods $t-5$ and t (calculated as the difference between t and $t-5$ in absolute as well as in relative terms); data downloaded from the United Nations World Population Prospects, 2015 revision (see Footnote 6).[8]

Polity at period *t*: polity score at period t, averaged for five-year periods from single-year data obtained from the Polity IV dataset of the Center for Systemic

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4 Available at: https://esa.un.org/unpd/wup/ (accessed: 20 February 2017). Note: the data of the 2014 revision of World Urbanisation Prospects are consistent with the size of the total population of each country as estimated or projected in the 2012 Revision of World Population Prospects.

5 For French Polynesia (t = 1950–54), we derived the indicator for urbanisation dynamics from the difference between the periods 1955–59 and 1950–54 (no data available for the period $t-5$).

6 Available at: https://esa.un.org/unpd/wpp/ (accessed: 15 February 2017).

7 For French Polynesia (t = 1950–54), we derived the indicator for population density dynamics from the difference between the periods 1955–59 and 1950–54 (no data available for the period $t-5$).

8 For French Polynesia (t = 1950–54), we derived the indicator for migration dynamics from the difference between the periods 1955–59 and 1950–54 (no data available for the period $t-5$).

Peace.[9] The polity score (POLIT) of the Polity IV project is derived from two scale indicators for institutionalised democracy (DEMOC) and institutionalised autocracy (AUTOC). The polity score ranges from −10 (strongly autocratic) to +10 (strongly democratic).[10]

Polity dynamics: index for polity type and transition during the 10-year period $t - 5$ and t. We derived this 'pd index' from the abovementioned single-year polity scores developed by the Center for Systematic Peace, excluding the power of the indicator value, but including the following values: 0 = neutral, 1 = exclusively democratic, 2 = exclusively autocratic, 3 = change from autocracy to democracy, 4 = change from democracy to autocracy, 5 = crisis, and 6 = colony.[11] Finally, these categories were further grouped into the categories 'exclusively democratic' (pd = 1), 'exclusively autocratic' (pd = 2), 'regime change' (pd = 3 or 4), and 'others' (pd = 0, 5, or 6).

Relative economy: five-decades ranking of relative GDP per capita over the period 1960–2009. The five-decades ranking was derived from the average of rankings for the decades 1960–69 (n = 63), 1970–79 (n = 71), 1980–89 (n = 88), 1990–99 (n = 96), and 2000–09 (n = 99). The decadal average GDPs per capita were

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9 Available at: http://www.systemicpeace.org/inscrdata.html (accessed: 15 February 2017).

10 The indicators DEMOC and AUTOC express the countries' levels of institutionalised democracy and autocracy by weighted additive 11-point scales (0–10). Both are derived from codings of (1) the competitiveness of political participation, (2) the openness and competitiveness of executive recruitment, and (3) the constraints on the chief executive. Despite being based on the same assessment domains, DEMOC and AUTOC differ in the specific coding categories they use. Because many polities have mixed authority traits, countries can have middle scores on both the autocracy and the democracy scales. The combined POLITY score is computed by subtracting the AUTOC score from the DEMOC score. More details can be found in the Polity IV Project Dataset User's Manual (available at: http://www.systemicpeace.org/inscr/p4manualv2015.pdf). If no polity score was available for period t, we derived the score indicator from the earliest years available: Bahrain refers to the period 1971–76 (t = 1965–69), Fiji to 1970–74 (t = 1960–64), Namibia to 1990–94 (t = 1980–84), Papua New Guinea to 1975–79 (t = 1970–74), Singapore to 1959–1963 (t = 1955–59), Suriname to 1975–79 (t = 1960–64), United Arab Emirates to 1971–75 (t = 1970–74), and Vietnam to 1976–81 (t = 1970–74); while Tajikistan, Turkmenistan, and Uzbekistan (t = 1970–74) were assigned the data for the former USSR. In addition to the 21-point scale POLIT indicator, we also used a manual recoding of the polity score into the categories 'strongly autocratic' [POLIT < (−5.0)], 'rather autocratic' [POLIT = (−0.5) − (−0.0)], 'neutral' [POLIT = 0], 'rather democratic' [POLIT = (+0.0) − (+5.0)], and 'strongly democratic' [POLIT > (+5.0)]. However, this variant with reduced categories did not provide any results that differed from those of the original polity scale of the Polity IV project.

11 The following specific adjustments were necessary: Ecuador started with POLIT = 2 in 1960, then POLIT = −1 until 1967, then POLIT = 5 in 1968–69; we defined the polity dynamics (pd) in this case as pd = 2. El Salvador is assessed with POLIT = −3 from 1960 to 1963, then with POLIT = 0 from 1964 to 1971, followed by POLIT = −1 until 1976 and POLIT = −6 in 1977–78; we defined pd = 2. Finally, we assessed the polity dynamics manually in the following cases for which no polity score was available: Maldives = 1, Micronesia = 2.

Table 2:
Descriptive statistics of the study variables, presented separately for the ET and the other DT countries, with ANOVA test statistics for the differences between the ET and the other countries

	ET countries		Other DT countries		
	N	Mean	*N*	Mean	Sign.
Period *t*	25	1976.9	77	1979.9	.288
Primary education at period *t*	20	40.5	63	34.9	.345
Primary education dynamics (abs.)	20	8.6	63	6.3	.016*
Primary education dynamics (rel.)	20	32.3	63	33.7	.849
Average years of schooling at period *t*	20	4.6	63	3.7	.066†
Average yrs. of schooling dynamics (abs.)	20	1.0	63	0.7	.003**
Average yrs. of schooling dynamics (rel.)	20	28.9	63	29.0	.981
Urbanisation at period *t*	25	55.0	77	32.7	.000***
Urbanisation dynamics (abs.)	25	3.0	77	2.6	.511
Urbanisation dynamics (rel.)	25	6.8	77	10.8	.091†
Population density at period *t*	25	151.4	77	69.9	.116
Population density dynamics (abs.)	25	28.2	77	8.6	.064†
Population density dynamics (rel.)	25	23.5	77	15.4	.000***
Net migration rate at period *t*	24	5.9	73	1.7	.355
Migration dynamics (abs.)	24	−0.5	73	5.0	.257
Migration dynamics (rel.)	24	−95.1	73	−1233.0	.717
Polity at period *t*	18	−5.5	67	−2.2	.038*
Relative economy	24	74.5	75	42.2	.000***

Note: $^{\dagger}p < 0.1$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.
Source: The authors' own analyses.

calculated from the annual values that were available from the databank of the World Bank Group.[12]

4 Results

The results of the first analysis reveal that the ET and the DT countries vary with regard to most of the chosen variables. Table 2 displays the descriptive statistics (number of observations *N* and mean values) for all of the study variables, presented separately for the ET and the other DT countries, with the last column showing the one-way ANOVA tests for the difference between the ET and the DT countries.

[12] Available at: http://databank.worldbank.org/data/home.aspx (accessed: 15 February 2017).

On average, the ET countries left DT phase 2 three years earlier than the other DT countries (not statistically significant), and they had higher levels of education at that time (not statistically significant for the proportion of women with at least primary education, but mildly statistically significant for the average years of schooling). The education dynamics are found to be statistically significantly higher among ET countries when the changes are measured in absolute terms, but no differences between ET and other DT countries can be seen when the education dynamics are assessed in relative terms.

The largest and the most statistically significant differences between the ET and the other DT countries are observed for levels of urbanisation and population density. Whereas the proportion of the population residing in urban areas at the time of leaving DT phase 2 is 55.0 per cent across all of the ET countries, the corresponding proportion is only 32.7 per cent across the other countries. The number of persons per square kilometre at that time is 151.4 among the ET countries, and is 69.9 among the others. For both urbanisation and population density, we also see mildly significant differences in the relative dynamics. However, among the ET countries, these dynamics appear to be larger with regard to population density, but smaller with regard to urbanisation. The absolute changes show no statistically significant differences in both cases. Moreover, the net migration rate at period *t* and its dynamic indicators show no statistically significant differences, even though the rate is almost threefold among the ET countries (5.9 versus 1.7 immigrants per 1000 population).

With regard to polity, the differences between the ET and the other DT countries are revealed to be statistically significant. The ET countries exhibit higher levels of autocracy at the time of leaving DT phase 2. Our indicator for polity dynamics cannot be expressed by arithmetic means (and thus is not shown in Table 2), but the distributions across our categories correspond to the differences in the polity indicator. During the decade prior to leaving DT phase 2, 62.5 per cent of the ET countries were exclusively autocratic, 12.5 per cent were exclusively democratic, 4.2 per cent experienced a regime change, and 20.8 per cent belonged to the group of others (including colonies, neutral countries, and countries in military crisis). The corresponding numbers for the other DT countries are 50.0, 20.3, 17.6 and 12.2 per cent, respectively.

Finally, for our indicator for economic conditions, we find highly statistically significant differences between the ET and the other DT countries, with the former being characterised by a higher average position in our constructed five-decades ranking. However, it is important to note that the available data did not enable us to derive a reliable indicator that reflects the economic conditions at period *t*. Even after the five-decades ranking is applied as the average of the decadal rankings, the indicator is strongly biased towards more recent times. This is because for many countries, the time series for GDP per capita starts in the 1990s or later; i.e., at a time when globally, the average GDP per capita was markedly higher than in the previous decades.[13] Because this indicator is likely to reflect the more recent economic situation rather than the economic situation at the time when the countries left DT phase 2, we cannot include the economy when considering the empirical evidence for the possible drivers of ET. In sum, the ANOVA statistics suggest that both education and urbanisation are the most important factors in the ET process; and that while the dynamic appears to be more relevant for education, the absolute level seems to be more relevant for urbanisation.

5 Summary and conclusions

The demographic transition (DT) is one of the central concepts of demography, and it is one of the few long-standing theoretical approaches in the field that continue to have a high degree of practical relevance up to today. Although the DT was first described some 90 years ago, many questions about this process are still unanswered, such as the question of what its indispensable triggers are. The aim of the presented study was to extend our understanding by providing an innovative perspective on the DT. Our study contributes to the existing research on this topic in three main ways:

1. We introduced a new approach for determining a population's stage within the DT. This approach allowed us to assign each country of the world to the prevailing phase of the DT at any given time.
2. This approach enabled us to detect a group of populations that progressed through the DT at an exceptionally fast pace over the last 60 years. We referred to this accelerated DT process as 'express transitioning' (ET).
3. The results of our descriptive analysis of the ET countries compared to all of the other populations that experienced the DT since 1950 suggest that urbanisation and education are the factors most strongly associated with this special case of the DT process. While the dynamic appears to be more relevant for education, the absolute level seems to be more relevant for urbanisation. In addition, democratisation might contribute to the ET process as well.

Most of the existing research on the DT either focused on larger spatial entities (such as whole continents) or relied on case studies on individual countries because of restrictions in data availability and quality. Therefore, our global approach, which uses a long time series of demographic indicators and a large number of explanatory variables, is innovative, yet challenging to implement. In addition to facilitating the description of the ET process as such and the identification of the most important factors associated with this process, the present study might help to extend our

[13] The average GDP per capita of the studied countries with available data was US$ 362.40 in the period 1960–69, US$ 1582.00 in 1970–79, US$ 2352.53 in 1980–89, US$ 2783.67 in 1990–99, and US$ 4375.09 in 2000–09.

understanding of the DT in general. Our findings can be seen as providing support for the work of Boquier and Costa (2015) and Dyson (2011), who suggested that urbanisation could be an important determinant of the overall DT process. While we could not prove in this preliminary study that urbanisation is a distinct determinant, we were at least able to show that it is a constant epiphenomenon. Given the nature of urbanisation, this is not surprising. The concept of urbanisation refers to more than just the proportion of the population living in urban areas. It also refers to the emergence of high-density agglomerations of built structures with relatively developed infrastructure and economic conditions, as well as political significance. Furthermore, urban areas are places that foster societal innovation and a distinct 'urban lifestyle' that is shaped by individualisation (Simmel 1903; Wirth 1938). This means that urban areas are potentially favourable places for societal change, as the infrastructure and the wide range of opportunities they provide in terms of education, culture, health care, and the labour market are accessible to many people. This tangible infrastructure and the specific social environment of urban spaces may be advantageous for fostering the cultural change and changes in individual behaviour that finally lead to fertility decline, and, thus, to an acceleration of the DT process.

Our analyses suggest that urbanisation might be even more closely associated with ET than education, at least when we consider the significance levels. Our analyses further indicate that education dynamics – rather than education level – is a highly relevant factor in the DT process. This finding supports the results of previous studies that described an increase in the education of women as a pivotal factor in the recent fertility decline in the so-called developing countries (e.g., Axinn and Barber 2001; Murtin 2012; Cuaresma et al. 2014). The effects of the education level might be missing because the education of women is a distinct indicator, whereas urbanisation is multidimensional in its meaning. Finally, we found some support for the approaches of Dyson (2012) and Wilson and Dyson (2017), who have argued that DT is related to democratisation.

It is, however, important to note that our findings refer to the very restricted group of countries that underwent ET and DT processes after 1950. Thus, our results may not be fully generalisable. Moreover, although our analyses covered a wide range of relevant economic and societal conditions, it is probable that the examined variables did not cover the whole range of possible determinants of both the ET and the general DT processes. Future research should identify and analyse further possible factors, and give special attention to variables or proxies that reflect cultural dimensions. It is also likely that demographic changes are not processed homogenously across national populations. Thus, analyses at the level of smaller regional units and subpopulations, such as education or ethnic groups, are needed. However, data availability remains a major obstacle to addressing all of these issues, and to overcoming the limitations of our study. Reliable global data are still rare and sparse. The restrictions of our indicators and the total impracticality of using the economic variable in our research illustrate this problem. As we mentioned above, the main factors that underlie the DT may be related to changing norms, such as changes in culture or living arrangements. As these factors are often of a qualitative nature, they may be difficult to measure quantitatively. The polity indicator chosen in this study as a proxy for governance is an example of the challenges we face. Governance is an important factor, but it is difficult to measure, and the polity index we used can provide only a rough picture and rather superficial insights. Thus, examining this issue in more detail could prove rewarding. Follow-up research should also include the testing of different time spans for the identification of changes in the DT process. The choice of five-year periods may itself have a determining impact on the presented findings. We are aware that single-year data would have been preferable; but again, such data are not available. Finally, the long time series and the rich data matrix prepared for this study could be explored further, and methods that control for time-invariant country characteristics, such as cultural and institutional features, could be applied. This would bring the analysis closer to being able to determine the causal drivers of the DT process than is possible with the methods applied in the present study.

Despite the abovementioned challenges concerning data availability and quality, examining ET appears to be a promising approach. In the fields of applied demography, development economics, and development aid, the low-fertility-based concept of a ‘demographic dividend’ (Bloom et al. 2003) represents a major paradigm for improving the economic and societal conditions of currently disfavoured societies in the Global South. Following the example of the ‘Asian Tigers’, several African countries are seeking to generate a demographic dividend, or an economic surplus that emerges from the contributions of large numbers of young people of working ages. But to reap this economic dividend, it is crucial that the younger generations are in good health, are well-educated, and have access to job opportunities. The indispensable basis for all dividend-related outcomes is a significant decline in fertility, as the major demographic condition of the paradigm is that a country’s (young) dependent population decreases in relation to the working-age population, thereby generating and harnessing the demographic dividend. This means that the concept is directly linked to the DT, and especially to phases 3 and 4. Thus, having more precise knowledge about the catalysts and the conditions of the DT is important for advancing both the theory and the implementation of the demographic dividend. Given that the window of opportunity for taking advantage of a demographic dividend (i.e., the time span before a relatively large population cohort of working ages enters old-age dependency) is limited, it is essential that we understand not just the underlying causes of the DT, but its tempo – which we focused on by studying ET. In other words: since the strength of the demographic dividend depends on the speed of the DT, knowledge of the ET process may help us better understand why per capita income is growing faster in some African countries than in others (Mason 2001).

To conclude, despite all the challenges mentioned above, we were able to propose an experimental quantitative analysis of the DT since 1950 in a systematic and coherent global perspective. By combining the DT phase and stage models, we were able to overcome the deficiencies of these two concepts, and to identify the stages of the DT process on the basis of empirical data. Hence, we were able to assign each population of the world to a specific stage of the DT process for every five-year period from 1950–55 to 2005–10, and to identify a group of countries that underwent the DT especially quickly. Our findings suggest that urbanisation and its links and interdependencies with the DT merit further investigation, because most of the previous research on the DT concentrated on other factors. From a historical perspective, we can see that the DT has generally been accompanied by a phase of urban growth (because the DT was linked to industrialisation, and industrialisation is intrinsically tied to urban development and societal change). However, the reasons why urban growth occurs can differ greatly. For example, cities can emerge from ancient foundations, or from centres of industry, as often occurred in 19th century Europe. More recently, megacities have been developing in Asia and Africa, which – and this is important to note – can occur with or without major economic dynamics. The present study cannot prove whether urbanisation is actually a prerequisite for the DT. It is, however, obvious that these two processes almost always appear together and in parallel to each other. Our findings suggest that at least for the specific ET process, urbanisation in conjunction with increasing education are necessary preconditions. Exploring distinct causalities in this context by joining the data-driven findings of demography with knowledge from urban sociology and urban geography should be the next, albeit challenging step towards gaining further insights into this important and still open research question.

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Appendix

Table A.1:
Overview of the studied DT countries with the corresponding DT phases from 1950–55 to 2005–10

	1950–55	1955–60	1960–65	1965–70	1970–75	1975–80	1980–85	1985–90	1990–95	1995–00	2000–05	2005–10
Express transitioners:												
Algeria	1	2	2	2	2	2	2	4	4	5	5	5
Bahrain	1	2	2	2	4	4	4	4	4	5	5	5
Belize	2	2	2	2	2	2	4	4	4	4	4	5
Brunei Darussalam	2	2	2	4	4	4	4	4	4	5	5	5
Cape Verde	2	2	2	2	2	2	2	4	4	4	4	5
Costa Rica	2	2	2	4	4	4	4	4	5	5	5	5
Honduras	1	1	2	2	2	2	2	4	4	4	4	4
Iraq	1	1	2	2	2	2	2	2	4	4	4	4
Jordan	2	2	2	2	2	2	2	2	4	4	4	4
Kuwait	2	2	2	2	2	4	4	4	4	4	5	5
Libya	1	1	2	2	2	2	2	4	4	4	5	5
Mayotte	2	2	2	2	2	2	2	2	4	4	4	4
Mexico	2	2	2	2	2	4	4	4	4	5	5	5
Micronesia (Fed. States of)	2	2	2	2	2	2	2	4	4	4	4	4
Oman	1	1	1	2	2	2	2	2	2	4	4	5
Paraguay	2	2	2	2	4	4	4	4	4	4	4	4
Qatar	2	2	2	2	2	2	4	4	4	4	4	5
St. Vincent and the Grenadines	2	2	2	2	4	4	4	4	5	5	5	5
Saudi Arabia	1	1	2	2	2	2	2	2	4	4	4	4
Singapore	2	2	4	4	5	5	5	5	5	5	5	5
State of Palestine	2	2	2	2	2	2	2	2	2	4	4	4
Syrian Arab Republic	2	2	2	2	2	2	2	4	4	4	4	4
Tonga	2	2	2	2	4	4	4	4	4	4	4	4
United Arab Emirates	1	2	2	2	2	4	4	4	4	4	5	5
Viet Nam	2	2	2	2	2	4	4	4	4	5	5	5

Continued

Table A.1: Continued

	1950–55	1955–60	1960–65	1965–70	1970–75	1975–80	1980–85	1985–90	1990–95	1995–00	2000–05	2005–10
Other DT Countries:												
Albania	2	2	3	4	4	4	4	4	5	5	5	5
Bangladesh	1	2	2	2	2	2	2	3	4	4	5	5
Benin	1	1	1	1	1	2	2	2	2	2	3	3
Bhutan	1	1	1	1	1	1	2	2	3	4	4	5
Bolivia	1	1	1	2	2	3	3	3	3	4	4	4
Botswana	2	2	2	2	2	2	2	3	4	4	4	5
Brazil	2	2	2	3	3	4	4	4	5	5	5	5
Cambodia	1	1	1	1	1	2	2	2	3	4	4	4
Cameroon	2	2	2	2	2	2	2	2	2	3	3	3
Central African Republic	1	1	1	1	1	2	2	3	3	3	3	3
China	1	1	1	3	3	4	5	5	5	5	5	5
Colombia	2	2	2	2	3	4	4	4	4	5	5	5
Comoros	1	1	1	2	2	2	2	2	3	3	3	3
Congo	2	2	2	2	2	2	2	3	3	3	3	3
Côte d'Ivoire	1	1	1	1	2	2	2	2	2	3	3	3
Djibouti	1	1	2	2	2	2	2	2	3	3	4	4
Dominican Republic	2	2	2	2	3	3	4	4	4	4	5	5
Ecuador	2	2	2	2	3	3	4	4	4	4	4	5
Egypt	1	2	2	2	3	3	3	3	4	4	4	4
El Salvador	2	2	2	2	3	3	3	4	4	4	5	5
Eritrea	1	1	1	1	1	1	1	2	2	2	3	3
Ethiopia	1	1	1	1	1	1	1	2	2	2	2	3
Fiji	2	2	2	3	4	4	4	4	4	4	4	5
French Polynesia	2	3	3	3	3	4	4	4	4	5	5	5
Gambia	1	1	1	1	1	1	2	2	2	2	3	3
Ghana	1	1	2	2	2	2	2	3	3	3	3	4
Grenada	2	2	2	3	3	4	4	4	4	5	5	5
Guatemala	1	1	2	2	2	2	2	3	3	4	4	4
Guinea	1	1	1	1	1	1	1	2	2	2	3	3
Guinea-Bissau	1	1	1	1	1	2	2	2	2	2	3	3
Haiti	1	1	1	2	2	2	2	3	3	3	4	4
Iran	1	1	2	2	2	2	2	3	4	5	5	5
Kenya	1	1	2	2	2	2	2	2	3	3	3	3
Kiribati	1	2	2	2	3	3	3	3	3	4	4	4
Lao People's Democr. Rep.	1	1	1	2	2	2	2	2	3	3	4	4
Liberia	1	1	1	1	1	1	2	2	2	2	3	3
Madagascar	1	1	1	1	2	2	2	2	2	3	3	3
Malawi	1	1	1	1	1	1	2	2	2	2	2	3
Malaysia	2	2	2	3	4	4	4	4	4	4	5	5

Continued

Table A.1: Continued

	1950–55	1955–60	1960–65	1965–70	1970–75	1975–80	1980–85	1985–90	1990–95	1995–00	2000–05	2005–10
Maldives	1	1	1	1	2	2	2	2	3	4	5	5
Mauritania	1	1	2	2	2	2	2	2	3	3	3	3
Mongolia	2	2	2	2	2	2	3	3	4	5	5	5
Morocco	2	2	2	2	2	3	3	4	4	4	5	5
Myanmar	1	1	1	2	3	3	3	4	4	5	5	5
Namibia	1	2	2	2	2	2	2	3	3	4	4	4
Nicaragua	1	2	2	2	2	2	3	3	4	4	4	5
Pakistan	1	1	2	2	2	2	2	2	3	3	4	4
Papua New Guinea	1	1	1	1	2	3	3	3	3	3	4	4
Peru	1	2	2	2	2	3	3	4	4	4	5	5
Philippines	2	2	2	2	2	3	3	3	4	4	4	4
Republic of Korea	2	2	3	3	4	5	5	5	5	5	5	5
Réunion	2	2	2	3	4	4	5	5	5	5	5	5
Rwanda	1	1	1	1	1	2	2	2	2	2	3	3
Saint Lucia	2	2	2	2	3	4	4	4	4	5	5	5
Samoa	2	2	2	2	2	2	3	3	4	4	4	4
Sao Tome and Principe	2	2	2	2	2	2	2	3	3	3	3	4
Senegal	1	1	1	1	1	2	2	2	2	3	3	3
Solomon Islands	2	2	2	2	2	2	2	2	3	3	3	4
South Africa	2	2	2	3	3	3	3	4	4	4	5	5
South Sudan	1	1	1	1	1	1	1	1	2	2	3	3
Sudan	1	2	2	2	2	2	2	2	2	3	3	3
Suriname	2	2	2	3	3	4	4	4	5	5	5	5
Swaziland	1	1	2	2	2	2	2	2	3	3	4	4
Tajikistan	2	2	2	2	2	3	3	3	3	4	4	4
Thailand	2	2	2	2	3	4	5	5	5	5	5	5
Togo	1	1	1	2	2	2	2	2	2	3	3	3
Tunisia	1	1	1	2	2	3	3	4	4	5	5	5
Turkey	1	1	2	3	3	3	4	4	5	5	5	5
Turkmenistan	2	2	2	2	2	3	3	3	4	4	5	5
United Republic of Tanzania	1	1	1	2	2	2	2	2	2	3	3	3
Uzbekistan	2	2	2	2	2	3	4	4	4	4	5	5
Vanuatu	1	1	2	2	2	3	3	3	3	4	4	4
Venezuela	2	2	2	3	4	4	4	4	4	5	5	5
Western Sahara	1	1	1	1	1	2	3	3	4	4	5	5
Yemen	1	1	1	1	1	2	2	2	2	2	3	3
Zambia	1	1	2	2	2	2	2	2	2	2	2	3
Zimbabwe	2	2	2	2	2	2	2	3	3	4	4	4

Note: For a description, see the text.
Source: The authors' own analysis with data of the United Nations World Population Prospects, the 2012 revision (United Nations 2013).