NEW GENERATIONS

IN DEMOGRAPHY:

NEW CHALLENGING ADVENTURES IN THE POPULATION SCIENCE

University of Economics, Prague

Jakub Fischer, Petr Mazouch, Klára Hulíková Tesárková, Olga Kurtinová (eds.)

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Preface

Yonathan Anson
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It is a pleasure to see the publication of this book, which truly represents the spirit of the Young Demographers' meetings, which have now, after 10 years, become a standard fixture of the European demography calendar. They have also propelled Prague to the forefront of demographic research, adding to the delights of this beautiful city an occasion to meet and meet again old friends, and to follow the progress of young demographers from neophyte to the fully fledged status of researcher and teacher. Today's young demographers are tomorrow's masters!

The first conference of Young Demographers was organised in Prague at the Charles University, Faculty of Science, in 2009. It was designed as a platform offering young demographers (not only from the Czech Republic) the chance to meet up, present their work, and gain useful advice from more experienced colleagues. This conference now meets every year and each year attracts more and more young scholars to Prague.

The initial inspiration for the conference came out of necessity. Two young Czech Ph.D. students, lacking the money to travel abroad during their studies, decided to organise an international conference and to invite their foreign colleagues to Prague. About 50 participants attended. A few years later, as I know in 2013, they continued as a partially restored team of organizers, with even more success, and since then there is a regular flow of abstracts submitted, most of them from outside the Czech Republic. Recently, the growing number of submissions has led to the inclusion of a poster session, to enable even more presenters to come to Prague. Each year, there are around 60 participants, more than half of them active participants (with paper) from foreign countries. Most of the participants are usually from Europe (Germany, Denmark, Spain, Baltic countries, Poland, etc.), but there are also representatives from other continents (USA, South Korea, Mexico, some African countries, India, Israel, etc.). The topics discussed during the meetings vary widely: not only contemporary mortality, fertility and migration but also historical demography, population policy, methodology, population ageing, and much more. In brief, the whole range of demography is here, showing the variability and flexibility of the subject at a level that any international conference would be proud of.

In the past few years some more senior scientists have been invited to present an opening lecture to inspire and motivate the participants in their own work. The conference is now well recognised, and each year receives financial support from the Academic Senate of the Faculty of Science, the Geographical Institute of the Faculty of Science and the home Department of Demography and Geodemography. Nonetheless, the format remains informal, enabling more and less experienced participants to meet and learn from each other, discuss their work and share their passion for the subject and the scientific endeavour. This year, a workshop in historical demography has also been added and will hopefully become a regular feature of future meetings.

This year, 2019, marks ten years since the first conference of Young Demographers and this landmark has motivated the preparation of this special volume

marking the event and presenting the work of some young (and some slightly older) demographers, participants of the conference. The book covers a range of topics, from an introductory overview of Demography as a science, to country level discussions and analyses and the intricacies of formal demography. It presents a fine introduction to the breadth of the field for someone whose thoughts lie in this direction, or even one who has already decided!

Ten years is a whole generation in scholarly terms and already a new group of young Ph. D. students has stepped in to take over the organisation of the conference (with help and advice from more experienced colleagues). For someone who has followed the growth of this conference, seen it move from an idea to a regular feature of the demographic calendar there is a gratifying feeling that demography in Europe is in very capable hands and we can look forward to a lot of exciting new work over the coming years.

Jon Anson
Beer Sheva, January 2019

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Introduction: Ten years of Young Demographers

Klára Hulíková Tesárková

In 2009, the first conference of Young Demographers was organized in Prague at the Charles University, Faculty of Science. It was a platform offering a possibility for young (not only Czech) demographers to meet their foreign counterparts, present their work, and gain useful advice from more experienced colleagues. This conference was then repeated every year since and in the latest years especially, attracted more and more young people to Prague.

The 10th conference of Young Demographers is already organized for February 2019. As with the last several years of the event, this year the conference is prepared in cooperation with members of the Department of Demography and Geodemography, Faculty of Science, and a few doctoral students of Demography. It is this close cooperation and significant share of works made by students themselves that makes this event so unique from an organizational point of view. This format also leads to a less formal atmosphere during the conference as well as in communication with the participants.

Today, we are extremely happy that we can hold in our hands this book prepared on the occasion of the 10th anniversary of these pleasant events, always full of enthusiasm and fresh ideas. This book is a celebration of Young Demographers, a gift to all of the past, current, and future participants of the conference and also a promise for the future.

The aim of this publication is to present the cross-section of innovative streams in international demography as seen by the young researchers in demography. It covers methodological issues, topics related to fertility and population policy, and mortality as well as population aging.

During the last 10 years many scientists attended the conference of Young Demographers in Prague, some of them repeatedly. A decade later, some of them are already world-known, respected scientists and we, the organizers of the conferences, could only be proud on the fact that those potential future leaders in demographic research were (and hopefully will be) a part of the Young Demographers. Because we wanted to illustrate the personal as well as professional development of young scientists in demography, we asked some of our colleagues around the world, past participants of the conferences, to introduce their research topics. Luckily, most of them agreed.

Just after the introductory part of the book, Daniela Arsenović describes her research devoted to climate and its influence on mortality development. Daniela is without any doubt one of the most active and internationally known young demographers from Serbia and Southeast Europe in general. She is also a relatively frequent guest in Prague – she is always welcomed for the conferences of Young Demographers.

We were happy when she also attended the workshop of Health, Morbidity, and Mortality Working Group of the European Association of Population Studies organized in 2015 in Prague.

Martina Štípková is one of the first and most frequent participants of the conferences of Young Demographers. She came originally from the University in Pilsen (Plzeň, Czech Republic) before working in and cooperating with other universities and scientific centers in the Czech Republic as well as abroad. She is also one of the Czech representatives among the attendants of the European Doctoral School of Demography and scientific courses organized within the Max Planck Institute for Demographic Research in Rostock, Germany.

Jonas Schöley, originally from Germany, co-author (with Ilya Kashnitsky) of the following chapter, is currently one of the most progressive demographers in the world. He always expresses a very original attitude to the demographic issues. Currently, he is especially known for his work with visualization in demography. The same could be said about Francisco Villavicencio, another author presented in this book, originally from Spain. Within this book, he presents some topics related to methodological aspects of demography. He is already well known thanks to his research on the issue of time in demography. Jonas and Francisco are both former participants of the conferences of Young Demographers and aroused considerable interest and enthusiasm for their contributions. Moreover, both of them are already well established in the international demographic field and, among others, presented their work during the Population Association of America annual conferences.

Personally, I am very happy that one of the authors in the book is Adéla Jodlová. Only last year she graduated with a Bachelor's Degree in Demography from the Faculty of Science, Charles University, and her Bachelor's Thesis, as well as the chapter within this book, is devoted to the issue of population aging in the world. She is one of the promising persons for the future, currently hard-working in a Master's program of Demography having her first scientific experiences.

I am also very happy that another author in the book is one of my closest colleagues and friends, Petr Mazouch. He contributed to this book along with Jakub Fischer and always devotes his exceptional enthusiasm to demographic issues and their application in economy. It is partly thanks to the interest and passion of Petr and Jakub, that this book could be published at all. Their contribution to this publication continues with the established cooperation of the University of Economics in Prague and Department of Demography and Geodemography, Faculty of Science of Charles University.

Olga Kurtinová is my closest colleague from the Department of Demography and Geodemography and also the traditional co-organizer of the conferences of Young Demographers. She is always there when and where she is needed. Several years ago, when the continuation of the conference of Young Demographers was almost endangered, she returned from her studies abroad and helped to rise the events to their current level.

From all of the contributions in the book, one can learn about a new generation of demographers – people who are mostly at the level of post-doc, starting their own research projects and building their first research teams. Some of the authors are more experienced in international science, while some of them are more experienced in teaching or even academic administration. However, all of them contribute to the overall picture of young people in the discipline.

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At the same time, the book introduces the field of study itself to the reader. Particular topics presented in the following chapters represent various research aims and current, hotly-debated issues.

Of course, the range of the book is limited and many young progressive scientists and their work still wait for an introduction. However, the book reaches its aim to illustrate the new generation in topics of demography and a new generation of scientists which has the potential to be the leaders of demographic research during the mid of the 21st century.

1.1 Personal closing of the introduction

As mentioned above, this book is published on the occasion of the 10th anniversary of the international conferences of Young Demographers, held traditionally each February in Prague and hosted by the Faculty of Science, Charles University (Prague, Czech Republic). During the last 10 years of these conferences, there were some years that were better than others. However, the tradition became stronger each year.

Personally, I am very lucky to be among the organizers each year. Thanks to the conferences, I had the possibility to meet many interesting people with promising research topics and admirable scientific as well as personal development. Nowadays, I have many demographic colleagues (or even friends) all around the world. So, in the end, I am grateful for this possibility and for all the experiences flowing from my work in the organization committee each year.

My work would be much harder or even impossible without the help of my colleagues and our active students. So here, I would like to thank my past and present colleagues and co-organizers: Šárka Šustová, Alena Filasová, Barbora Kuprová, Martin Koňařík, Dan Kašpar, Tereza Pachlová, Jitka Slabá, and, finally, Luděk Šídlo, co-founder of the organization of Young Demographers and of the annual conferences.

My special gratitude goes above all to Petr Mazouch, my very close friend, schoolmate, and co-editor of this book, who has infinite passion and enthusiasm for demography; and Olga Kurtinová, also my schoolmate, co-editor, and an exceptional and supportive friend, whose knowledge of demography I always admire.

Here, I would also like to thank the two reviewers of this book, for all their comments, advices, and time devoted to the texts. Moreover, we are grateful to the traditional partners of the conferences – the SAS Institute of the Czech Republic, the Institute of Sociology of the Czech Academy of Sciences, the Czech Statistical Office and above all to the Department of Demography and Geodemography, Faculty of Science (Charles University). This chapter and the whole book have been supported by Charles University Research Centre program UNCE/HUM/018.

Last but not least, I am grateful to my family – my parents and especially to my beloved husband and daughter – for their understanding, endless patience, and support…

Klára Hulíková

Prague, December 2018

Demography: the study of population phenomenon

Olga Kurtinová

This contribution deals with a fundamental question: "What is demography?". Demography is broadly known as a scientific discipline that deals with the population size, structure and its renewal by demographic processes of natality and mortality. However, this specification in various modifications is used quite often, it is only a prat of the story.

The word demography comes from two antient Greek "demos" and "graphy" which mean "the people" and "writing about or recording something". The Belgium statistician Achille Guillard (1799–1978) was the first who used this word for the scientific discipline focusing on reproduction of human population in 1855.[1] He defined demography as follows: *"is the natural and social history of the human species or the mathematical knowledge of populations, of their general changes, and of their physical, civil, intellectual, and moral condition."* [Carmichael, 2016, p. 2]. Nevertheless a father of demography as a scientific discipline is recognized John Graunt (1620–1674), an English a haberdasher, who wrote the book *"Natural and Political Observations Made upon the Bills of Mortality"* (1662).[2] Based on bills of mortality, which were the weekly mortality statistic in London, and data on christenings and marriages in London he studied numerical regularities in population. His major contribution is in introduction of the forerunner of today's life table[3], the ratio between men and women in population and the proportion of deaths from certain causes of all deaths in successive years and different areas.

The exact moment, when human started to think about their reproduction, the desirable size of population and its distribution, is unknown. Although the thoughts about population are present in some preserved records as the Laws of Eshnunna[4], the Code of Lipit-Ishtar[5], or the Hammurabi Code[6], it was written in ancient times. In a simplified way, population issues became important for humans at the moment when they started to form cities and states in the past, because population size was recognized as a source of military forces and economic prosperity of the empire, states or city. On the other hand, officials were also afraid of overpopulation which could induce instability due to growing scarcity of food. The first systematic thoughts about population are

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1 Éléments de statistique humaine ou démographie comparée. Guillaumin et cie, 1855, 376 p.
2 Hauser and Duncan (1959) consider as the first demographic study the work of a Switzerland physician F. Platter who statistically studied the effects of the plague in Basel in the period 1609–1611.
3 Edmund Halley (1656–1742) constructed the first life table based on data for the city of Breslau (now Wroclaw in Poland) for the period 1687–1691 in 1693.
4 The law of an ancient Sumerian city-state in central Mesopotamia dated to 1930 BC.
5 The code of the 5th king of Isin Lipit-Ishtar, who ruled in the period ca. 1870 BC–1860 BC.
6 The code of law of Babylonia, the state in Mesopotamia, dated back to about 1754 BC.

included in work of Plato (ca. 428/427–348/347 BC) and Aristoteles (384–322 BC), the antient Greek philosophers who significantly influenced the foundations of current science, and Confucius (551–479 BC), a Chinese teacher and philosopher. Additional contribution to population thought was made by Saint Thomas Aquinas (1225–1274), an Italian philosopher, theologian, and jurist in the tradition of scholasticism, and ibn-Khaldun (1332–1406), an Arab historiographer and historian, in the 13th and 14th century. The one of the groundbreakers of the population theory is also Giovanni Botero (1540–1617), an Italian thinker, priest, who considered high population density as an advantage for the state, on the other hand he speculated the reasons for establishment of limits on population growth. The most influential work, which stimulated interdisciplinary approach in demography, is well known book of Thomas Robert Malthus (1766–1834), an English cleric and scholar, „*An Essay on the Principle of Population*" published in 1789. The essay focuses on relationship of food production and population growth and assumes that population multiples geometrically and food production arithmetically. Therefore, the population excess leads to a food shortage and starvation and this pattern is from his point of view inevitable.

Prior to the beginning of the 20th century, demography dealt with demographic processes, predominately mortality and natality[7] and/or population size, structure and growth, but did not connect both fields directly. It was the one of the reasons, while demography did not form as a fully independent scientific discipline for long time. The state of affairs changed with the work of Alfred Lotka (1880–1949), an US mathematician, physical chemist, and statistician, in 1907[8] and 1911[9][Bacaër, 2011]. He gave a mathematical expression for the relationship between birth rate, death rate, population growth rate, and age structure in a stable population in which birth and death rates were kept constant in the long-run[10]. It was the milestone in history of demography, because the model of stable population joined formally the demographic processes with the population structure and dynamics. That contributed to demography flourish to the independent scientific discipline, which we know nowadays. Afterwards demography gained step by step more space in study programs at universities. For instance, the first course of demography at the Charles University, which was established in 1348, was introduced at the Faculty of Philosophy in 1899, the Institute of Anthropology and Demography[11] as a part of the Faculty of Science was established in 1920 [Pavlík, 2000], and the Department of demography and geodemography at the same university and faculty was constituted in 1990.

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7   Pierre Simon Laplace (1749–1827), a French statisticians and mathematician, proposed the first fertility research in French region.

8   Lotka, A.J. 1907. Relation between birth rates and deaths rates. Science 26, issue 653, pp. 21–22.

9   Sharpe, F.R.; Lotka, A.J. 1911. A problem in age-distribution. *Philosophical Magazine Series 6*, Volume 21, Issue 124.

10 The first contribution to the stable theory made Leonhard Euler (1707–1783), a Swiss mathematician, in his work "*A General Investigation into the Mortality and Multiplication of the Human Species*" published in 1760.

11 From 1923 Demography was taught by František Jaroslav Netušil (1890–1927), who was a student of Raymond Pear. His lectures related to Demography were: Theory of Demography (1923), Demography of the Czech Lands (1926) and Demographic Methods (1927). From 1929, Demography was taught by Antonín Boháč (1882–1950), who had lectures: Principles of Population Science (1929), The System of Population Science (1930–1932), Results of Population Census (1933), Population Problems of France (1934), Dangerous Places in the World Population (1935), Population Problems (1945), and Nature, Population and Society (1949).

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These days demography is defined as a mathematical system of laws and relationships (narrow sense):

"*… is the science of population*" [Shryock, Siegel and Associates, 1976, p. 1; Weeks, 2002, p. 4; MPIDR, 2018]

"*…is the study of population structure and change*" [Hinde, 1998, p. 1]

"*…is the study of demographic processes, …*[studies] *the behavior of human population*". [Preston et al., 2001, Preface]

"*…is the scientific study of human population*" [McDonald, 2014]

"*…is the statistical study of human populations especially with reference to size and density, distribution, and vital statistics*" [Merriam-Webster, 2018]

These definitions are simple. Therefore, they are easier to remember and communicate, but they are not so precise.

Another approach, demography as part of a broader science (sociology, economics, geography, psychology, history, evolutionary biology, public and social policy, etc.) which perceives demographic processes as social process related to other social processes (broader sense):

"*…is the study of the size, territorial distribution, and composition of population, changes therein, and the components of such change*" [Huaser and Duncan, 1959, p. 31]

"*…is the study of human populations in relation to the changes brought by the interplay of births, deaths and migration*" [Pressat, 1985, p. 54]

"*…is the scientific study of human population, including its size, distribution, composition, and the factors that determine changes. [Demography] focuses on five aspects of human population: (1) size, (2) distribution, (3) composition, (4) population dynamics, and (5) socioeconomics determinants and consequences of population change*". [Siegel and Swanson, 2004, p. 1].

"*…is the study of human populations: their size, composition, and distribution, as well as the causes and consequences of changes in these characteristics*". [McFalls, 2007, p. 3]

"*…is the study of human populations – their size, composition and distribution across space – and the process through which populations change. Births, deaths and migration are the 'big three' of demography, jointly producing population stability or change*" [Stockholm University Demography Unit, 2018]

"*... is the scientific study of human populations primarily with respect to their size, their structure and their development; it takes into account the quantitative aspects of their general characteristics.*" [Demopedia, 2018].

In sum, in narrow sense demography focuses on demographic reproduction due to the demographic processes of natality and mortality. Sometimes it also includes migration. But however, migration as a movement of people from place to another, may influence the size, distribution and dynamics in a given population, it is not a natural change of the population. In broad sense demography studies both demographic reproduction and its changes, and conditions and consequences

of the demographic reproduction. In this case demography overlaps to other social sciences as sociology, economics, history, geography, epidemiology, anthropology, psychology, etc.[12] That means demography provides not only the information about size, structure and distribution, but also study factors which caused that state. In addition to that, object of demography is human population, the subject is demographic reproduction. The demography is, more than probably any other social science, identified by its object and subject matter rather than by conceptual premises of how to study it.

However not all listed definition stress that unequivocally, it is necessary to notice that demographers study mainly human population. The term "population" is used differently in demography and statistics. It is assumed that term "population" in science firstly used Francis Bacon (1561–1626), an English philosopher, statesman, and scientist in 1612[13] and it was in the sense of human population. But population in statistics, in case of sampling, means the universe of units under consideration, which may be individuals, dogs, flowers etc., while population in demography relates to the number of people in a given area. In addition to that, number of inhabitants is not necessarily a synonym to population. While inhabitants are people living within a political or geographical boundary; i.e. number of inhabitants of a given state, population are people with a given characteristic. Therefore, inhabitants of a given state may come from several populations, or given population can reside in several states. For demographers it is necessary to clearly specify what population is included in their research.

The progress in the methodological development of demography is closely related to improvements in data collection. Demographers have mainly three sources of population counts[14] these days: population census, vital statistics and surveys[15]. While population census produces data about individuals at a particular instant in time, vital statistic produces records of events during a particular time interval, usually a year. Therefore, census data provide cross-sectional snapshot of population stock, its size and structure, and vital statistics on births, deaths and other demographic events provide flows over time. Surveys may provide data about individuals and events in broad context according to survey's design, but these data are just sample.

Population counts and statistics date back to thousands of years ago. The population census belongs to the oldest statistician action[16] and it is an exhaustive survey. In other words, the population of the entire territory of the given state is counted. In addition to that, each person is enumerated separately, population census is conducted based on

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12 Hauser and Duncan (1959) and some other authors distinguish Demography and Population studies which focus on relationship between demographic and non-demographic variables.

13 Essay: Of the True Greatness of Kingdoms and Estates.

14 Demographers work with two types of data: 1) peoples' demographic characteristics as age, sex, marital status, attained education, economic status, etc. 2) demographic events as births, deaths, marriages, divorces, abortions, migratory moves, etc.

15 The progress of computing technologies in the recent decades allows demographers to use other administrative sources.

16 The first censuses which are documented in ancient Egypt, China, Palestine, Greece and Rome, were made for military and tax purposes, therefore they did not include entire population. The population censuses which covered all population were conducted not only in Europe in the middle of the 18th century: Sweden (1748), Prussia (1748), Finland (1749), Austria (1754), Finland and Denmark (1769), Switzerland (1789), the United States (1790).

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law and it is compulsory for all individuals, it relates to a single point of time and it is held at least at ten years intervals. For the reason of international comparability modern censuses follow the United Nation recommendations. According to UN data about the 2020 World Population and Housing Census Program, 194 countries have scheduled population census, 33 countries have already conducted census and 11 countries have not scheduled census. It is assumed that the proportion of enumerated population in the world will reach 97.5% in 2024 [Statistics division, 2018a]. The vital statistics[17] provide information on births, deaths, marriages, divorces, abortions and migrations. The purpose of the registration system is essentially administrative and legal rather than demographic. Therefore, records cover the basic items such as date of the event, age, sex, marital status, occupation, cause of the death and their scope and quality vary from country to country. The Statistics division [2018b] assumes that only 68% of countries register at least 90% of births occurred and only 55% countries register at least 90% deaths occurred. The data set quality of vital statistics correlates with development of the countries, more developed countries provide more accurate vial statistics than less developed countries.

The third source of demographic data is survey. Its' advantage is in scope of questions which can be included, the lower costs of the survey in comparison with the population census, and furthermore the survey can be organized and conducted relatively quickly. The main disadvantage of a survey is the sample error. In demography sample surveys are important because they provide information which allow demographers study the factors influencing the population development. In less developed countries, where population census or vital statistics do not exist or provide poor quality data, surveys are the only sources of demographic data. In addition to that, demographers have to carefully consider data quality regardless the source of population data.

Among other scientific disciplines demography is between natural and social sciences. The human reproduction is by its nature biological, but at the same time is determined by social factors. Demography, especially formal demography, which is considered often as a core of this science, has accurate mathematical and statistical background. On the other hand, an explanation of population dynamics as a social phenomenon is not followed by development of theory. Demography is criticized for its week conceptualization frequently [De Bruijn, 2006]. That means, models, concepts and frameworks are undoubtedly a part of demography, but an existence of a rigor scientific theory is questionable. If demographers speak about demographic theory, they mention the First Demographic Transition[18] and sometimes the Second Demographic Transition.[19] The First Demographic Transition focuses on the transition from high birth and death rates to lower level of birth and death rates which have

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17 The significant improvement in vital registration system in Europe took place in the middle of the 16th century. For instance, in 1532 bills of mortality, which used John Graunt in research, were provided in England. The first registration of births and deaths occurred in northern Europe: Finland (1628), Denmark (1646), Norway (1685), Sweden (1686).

18 Adolphe Landry (1874–1956), a French demographer and politician, was the first who defined that in his work *"Les trois théories principales de la populationin"* in 1909 and "*La Révolution démographique. Études et essais sur les problèmes de la population*" in 1934. Warren Thomson (1887–1973) and Frank Notestein (1902–1983), American demographers, made a significant contribution to this theory also.

19 The theory was defined by Ron Lesthaeghe and Dirk van de Kaa in their work „*Twee demografische transities*?" published in 1986.

taken place as a given society developing from a preindustrial to an industrial society. The Second Demographic Transition deals with the low sub-replacement intensities of fertility that occurred in developed economies in the second half of the 20th century. The main critique of both theories is that they describe only the pattern of development, but they are not general and predictive.

Demography concerns with the measurement of population phenomenon and explains the specificity of population development (the pattern, differentials, trends) revealed on the results of demographic analysis. The uniqueness of demography as a scientific discipline is in its subject of study, because only demography focuses on the demographic reproduction, in data sources (population censuses, vital statistics, surveys), and its interdisciplinary approach, because to understand the population phenomenon demography overlaps in some parts with several social disciplines.

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Demography – living or dead science?[20]

Jakub Fischer, Petr Mazouch, Klára Hulíková Tesárková

What is the meaning of demography for population development analysis today? And what is the position of demography among the other sciences? Is the present scientific and research activity in demography more an analysis of data with an application of conventional methods or is demography a progressive science inspiring other disciplines as it was in the past? What is the interdisciplinarity of demography today? And can we apply any demographical methods in some other disciplines?

We try to answer those questions in this chapter, which comes before chapters focused on actual specific demographic scientific and research questions. The aim is not to defend demography as a science or to summarize a list of merits of demography, but to show that demography is not only important from a data perspective, but also from the perspective of theory, where other disciplines could apply methods which were developed in demography and now applied in totally different areas. Proof that demography is not a dead science and has a rich history is included in the next chapters, which represent current problems in demography and which are being solved by certain young demographers.

Encyclopedia Britannica[21] defines demography as a "*statistical study of human populations, especially with reference to size and density, distribution, and vital statistics (births, marriages, deaths, etc.)*". This definition is very general and we know that demography in itself or as an interdisciplinary science covers a much wider area than we can find in the definition.

Demography has changed a lot over its entire history, where the first use could be called the first demographical experiment, estimates of the size and structure of a population, are from the age of the pharaohs [Carletge et al., 1997]. In the first stage, as in the pharaonic age, the aim was to get information about the size and structure of a population. But the first attempt to analyze the causes of the *changes* in the population (mortality, fertility, migration) moved demography to the level of science. We can see John Graunt's publication as a milestone. It focused on a deeper analysis not only about data on the size and structure of a population, but also on mortality and fertility patterns [Lorimer, 1959].

Many other works and authors followed John Graunt and over almost four centuries demography has become a well-known, respected and wide-reaching science, whose spectrum [Horvath, 1987] can be defined by basic data providing (by census or vital statistics) on one side (Horvath [1987] calls this "*pure*" or "*formal*" demography) and the analysis of some other variables, which are very often based on sample surveys

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21 https://www.britannica.com/topic/demography

which Horvath calls "*Social Demography*" and where demography breakthroughs into some other disciplines can be found.

In this opening chapter, we first focus on the usage and importance of demography for population policy, second, we look at the interdisciplinary position of demography with other socio-economic disciplines and, finally, the demographic methods used in areas absolutely without any connection with population will be introduced.

3.1 Demography at the center of interest nowadays – a necessity for politics

Demographic science and research can be "pure" demography or "applied" demography. In the case of managing the national economy, we see the application of demography every time. Demographic developments during recent decades have been nearly revolutionary and today political administrations cannot ignore current population trends [Teitelbaum, 1992]. The recent developments have to be considered in a wider context, where a rapid population increase started primarily after the World War II, particularly in developing countries. In developed countries a mortality decline was already observed several decades earlier, followed by a decrease of fertility. In developing countries, the drop of fertility was still not universal by the end of the 20th century.

The population development in the second half of the 20th century can be understood to be a very special and extraordinary period of human history [Lam, 2011]. This is above all because of the rapid population growth in the first decades following World War II, the increasing poverty rate and environmental conclusions. On the other hand, many of these problematic issues were at least partly resolved, some others, however, remain just as challenging for the future [ibid.].

In general, demographic issues nowadays can be divided into two groups – problems of population development in developing countries and problems of population development in developed countries. Clearly, both groups of countries have to deal with nearly opposite trends or values of demographic measurements.

Because of the extreme tempo of population growth, above all from the 1950s and 1960s, the demographic issues garnered considerable attention, although the actually discussed topics have changed (at least partly) from that time. Except for the rapid population growth (above all in developing countries), four other issues of extreme importance can be defined at the end of the 20th century [Teitelbaum, 1992:66], again related specifically to developing countries: 1) a high level of fertility in some of those countries, 2) significant population momentum in those countries (leading to the continuation of the population growth even if the fertility level drops), 3) rapid urban growth rates, again above all in high-fertility and developing countries, 4) the increasing role of international migration, above all from those developing and high-fertility countries.

On the other hand, the developed countries nowadays are seriously affected by the process of population aging. Moreover, this is highlighted by the numerous generations born after World War II, the generations of "baby boomers". In the U.S., those generations are estimated to have been born between 1946 and 1964 [Scommegna, 2018], in Central Europe (e.g. in the Czech Republic) the numbers of births started to decrease relatively rapidly after the end of World War II. When those populous generations reach senior age (usually defined by ages 65 and more), the share of this age group starts to increase

significantly. Moreover, this is reinforced by following less populous generations. This is the case of many developed, especially European, countries.

With the increasing share of seniors in populations, the question of their health status arose. From an economic point of view, there is an advantage to a longer-working (or productive and economically active) population. However, older people not only need to be motivated and supported to stay longer (to a higher age) on the labor market, but they also have to be in good health and in good physical as well as mental shape. If these conditions are fulfilled and people are, on average, working to a higher age, then (not only) financial benefits can be achieved. The working older people could retire later, but more financially secure. On the other hand, the government could spend less on pensions or other social and health services. Unfortunately, the U.S. research does not confirm any improving health status of the baby boomer seniors in comparison to previous generations [Scommegna, 2018]. Primarily the increasing prevalence of chronic diseases (i.e. like diabetes, reinforced or partly caused by e.g. a rising prevalence of obesity) could be pointed out [ibid.].

As can be seen from these few examples, the population issues are of crucial importance nowadays. In relation to developing countries, the problem of the high tempo of population growth could be mentioned, which is also tied to a high fertility level, the existence of fertility planning programs and access to health services, contraception or education. On the other hand, in developed countries probably the most visible problem is the aging population and its consequences and perspectives for the future. It is usually related to a low fertility level (far below the level of reproduction), i.e. also the questions related to population policy, the health status of the population or the overall living standards or life style of the population have to be discussed. All these issues (and many more) are part of demography as a discipline. All these issues are still more and more frequently discussed in the public. Naturally, this also means that demography as a subject has started to be seen, mentioned and discussed more often in the media and in the public.

It could be also supposed that reaching a worldwide population of 7 billion, often mentioned and discussed in the media, has attracted attention to demographic issues [Lam, 2011]. However, there are more reasons why demography and population issues should be taken more as a common and important part of our everyday life, of social contexts and public interest. As mentioned above, many current demographic trends could be seen to be revolutionary. These could include, for example, the long and extremely rapid population growth in the aforementioned least developed countries, or the highest ever seen proportion of seniors in some populations, its rising tempo in others, the migration crisis observable in Europe, and unprecedented long-term low fertility levels in many developed countries.

3.2 Interdisciplinarity of demography in research

With the increasing number of data sources where, in addition to traditional demographic variables (age, sex), some other variables are surveyed (economic activity, health status, marital status and other socio-economic variables), the areas of possible analysis have become wider. In actual trends, we can still find topics which are oriented directly on basic demographic indicators such as mortality, fertility or migration, but the area is

narrowing over time. Strictly demographic topics are focused on different areas such as data reconstruction, which could be close to historical demography (for example the chapter by Mazouch and Hulíková Tesárková), or on problems with missing data imputation by more complicated models (as in the chapter by Francisco Villavincencio or Zimmermann, Mazouch, Hulíkova Tesárková [2014]). By this activity, wider data sets are available over time (prolonging historical time series) or more detailed in space (data from smaller areas such as districts or towns). This is also how some other disciplines expand the available data – in Economic statistics, for example, the GDP data in the past was reconstructed [Sixta, Vltavská, Fischer, 2013] and now the time series are longer and could help us to analyze more relationships in the past or to estimate past trends and economic cycles. Another way to extend the data sources is to add the newest data and verify historical trends or estimate future developments.

A much more dynamic area is the combination of traditional demographic topics with other socio-economic phenomena or the application of some advanced mathematical methods to demographic data. There are areas which are closely connected with demography, for example the insurance industry which uses methods and data from actuarial demography, or some areas which correspond with demography just partially and use some other variables (such as indicators of economic activity, health status or education level, etc.) or some other data sources which cover demographic variables just as additional variables (sample surveys focused on some concrete topics, such as living condition surveys or household budget surveys).

One of those areas is also the measuring and quantification of the level of human capital in society where, in addition to a classical quantitative approach based on demographic data (the size of the population), we can also include the qualitative aspect of individuals expressed, for example, by the Highest Level of Educational Attainment or by years of schooling (for example Mazouch, Fischer [2011], or Finardi, Fischer, Mazouch [2012]). Another example could be the estimation of healthy life expectancy presented by Sullivan [1971], which combines information about conditions of health in the population and the general mortality level, for demographic health statistics are very important.

Another example is the demography of families and households, which uses data about the structure and formation of families and households, which could be understand as a link between demography and sociology (for example Teachman, Tedrow a Kim [2013] or Bartoňová [2008]).

Economics is another very specific discipline where demography plays an important role. There are problems where demography is crucial, for example pension systems where, for countries with Pay-as-you-go system, the demography is a basic parameter to keep the system working (in more detail for example Yang [2016]). Or there are some indicators of economic activity with which the combination of demographic indicators could better explain the problems of the unemployed part of the population, but also to the employed population and its structure [Swift, 2017]. In measuring productivity, where the classical approach measures output per person, the quality of the person could be also included (Sixta, Vltavská [2016]). Between economics and sociology we can find the analysis of living standards, where demographic aspects are very important (household size, children in households etc.) [Atkinson, Malier, 2010].

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3.3 Using of demographic methods in other areas

In Horvath [1987] there is no direct demographic method except life tables, because all those methods are just mathematical or mathematical-statistical applications in demography. We cannot claim this for sure because there are several proofs that some methods which are now applied as general (theoretical) methods were first developed in demography or were first applied to and defined on demographic data and now we can find also those methods in some other disciplines.

It is indisputable that demographical data was one of the first types of data which allowed people to work with big numbers (the results of censuses were processed by mathematical methods and applications). Demography is also very important for the insurance industry and in life insurance many theoretical methods were first developed in demography and now insurance has developed them.

A prime example showing that demography was the area where some now general methods were developed is standardization. Direct standardization was published by Neison in 1844 and an indirect method was published also by Wolfenden in 1923 [Nieson, 1844 and Wolfenden, 1923]. Those methods are still widely used in index decomposition.

Demographical methods are applied in very specific areas which are far from application to a population as we understand it. For example, EUROSTAT-OECD has developed a project[22] focused on Business Demography Statistics, where indicators which characterize an existing population of businesses are analyzed. For this special area, births or the ability to survive (5 years after birth) and mortality, indicators which are typical for demography, are analyzed.

A mortality analysis could be used in the analysis of investments (fixed capital stock), more specifically machinery and equipment. Mazouch and Krejci [2016] and Krejci et al. [2015] used basic demographical methods of mortality analysis to estimate the value of the regional net fixed capital stock and the age structure of the machinery and equipment in Czech agriculture. In addition to life expectancy, some other quantile indicators and graphical methods from demography were also used.

The application of demography to some specific group or subpopulation could help to estimate the future needs of some specific field or branch. Fischer [2007] used a demographical analysis to forecast the development of the structure of dentists in the future. This kind of population forecast was based on 5-year age intervals, fertility was replaced by graduates from universities, mortality was expressed as leaving the field and the model was also able to work with migration, as many of the dentists in the Czech Republic are from abroad (i.e. Slovakia, Ukraine) and, on the other hand, some Czech dentists also leave to work abroad, usually to some western countries.

3.4 Conclusion

All the aforementioned proofs show that demography is not a discipline which is wasting away. What is more, we can see that its importance is increasing with respect to very important needs, such as managing the national economy. From the perspective of pure demographic topics, it is more difficult to find new trends where demographic analyses could develop, but we can see that it is possible thanks to new mathematical (or statistical-mathematical) methods which we can apply in the demography.

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22 http://www.oecd.org/sdd/business-stats/39974460.pdf

An important role is to reconstruct historical data or to get data in more detail so that we can perform a deeper analysis.

We can find a much wider application of demography in some interdisciplinary cooperation with some other socio-economic phenomena. Also, the increasing amount of available data is aided by a combination of better methodology and computer technology.

Last, but not least, we can see that demography is a science which inspires: methods and techniques from demography can be found in many other disciplines which are far from the basic topic of demography – populations.

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Climate and population in Central Europe: results for temperature-related mortality in Novi Sad

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4.1 Recent climate-related mortality research in world

The relation between climate and population, as well as climate impact on human health, is recognized for a very long time, since Hippocrates. In his famous book "*On Airs, Waters and Places*", 400 B.C, he stated that each time, if we want to investigate medicine properly, first the seasons of the year should be considered and the effects which each season produces [McMichael et al., 2003]. Due to this, climate-related effects on population are in focus of scholars from various scientific disciplines: medicine, demography, geography, sociology, climatology etc. Impact of climate on population, especially on human mortality, could be found in both urban as well as rural areas, but there is a concerning opinion that population in cities is exposed to higher risk, due to the intensive urbanisation. Various multicity and time-series analyses were carried out confirming the impact of extreme temperatures on mortality. Recent findings suggest that global climate change raises overall temperatures with the potential to increase future heat-related mortality as well [Li et al., 2018]. It is common concerning risk that under climate changes intensity and frequency of heatwaves will increase [Perkins et al., 2012; IPCC, 2013] delivering harvesting effects on mortality.

Growing attention to this task was given after heatwave in 2003. During summer 2003, Western Europe was affected by strong heatwave and the particularly harvesting situation was in France. In August 2003, in France was estimated that more than 10.000 excess death occurred between 1st and 20th August, with 60% overall increase of mortality compared with the seasonal norm [Vandentorren et al., 2004; Le Tertre et al., 2006]. According to Vandentorren and Empereur-Bissonnet [2005], it was the warmest year over the last 53 years (refers to minimal, maximal and average temperature, as well as duration). Population in France was not the only one affected by 2003 heatwave. Grize et al. [2005] investigated mortality excess for different age groups, gender and geographic regions in Switzerland and they founded a 7% increase in all-cause mortality in the period June–August 2003. The increase was more pronounced among elderly and in three cities (Basel, Geneva, and Lausanne) where the daily air temperature was above 35 °C and night temperature above 20 °C. A higher increase in mortality excess among elderly (75 and older) was confirmed also in Italy during summer 2003

[Conti et al., 2005]. Similar to summer 2003, countries in Central Europe experienced strong heatwave in 2007 and 2015. Investigation in the Czech Republic showed that summer 2015 was record-breaking in the duration of heatwaves as well as their impact on the heat-mortality increase. Urban et al. [2017] compared major heat effect in 2015 with those in 1994 and concluded that despite smaller absolute heat-related mortality excess in 2015 in comparison to 1994, the relative increase from baseline was higher in 2015. A stronger impact in 2015 on mortality excess was confirmed in older population (aged 65 and over) due to the absolute temperature anomaly during heatwave and duration and magnitude of heatwaves [Urban et al., 2017].

Despite this, winter mortality is still higher in most of the countries – with winter mortality excess between 5% to 30% [Healy, 2003]. In the study of European countries, carried out by Healy [2003], the winter mortality in EU-14 is about 14% higher, while the Portugal population suffers from the highest winter mortality excess (28%). Scholars bring diverse opinions about the impact of heat-related mortality on the decreasing trend in winter mortality. Keatinge and associates [1989] confirmed that improvement in living conditions and home heating could lead to reducing winter mortality. Healy also defined three groups of factors affecting winter mortality and human health: environmental (social, economic and natural), costs of healthcare and factors related to the lifestyle. Some recent research suggests that due to the rise in global average temperatures, future warming periods are expected over the upcoming decades with more frequent, intensive and persistent periods of hot temperatures in summer and higher temperatures in winter [Li et al., 2013] which could alert the balance between winter and summer and change the recognized seasonal pattern in mortality.

4.1.1 Climate-related mortality research in Serbia

At the University of Novi Sad, Faculty of Sciences, significant part of recent research in population features is focused on mortality and population ageing in urban areas and relation with climate changes. Starting with the fact that since 2007, globally more people live in urban areas (about 55% in 2018) and according to the United Nations projections until 2050 this share will rise to 68%, research group for urban climatology and demography in Novi Sad, in 2010, has been established with the aim of intensive climate investigation in urban areas and its impact on population and human mortality. In 2010, research about temperature-related mortality in the city of Novi Sad was launched at this faculty and it was the first research in Serbia dealing with climate-population issue. The research covered not only current climate-mortality trends but also the past trends, following changes under demographic and epidemiological transition. In the beginning, it was a non-formal research group, but in years after, the team was spread out and became more interdisciplinary, involving architects as well as researchers in the field of mathematics, statistics, informatics, and social medicine and biostatistics. Today, it is a leading group in climate-related population issues in urban areas, dealing with human thermal comfort, the impact of air temperature and heatwaves on human mortality, particularly on most vulnerable groups of a population such as old population and those with some of the chronic diseases. Until now, a significant number of research papers dealing with the problem of urban climate and human thermal comfort was published. Currently, the group is focused on building a network in the region of Central Europe, and in cooperation with colleagues from countries of V4 region trying to bring the most relevant findings and to identify approaches for mitigation of climate-related mortality in Central European cities, as well as an adaption for the purpose of public health systems.

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Except for the research for Novi Sad, several other studies published the results for other larger cities in the country dealing with short-term effects on mortality during summer 2007 (when strong heatwaves were registered around the country). The studies confirmed an increase in health risk during the heatwave in July 2007, particularly in most vulnerable groups e.g. old population and people with respiratory and cardiovascular diseases. Bogdanović et al. [2013] founded that mortality increased when the maximum daily temperature was above 35 °C, with 76% increase of mortality among elderly in comparison to the baseline, and with over two times higher mortality excess among the elderly female population. The increase in specific-causes deaths during the heatwave 2007 was observed by Stanojević et al. [2014]. They confirmed the increase in heat-related deaths with the highest influence on cerebrovascular and cardiovascular mortality.

4.1.2   Temperature and mortality in Central Europe: results for Novi Sad

Research about temperature-related mortality in the urban population of Novi Sad covered long historical changes in the seasonal pattern of mortality under the temperature oscillation over the year. The investigation included the period from the end of the 19th century until the beginning of the 21st century, following not only the climate change over time but also the epidemiological and demographic transitions. The most important results for the second half of 20th and beginning of the 21st centuries are presented in this chapter – all-cause and cause-specific mortality (cardiovascular diseases) and also mortality of the elderly (aged 65 and over). Mortality data was collected from civil registers (1953–1997) and from the database of the Statistical Office of Serbia (1998–2009) and numbers of deaths were aggregated on a monthly level. Data for temperature was taken from NOAA (National Oceanic and Atmospheric Administration, United States Department of Commerce) and the average temperature (Tsr) was used for the analysis. The analysis was performed using monthly crude death rate (CDR) and coefficient of seasonal variation in mortality (CSVM). Monthly crude death rates (CDR) per 100 000 were calculated with all months being standardised to 30 days. The coefficient of seasonal variation in mortality was used to detect seasonal variation of mortality during a year. CSVM is calculated as a difference between the number of deaths (M) in four winter months (December–March) and the average number of deaths in two four-month periods which precede winter (August–November) and follow winter (April–July).

$$CSVM = \frac{[M(Dec+Jan+Feb+Mar)]-[(M(Apr+May+June+July)+M(Aug+Sep+Oct+Nov))/2]}{[(M(Apr+May+Jun+Jul)+ M(Aug+Sep+Oct+Nov))/2]}$$

[Healy, 2003]

The analyses of air temperature and mortality demonstrate the relation between season of the year and the trend of the crude death rate. The relation between the crude death rate and the air temperature was analysed through the linear regression. Results of the regression analysis indicated that crude death rate and temperature are negatively associated, a decrease of average temperature is followed by an increase of the crude death rate. Coefficient of determination explained about 90% of the variation of the crude death rate with regard to the average temperature. Annual peak varies from year to year but it always falls for a winter month (usually, it was January). Lowest values of the crude death rate in observed period were found in August [Arsenović, 2014].

Table 4.1 | Coefficient of seasonal variation in mortality (CSVM) in Novi Sad, 1953/54–2008/09.

PERIOD	CSVM
1953/54–1963/64	0.25
1964/65–1974/75	0.19
1975/76–1985/86	0.11
1986/87–1996/97	0.12
1997/08–2008/09	0.07

Source: Author's calculation

Values of CSVM, presented in Tab. 4.1, show that mortality in winter period (December–March) is higher than the average number of deaths in preceding (August–November) and following (April–July) periods. CSVM varied over time and in the first observed period, 1953/54–1936/64, the coefficient has the highest value (winter mortality was 25% higher). CSVM in other four periods also showed that winter mortality is higher in comparison to the preceding and following periods but the decreasing trend of CSVM is evident. During the period 1964/65–1974/75, the winter mortality was 19% higher, in period 1975/76–1985/86, the mortality during winter months was about 11% higher, in the period 1986/87–1996/97, the winter mortality was 12% higher, and in 1997/98–2008/09, the winter mortality was 7% higher than in preceding and following periods [Arsenović, 2014].

To improve the results of CSVM, the t-test (Student`s) was used. The t-test was used to confirm whether statistically significant differences between the crude death rate in the winter period and in preceding and following periods exist. According to the t-test, the crude death rate in winter period is statistically different compared to the crude death rate in preceding, as well as following periods ($p < 0.05$). Preceding and following periods were separately tested and the analysis showed that there is no statistically significant difference ($p > 0.05$) between the crude death rate in the preceding period compared to the crude death rate in the following period.

Figure 4.1 | Coefficient of seasonal variation in mortality (CSVM), 1953/54–2008/09.

Source: Author

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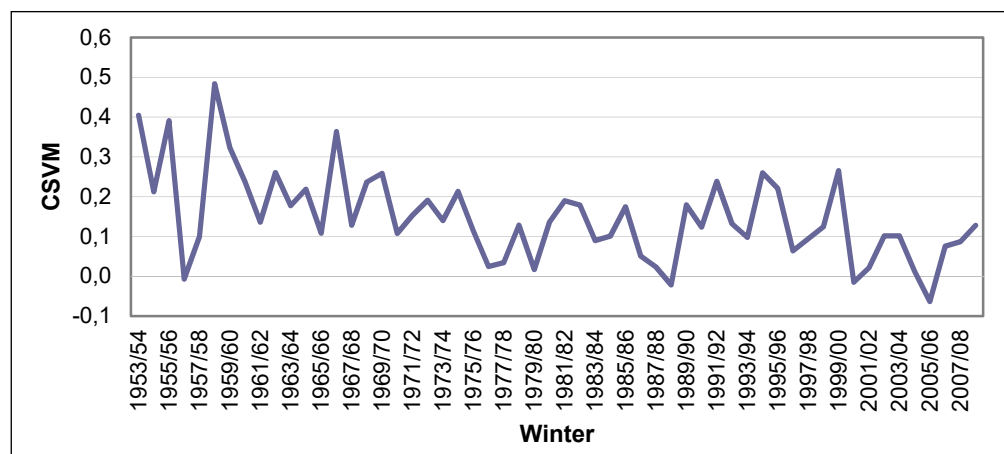
The winter mortality in Novi Sad in the period from 1953 until 2009 was about 15% higher than in the preceding and following periods if the year, which means that Novi Sad experienced a mortality increase during the winter season. This seasonal pattern is recognized in most of the temperate regions as well as in regions with different climates (Tab. 4.2). Results of Healy for the period 1988–1997 show that the winter mortality in EU-14 region is about 16% higher than in non-winter period. Analysis of each country separately gives evidence that Portugal has the highest seasonal variations in mortality in Europe [Healy, 2003]. According to the results of Healy, the winter mortality is about 28% higher than in other parts of the year. The evidence for Skoplje in Macedonia for the period 1996–2000 shows that mortality in the winter period is about 15.9% higher than in non-winter period [Kendrovski, 2006]. The research conducted by Nafstad et al. [2001], Pattenden et al. [2003] and Analitis et al. [2008] indicated that the cold-related mortality in colder regions started at lower temperatures than in warmer regions. This result supports the thesis that the population in a temperate climate are more sensitive to temperature changes. After comparing the results from Novi Sad and other similar researches in Europe, it can be concluded that the seasonal variation of mortality in Novi Sad follows a seasonal pattern observed in most of the countries of the North hemisphere.

Table 4.2 | Result for excess winter mortality across Europe.

PUBLICATION (source)	RESEARCH AREA	METHODS	RESULTS (in %)
Arsenović, doctoral thesis, 2014	Novi Sad, Serbia Period:1897/98–1952/53 1953/54–1996/97 1998/99–2008/09	CSVM – coefficient of seasonal variation of mortality	8.0 16.5 7.0
Healy, 2003	EU 14 Period: 1988/89–1996/97	CSVM – coefficient of seasonal variation of mortality	16.0
	Austria		14.0
	Belgium		13.0
	Denmark		12.0
	Finland		10.0
	France		13.0
	Gremany		11.0
	Greece		18.0
	Ireland		21.0
	Italy		16.0
	Luxembourg		12.0
	Netherlands		11.0
	Portugal		28.0
	Spain		21.0
	United Kingdom		18.0

PUBLICATION (source)	RESEARCH AREA	METHODS	RESULTS (in %)
Lake and Sverre, 1996	Norway, England and Wales Period: 1970–1991 (England and Wales); 1966–1986 (Norway)	EWM – differences between observed and expected winter	21.0 11.0
Davie et al., 2007	New Zealand Period: 1980/81–1999/00	EWMI	18.0
Kendrovski, 2006	Skoplje Period: 1996/07–1999/00	EWMI (same as CSVM)	15.9
Office for National Statistics, United Kingdom (ONS), 2010	England and Wales Period: 2006/07–2008/09	EWMI	16.7
West Midland Public Health Observatory (WMPHO)[23]	London Period: 2004/5–2006/07	EWMI	16.2
Northern Ireland Statistical and Research Agency (NISRA), 2011	Northern Ireland Period: 1974/5–2010/11	EWMI	16.4

Source: See the 1st column

4.1.2.1 Temperature and mortality for the elderly population in Novi Sad

The elderly population is one of the most vulnerable groups concerning the issue of temperature and mortality. Different studies dealing with temperature and mortality risk for the older population used the age group of 75 years and more [Analitis et al., 2008], in different ones the age group of 50 years and over [Rau, 2007] was used, but majority of papers applied the age group of 65 years and over [Huynen et al., 2001; Goldberg et al., 2001; Basu and Malig, 2011; Đurđev et al., 2012]. Also in the analysis for Novi Sad, the population aged 65 and over was used and the results show similar trends as it was confirmed for the total population. Hence, a strong relation was founded between the air temperature and mortality of elderly population. The crude death rate and temperature are negatively associated, with decrease of the average temperature, an increase of the crude death rate was detected. Annual peak was always in a winter month (in January), while the lowest value of the crude death rate was always during the summer months.

The crude death rate for the population aged 65 and more years (CSVM65+) shows that mortality in the winter period (December–March) was significantly higher than the average in preceding (August–November) and following (April–July) periods. The value of the CSVM65+ varied and had a decreasing trend over time, during the 1950s and early 1960s, the coefficient reached the highest values (winter mortality was 40% higher) [Arsenović, 2014]. In the next decade, winter mortality was about 30% higher compared to the other periods of the year and continued to decline to 10% and 20%. In the last observed period (1997/98–2008/09), winter mortality stabilized at 10% (Tab. 4.3; Fig. 4.2).

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23 http://www.wmpho.org.uk/excesswinterdeathsinenglandatlas/default.aspx

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Table 4.3 | Coefficient of seasonal variation in mortality (CSVM65+) for the elderly population in Novi Sad, 1953/54–2008/09.

PERIOD	CSVM
1953/54–1963/64	0.4
1964/65–1974/75	0.3
1975/76–1985/86	0.1
1986/87–1996/97	0.2
1997/08–2008/09	0.1

Source: Author's calculation

Figure 4.2 | Coefficient of seasonal variation in mortality (CSVM65+) for the elderly population, 1953/54–2008/09.
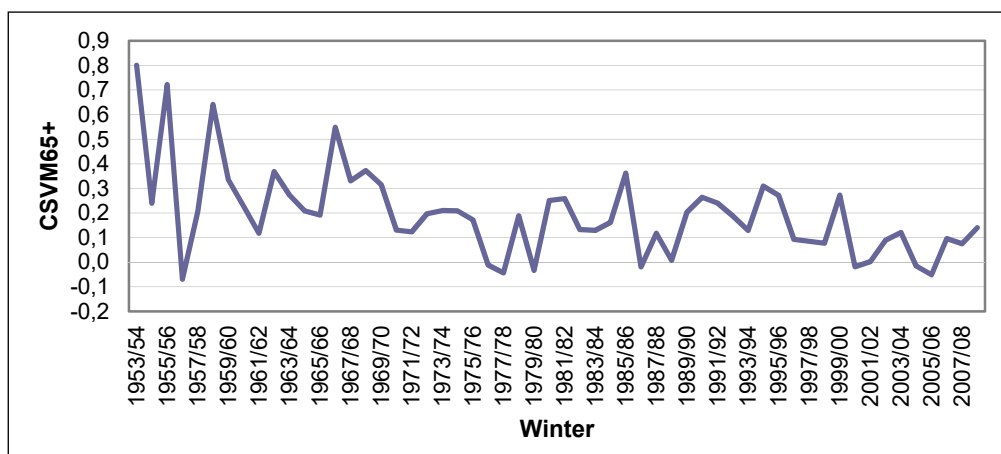
Source: Author

The Student's t-test confirmed the statistically significant differences between the crude death rate in winter period with regard to the crude death rates in preceding and following periods. The crude death rate in winter period is statistically different in comparison to preceding and following periods ($p<0.05$). While in the analysis of preceding and following periods, there is no statistically significant difference ($p>0.05$) between the crude death rates.

Due to the demographic transition and improvements in medicine, the life expectancy has a continuously increasing trend, hence, majority of all the deaths was in the age group of 65 years and over. During the 20th century, mortality of the elderly population reached the share of 62% of the total mortality counts and at the beginning of a new millennium, this share has risen to 73%. This implies that the seasonal changes of mortality in the elderly population contribute significantly to the seasonal pattern of the total mortality [Arsenović, 2014].

4.1.2.2 Temperature and cardiovascular mortality in Novi Sad, 1998–2009

Chronic diseases are the leading causes of death in the world and they are under the strong influence of climate conditions during the year. Results for Novi Sad are based on the analysis of cardiovascular diseases (CVD) as a leading cause of death (more than 50% of all causes in the population of Novi Sad). Due to the lack of data for the 20th century, the research was limited to the period 1998–2009 and the data about causes of death was based on the International Classification of Diseases, version 10, codes I00–I99.

The coefficient of seasonal variation in cardiovascular mortality indicated that the winter mortality was about 7% higher than mortality during the preceding and following periods. Tab. 4.4 shows the recent trends in winter CVD mortality, and in five of the observed years, the winter CVD mortality reached the same value compared with the other periods of the year (preceding/following). The regression analysis has confirmed the same trend between the air temperature and cardiovascular mortality, as it was found in the total and elderly populations. More than a half of causes of death are attributed to cardiovascular diseases and CVD mortality reveals the identical seasonal pattern during the years as the total mortality, and it can be concluded that the winter CVD mortality affects the winter mortality excess for all the causes [Arsenović, 2014].

In some years, the increasing trend of winter CVD mortality was under strong epidemic one, e.g, in the winter 1999/00 there was an influenza epidemic when the CVD-CSVM was about 0.3 (number of all-cause deaths excess was about 178). During the January and February 2000, the population in Novi Sad was affected by a strong influenza epidemic and it was one of the three strongest epidemics in period 1997–2007. According to the Institut for Public Health of Vojvodina Province, Center for Disease Control and Prevention, most of the recorded deaths in January and February 1999/00 related to the population aged 60 and over suffering from some chronic diseases (respiratory or cardiovascular). In the winter 1999/00, the cardiovascular and respiratory mortality excess contributed by more than 70% to the total excess of deaths [Arsenović et al., 2016].

Table 4.4 | Coefficient of seasonal variation in the cardiovascular mortality (CVD-CSVM) and cardiovascular mortality of the elderly population (CVD-CSVM65+) in Novi Sad, 1998/99–2008/09.

PERIOD	CVD-CSVM	CVD-CSVM65+
1998/99	0.2	0.1
1999/00	0.3	0.3
2000/01	0.0	0.0
2001/02	0.0	-0.1
2002/03	0.1	0.0
2003/04	0.1	0.2
2004/05	0.0	0.0
2005/06	0.0	0.0
2006/07	0.0	0.1
2007/08	0.1	0.1
2008/09	0.1	0.1

Source: Author's calculation

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For both, the elderly as well as the total mortality, the decline of vulnerability due to the air temperature-related deaths over time was observed. Apart from the changes in frequency of extreme temperature events over time, some other factors also play an important role in this process: central heating (central heating in Novi Sad was launched in 1961 when 491 apartments were included in the system of heating. Today, about 80% of homes have the central heating, Census 2011) and lifestyle risk factors. In addition, the main cause for changes in the seasonal pattern of mortality during the year, as well as of the oscillation of the coefficient of seasonal variation in cardiovascular mortality, can be found in the appearance of the heat waves, especially during the summer. This statement refers particularly to the period after 2000. Strong heat waves were registered in the summers 2003, 2006, and 2007 and an unusual number of heat-related deaths were reported across Europe. In 2007 (during the July), the area of Novi Sad (as well as the whole Serbia) experienced a strong heat wave, and in that period, mortality was about 35% higher compared to the same period in the previous as well as following years. However, the recent studies show that in the late 20th century and early 21st century, the European climate is very likely being warmer than in any time during the past 500 years [Luterbacher et al., 2004] and climatologists forecast that the temperature across Europe will rise over the coming decades and the frequency, intensity, and duration of periods characterized by extremely high temperature will double. This prediction in climate can significantly affect the distribution of mortality throughout the year, changing balance between winter and summer mortality.

4.2 Conclusion

It is well known that mortality risk increases as air temperature starts to change from an optimal range. Due to the fact that the investigation conducted in Novi Sad, as well as some other recent studies for Europe, indicated that the ratio between the winter and summer mortality has changed, the declining vulnerability to temperature-related mortality during the cold period of the year and changing level of the winter mortality excess is probably the effect of this changes. In the results for Novi Sad, higher winter mortality (in the range from 25% to 7%) for all-cause mortality was found and similar results were confirmed for the elderly population. The decreasing trend in winter mortality was confirmed in all the performed analyses. The cardiovascular mortality shows as well a higher seasonal pattern with the peak in colder period of the year. According to the assessment related to climate change, an increase in the air temperature due to climate change will reduce winter mortality and will affect the balance between winter and summer mortality. The results for Novi Sad show that the mortality excess during the summer period has an increasing trend. Time series analysis indicated that observed mortality during the late 1950s and early 1960s was lower than expected. At the beginning of 21st century, the observed mortality (during summer) is approximately higher about 5–6% than expected.

Despite the confirmed effects of climate changes, the declining CSVM since the middle of the 20th century could not be explained only by the air temperature. Some other variables have also an important role, e.g. improvement in the central heating and lifestyle risk factors (mostly related to the smoking, unhealthy diet, physical inactivity, alcohol consumption, etc.).

The recognized changes in temperature-related mortality are very important, however, the process of growing urbanization requires more investigation in order

to identify the major spots for public health policies. The future research should focus on more intra-urban analysis in cities dealing not only with the mortality level due to changes in the temperature but also identifying the risk level according to the level of urbanization and demographic characteristics of cities. The proposed future investigation could deliver an appropriate data and knowledge for the health management, contribute to the prevention of health hazards (heat- and cold-related mortality) and could significantly decrease the health risks in cities due to extreme weather conditions.

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Czechoslovak pronatalist policy, cohort size and health: hierarchical age-period-cohort analysis of birth outcomes in the Czech Republic

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5.1 Introduction[24]

There has been growing interest in studying time trends in health and wellbeing in terms of age, period and cohort components [Allman-Farinelli, 2008; Delaruelle et al., 2015; Reiter et al., 2009; Yang, 2008]. Following the classical work of Ryder [1965], the authors argue that the conditions experienced during childhood and adolescence are crucial for the variation of outcomes across cohorts. Size of cohorts is theorised to play an important role in forming the life experience of a cohort. However, both theoretical assumptions and evidence regarding the direction of the effect of cohort size are ambiguous and research about the effect of cohort size on health is rare, especially in the non-US context.

My research focuses on the maternal health of cohorts born before, during and after a baby boom that took place in the Czech Republic (the Czech part of Czechoslovakia at that time) in the 1970s. These cohorts experienced different social policies, educational opportunities and social climate during childhood and adolescence. I study birth outcomes of women from these cohorts who gave birth after 1990.

5.2 Theoretical arguments that link birth cohort size and wellbeing

A hypothesis that cohort size influences well-being was formulated by Easterlin [1968, 1987]. He argues that cohort size influences income, which in turn has further consequences. Members of small cohorts, compared to those of large cohorts, face less competition in the educational system and the job market. Consequently, they earn sufficient income and can afford to have large families, and are less prone to criminal behaviour, political alienation or suicide [ibid.]. Although Easterlin does not

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explicitly include health in the outcomes he studied, we can infer that, according to this perspective, cohort size should also be negatively related to health. If small cohorts achieve, on average, higher levels of education and higher incomes, they should be healthier, because education and income have positive impacts on health [e.g. Mirowsky and Ross, 2003]. If large cohorts have to compete more in order to achieve the same level of economic wellbeing, they experience a higher level of stress. This could influence their health negatively [c.f. Pearlin et al., 2005]. Moreover, arguments that large cohorts put pressure on the educational system and job market can also be applied to the health care system [Beck et al., 2014]. Crowding for health care might reduce its availability and/or quality, and consequently lead to the poorer health of large cohorts.

Stockard and O´Brien [2002] extended this perspective and linked it with the classical work of Durkheim. They argue that if the number of children relative to adults is large, they experience less supervision by adults and more interaction with peers. This makes the members of large cohorts less integrated within society, compromises their mental health and increases the risk of suicide [ibid.].

The empirical tests of the effect of cohort size on health are rare, use mostly data from the US and provide mixed results. South and Tolnay [1992] report that the influence of cohort size on health depends on the stage of life course. Larger cohort size is associated with higher mortality in childhood, but the direction of the effect is reversed in old age [ibid.]. Yang [2008] found a negative effect of cohort size on happiness. A positive effect of large cohort size on suicide among men (but not women) was shown across a wide range of modern industrialised countries [Stockard and O´Brien, 2002; Messner et al., 2006]. Other studies provide no evidence about an association (positive or negative) between cohort size and obesity [Reiter et al., 2009] and self-rated health among the adult population [Beck et al., 2014].

There are several theoretical arguments that could explain results that are not in line with the competition perspective outlined above. South and Tolnay [1992] refer to Preston [1984] who argues that the effect of cohort size varies by age. The well-being of children and the elderly, unlike the working age population, does not depend on the job market but on transfers within the state and family. State policies may mitigate the competition among children from large cohort size, e.g. by expanding the capacity of the child care, educational and health care systems. Such policies are likely to occur especially when large cohort size results from a pronatalist policy.

Neither can a negative effect of large cohort size on job market outcomes be considered universal. Carlson [1992] applied Easterlin's arguments about cohort size effects to the economic context of state socialism. On the basis of Kornai's [1982] description of a command economy, he points out that the relation between worker supply and demand on the one hand and incomes on the other, is not the same as in a market economy. State-owned companies are not restricted with respect to production (which is insufficient anyway), and their demand for workers is almost unlimited. When a large cohort reaches working age, firms provide more jobs for them. As a consequence, production increases and more customers are satisfied with the desired goods and services. Larger cohort size should thus improve economic wellbeing. A similar effect could appear during fast transformations of the job market that induce demand for workers with different skills, such as skills in using information technology. Members of a cohort entering the job market who have these new skills could thrive even if the cohort is large.

5.3 Czech baby boom of the 1970s and related policies

The size of Czech birth cohorts varied greatly in the second half of the 20th century, as shown in Fig. 5.1. The total fertility rate (TFR) grew after WWII, but peaked already in 1946 with 3.3 children per woman. It then dropped sharply to 2.1 children per woman in 1960. The decline of fertility was interrupted in the mid-1960s, rising to 2.4 in 1964. This can be attributed to an improved social protection of motherhood and promises (which later showed to be unrealistic) of politicians to solve the severe shortage of housing [Rákosník and Tomeš, 2012]. This effect on fertility was short-lived and the TFR rapidly fell below the level of reproduction by the end of the 1960s. However, a much more pronounced surge of fertility followed in the 1970s. The TFR rose to 2.4 children per woman in 1974, and the absolute number of births increased by 36% between 1969 and 1974. The TFR started to decline after 1974 but remained above the 2.1 level until 1981. A moderate fertility decline continued during the 1980s and accelerated after the collapse of state socialism in 1989. The TFR fell from 1.9 to 1.13 children per woman between 1989 and 1999 due to a rapid postponement of childbearing in the 1990s [Sobotka et al., 2008]. It then rose again and stabilised at around 1.5 children per woman after 2008.

Figure 5.1 | Total fertility rate, crude birth rate (right y-axis), and number of births in the Czech Republic, 1945–2014.
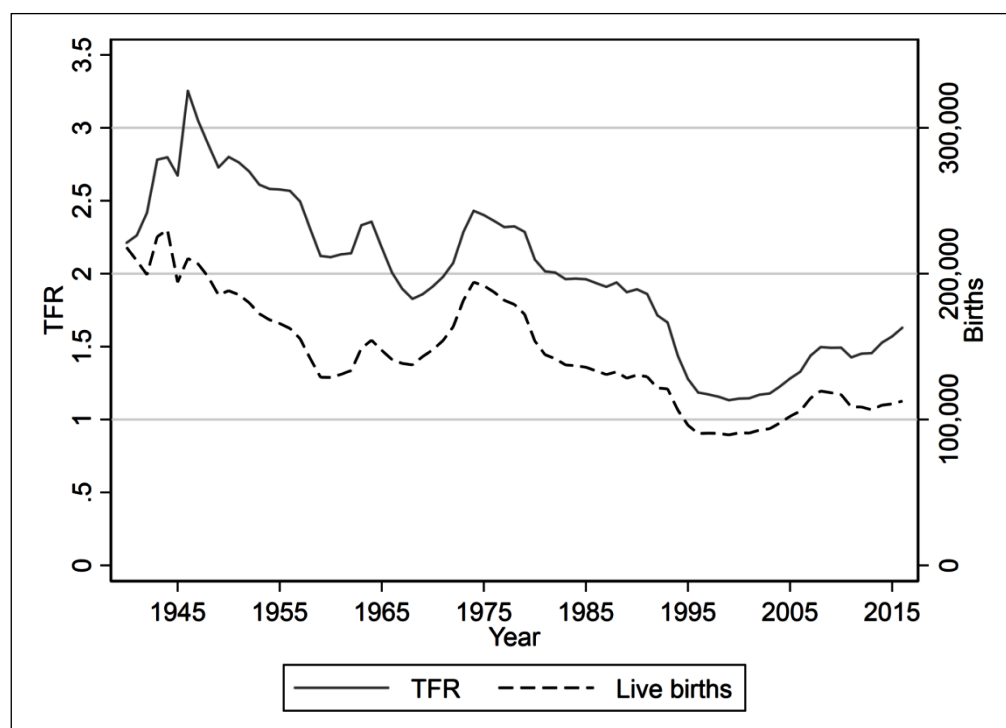
Source: Czech Statistical Office, author's computations

5.3.1 Pronatalist policy

The baby boom of the 1970s resulted from the coincidence of large post-war cohorts who entered reproductive age and a massive pronatalist policy introduced between 1969 and 1972 [Koubek, 1990]. The set of pronatalist policy measures included the introduction of a maternity allowance that allowed mothers to personally care for their children up to the age of two, increment of child allowance and increased protection of pregnant women and mothers of infants at the workplace as well as policies that eased access to housing for young families [Koubek, 1981; Rákosník and Tomeš, 2012]. Families were also provided with indirect benefits, such as housing deductions, travel cost deductions and tax deductions for each child, subsidised day-care institutions, meals at schools or textbooks [Hašková and Uhde, 2009]. The pronatalist campaign was extremely costly and, together with other generous social policies, inhibited the economic prosperity of the country. A large part of the economic burden rested on employers (state-owned firms) who, during the 1980s, had been assigned more and more responsibility for satisfying the social needs of the employees [Rákosník and Tomeš, 2012]. This limited the investments in innovation and led to an economic downswing. Although most of the family policy measures continued till the collapse of the regime in 1989, the rising prices and decreased standard of living compromised the economic wellbeing of families in the 1980s [Rákosník and Tomeš, 2012; Koubek 1981, 1990].

5.3.2 Educational policy

The educational system experienced by all cohorts under study included an 8–9 years long basic education (corresponding to ISCED-97 1–2), two tracks of secondary education and tertiary education (ISCED-97 4–6). The tracks at the secondary level were 2–3 years-long lower vocational education (ISCED-97 3C) and several types of 3–4 years-long vocational and secondary schools (ISCED-97 3A and 3B) that grant successful graduates' diplomas necessary for the transition to the tertiary level. This type of secondary education is termed complete secondary.

Secondary education (both vocational and complete secondary) expanded massively under state socialism. Providing all young individuals with some secondary education was an explicit political goal. This effort culminated with a 1978 reform of educational system enacted by Act nr. 63/1978. This reform shortened the basic school from 9 to 8 years and, at the same time, introduced a 10-year compulsory education. This implied that students were obliged to enrol in a vocational or secondary school after the 8 years of basic school. This transition to secondary level was unprecedented in the Czech educational system. As a result, the proportion of basic school graduates who did not continue education at the secondary level dropped to less than 10% by the end of the 1970s and even below 5% by the end of the 1980s [Kreidl, 2002].[25] The expansion of secondary education thus compensated for the rise in the number of students from the baby-boom cohorts. On the other hand, the wide secondary education opportunities applied mainly to vocational schools. Access to the more

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25 The small number of persons who did not enrol in secondary education probably consists of those who repeated years and thus accomplished the ten years of compulsory education at the basic school. Another reason could be misreporting of the transition by those respondents who enrolled in the secondary level but did not graduate from it.

prestigious complete secondary school and post-secondary education remained low and restricted by political criteria[26] [Kreidl, 2002, 2008].

The collapse of state socialism freed the educational system from communist ideology, and political criteria stopped being relevant for admission to secondary and tertiary education. Several reforms of education took place soon after the collapse of state socialism. In 1990, the ninth grade of basic school was reintroduced and the length of compulsory education was cut back to 9 years (1990 amendment of Law 29/1984). Schools at all levels gained more independence from the state and the heterogeneity of educational programs increased. The most notable change in terms of access to education was its expansion at the post-secondary level. The expansion was slow in the 1990s but speeded up after 2000 [Prudký, Pabian and Šima, 2010; Doseděl and Katrňák, 2017].

5.3.3 Economic and political transformation after 1989

The 'Velvet' revolution of 1989 changed life conditions profoundly. The country's borders opened and political censorship was cancelled. People gained more freedom in choosing their education and career, including a possibility to start one's own business (which was not legal under the socialist regime), and economic returns to education rose [Matějů and Kreidl, 2001; Doseděl and Katrňák, 2017; Večerník, 2009]. Traditional family norms weakened and new forms of the family started to spread and be approved as a manifestation of individual life styles [Sobotka et al., 2008].

In contrast, the transition to a market economy and political reforms increased economic risks for some population groups, including young families. Family policy became less generous and most benefits were subjected to income-testing [Hiršl, 2004; Krebs, 2005]. Mothers of young children have been facing marginalisation in the job market and an increased risk of unemployment [Hašková and Uhde, 2009; Mullerova, 2017]. Families with three and more children and single-parent families were among the groups with the highest risk of poverty [Czech Statistical Office, 2017a].

5.4   Research aim and hypothesis

The research question asks if the large cohorts born in the 1970s differ from the preceding and following cohorts in terms of their birth outcomes. Birth outcomes refer to the health of the mothers and at the same time inform about a health advantage or disadvantage transmitted to the descendants [Spencer, 2003]. The most commonly used birth outcome is birth weight [Kramer, 2003]. It is a strong predictor of infant's survival [e.g. Basso et al., 2006; Melve, Skjaerven, 2003; Spencer, 2003; Rychtaříková, Demko, 2001]. Birth weight also influences motor development and health during infancy and later childhood [De Kieviet, Piek, 2009; Örtqvist et al., 2009]. Long-term studies found even links between birth weight and health in adulthood [Barker, 1998, 2001] and length of life [Doblhammer, 2004].

Mothers and infants were a special target of health policy during the state socialism [Štembera, 2004]. This led to a dramatic decline in infant mortality between 1945 and 1960, followed by another moderate improvement of infant survival until the collapse of the regime [Czech Statistical Office, 2017b]. The efforts to provide

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26 Students with working class origin and from families loyal to the political regime were preferred.

high-quality health care for mothers and children were persistent during the whole period of state socialism, as a part of health policy that gave priority to population groups of working ages and children (i.e. future workers). In contrast, the pronatalist campaign with its positive effects on economic well-being of families was clearly situated in the 1970s. Hence, the analysis evaluates if short-lived social policies can have long-term health consequences that reach beyond one generation.

An analysis of complete fertility shows that the pronatalist policy of the 1970s influenced mostly the timing of births rather than the total number of children in families [Koubek, 1990]. Therefore, the TFR recorded in the year of birth of the cohorts under study is used as a proxy for how favourable the conditions for childbearing were.

I propose a "good start hypothesis". It states that there is a positive effect of cohort size on reproductive health. As explained above, the political efforts to support families during the baby-boomers' early childhood were enormous. The good material conditions during early life have a long-lasting favourable effect on health [Beck et al., 2014; Doblhammer, 2004; Schellekens and Poppel, 2016]. The potentially negative effect of increased competition for education and jobs could be suppressed by the educational expansion and transformed job market, which was hungry for young employees with new knowledge and skills.

Cohorts born since the mid-1970s made their decisions regarding education, career and family formation after 1989, i.e. under the new climate of freedom and self-actualisation on the one hand and economic uncertainty on the other. The test of the good start hypothesis also shows if the effect of the conditions of early life is strong enough to prevail over this later experience.

5.5   Data and methods

5.5.1   Data and variables

The data come from the national birth register. The analysed dataset contains records of births during 17 years between 1990 and 2014. I limit the range of maternal cohorts to 1965 to 1984 to cover the age range 25–30 (i.e. the prime childbearing ages) in each cohort. About 1% of these eligible cases were deleted because of missing information about maternal education. The final dataset includes 1,413,127 observations.

The dependent variable is birth weight. Birth weight is the single most informative birth outcome [Spencer, 2003].

The independent variables are the newborn's sex, maternal age, parity, educational attainment and marital status. The effect of age on birth weight has an inverted-U shape, so age and age-squared terms are entered in the models. Both of them are grand mean centred. The categories of parity are no previous birth, one previous birth and two or more previous births. Educational attainment is measured at time of birth. Student status is not available. The variable has four categories: elementary including uncompleted elementary (ISCED-97 2 and lower), lower secondary (or vocational; ISCED-97 3C), complete secondary (ISCED-97 3A and 3B) and post-secondary (ISCED-97 4–6). Marital status is a binary indicator of unmarried (vs. married) mothers. The cohabitation status of unmarried mothers was not recorded, so it is only possible to distinguish between formally married and unmarried mothers.

The cohort-level variable is TFR recorded in the year of birth of the maternal. The TFR measure was rescaled to take values between 0 and 1 (so that the coefficient gives the difference between minimum and maximum value of TFR) and centred.

5.5.2 Analysis

The data are analysed with hierarchical age-period-cohort (HAPC) models as proposed by Yang and Land [2006, 2013]. Common regression techniques are unable to identify the separate effects of period, cohort and age because there is a perfect linear relationship between them (*period = cohort + age*). HAPC avoids the identification problem by treating the observations as nested in two macro contexts, the cohort and the period. However, the ability of the method to correctly estimate the cohort and period effect has been debated (see Bell and Jones [2017], for a review of the arguments). The concerns about the correctness of the estimated cohort and period effects arise when linear trends are expected, especially when there is a large difference between the spans of the periods and cohorts [ibid.]. These problems are not present in this analysis because no linear effects are assumed and because the period spans over 25 years and the span of the cohort is 21 years. Models are estimated in Stata 13 using the restricted maximum likelihood, as recommended by Yang and Land [2013, p. 197]. Goodness of fit is evaluated with Akaike information criterion (AIC).

The analysis focuses on cohort effects. Period effects are shown in the Appendix (Fig. 5.A1).

5.6 Results

Descriptive statistics by 5-year categories of cohort are shown in Tab. 5.1. The most notable cohort trend is a rapidly rising proportion of unmarried mothers. It was only 12.5% in the oldest cohort and grew to almost 26% in the youngest cohort. The proportion of first-time mothers also rose, but this is biased by the age range of mothers in each cohort. The cohorts born between 1970 and 1974 (i.e. the early baby-boomers) seem to have suffered from a higher competition for education. The proportion of mothers with complete secondary and post-secondary education is by 5–9 percentage points lower than among the preceding and following cohorts. The category of vocational education is correspondingly overrepresented in the 1970–74 cohort.

Table 5.1 | Descriptive statistics by maternal cohort.

	MEAN (SD) OR %				
	1965–69	**1970–74**	**1975–79**	**1980–84**	**TOTAL**
Birth weight	3356 (526)	3350 (522)	3349 (515)	3316 (516)	3342 (519)
Age	28 (5)	27 (6)	29 (5)	28 (4)	28 (5)
Newborn's sex (male)	51.5	51.3	51.5	51.3	51.4
Parity					
No previous birth	32.2	45.7	47.8	57.0	47.3
1 previous birth	46.5	38.9	40.2	35.2	39.5
2+ previous births	21.3	15.5	12.0	7.8	13.2
Education					
Basic	9.7	8.6	8.8	9.8	9.1
Vocational	33.7	40.1	30.6	24.0	32.0
Complete secondary	42.1	39.3	42.3	42.7	41.6
Post-secondary	14.5	12.0	18.3	23.5	17.3
Unmarried mother	12.5	18.8	28.0	37.6	25.7
TFR	1.9 (0.1)	2.2 (0.2)	2.3 (0)	2 (0.1)	2.2 (0.2)
N	199,768	380,622	486,490	346,247	1,413,127

Source: Czech Statistical Office, author's computations

Results of estimated models are presented in Tab. 5.2. The baseline model M1 includes only age, parity and newborn's sex at the micro level and the cohort and period random effects. Model M2 adds two more covariates, education and marital status. Both of these variables have large effects and improve the fit of the model (AIC declines by more than 24,000 between M1 and M2). Fig. 5.2 plots the cohort intercepts predicted by these two models against the TFR. For model M1, it shows a rising trend in birth weight for cohorts born in the 1960s and the first half of the 1970s followed by a reversal. The 95% confidence band along the effect suggests that cohorts born between 1971 and 1976 had significantly better outcomes than the average and the outcomes of cohorts born in 1980 and later were significantly worse. The shape of the cohort trend is slightly modified when education and marital status are controlled for in

model M2. The declining trend among younger cohorts has later onset and is less pronounced in model M2. Cohorts born between 1973 and 1977 (i.e. the largest) have significantly better outcomes. Only two youngest cohorts have significantly worse outcomes suggesting that most of the unfavourable cohort trend observed in model M1 is explained by the control variables (i.e. education and marital status).

Table 5.2 | HAPC models of birth weight (N=1,413,127).

	M1	M2	M3	M4	M5
Age	4***	0***	5***	0	0
Age squared	-1***	0***	-1***	0***	0***
Newborn's sex (male)	139***	139***	139***	139***	139***
Parity (1 prev. birth = ref. cat.)					
No previous birth	-112***	-122***	-112***	-122***	-122***
2 + previous births	-67***	-19***	-67***	-19***	-19***
Education (Compl. sec. = ref. cat.)					
Basic		-216***		-216***	-219***
Vocational		-42***		-42***	-43***
Post-secondary		18***		18***	17***
Unmarried mother		-56***		-56***	-56***
TFR			17*	15***	6
TFR x Basic ed.					38***
TFR x Vocational ed.					11***
TFR x Post-secondary ed.					6
Constant	3350***	3379***	3349***	3378***	3379***
Random effects					
Var (Cohort)	182	35	114	13	13
Var (Period)	251	415	359	438	440
AIC	2107276	2082739	2107283	2082736	2082707

Source: Czech Statistical Office, author's computations

Note: *$P < 0.1$, **$p < 0.05$, ***$p < 0.01$

Models M3 and M4 test the good start hypothesis by adding the TFR measure. Model M3 extends M1 and is not better than it according to AIC. Model M4 controls also for education and marital status and seems to be marginally better than M2 (AIC drops by 3). The effect of TFR is positive in both models, which is in line with the hypothesis. According to model M4, children born to a mother from the largest cohort are on average 15 g heavier than those from the smallest maternal cohort.

Model M5 allows the effect of TFR to vary by education. The interaction is statistically significant (AIC drops by 29 between M4 and M5). Beta coefficients show that the positive effect of TFR is strongest among mothers with the lowest education. The interaction term is 38 g which implies a total effect of TFR in this educational group of 44 g (6 + 38 g). The effect of TFR is weaker but still positive and significant in the group with vocational education. Cohort size has no effect among mothers with complete secondary and post-secondary education.

Figure 5.2 | Cohort effects predicted by selected models and the trend in TFR.
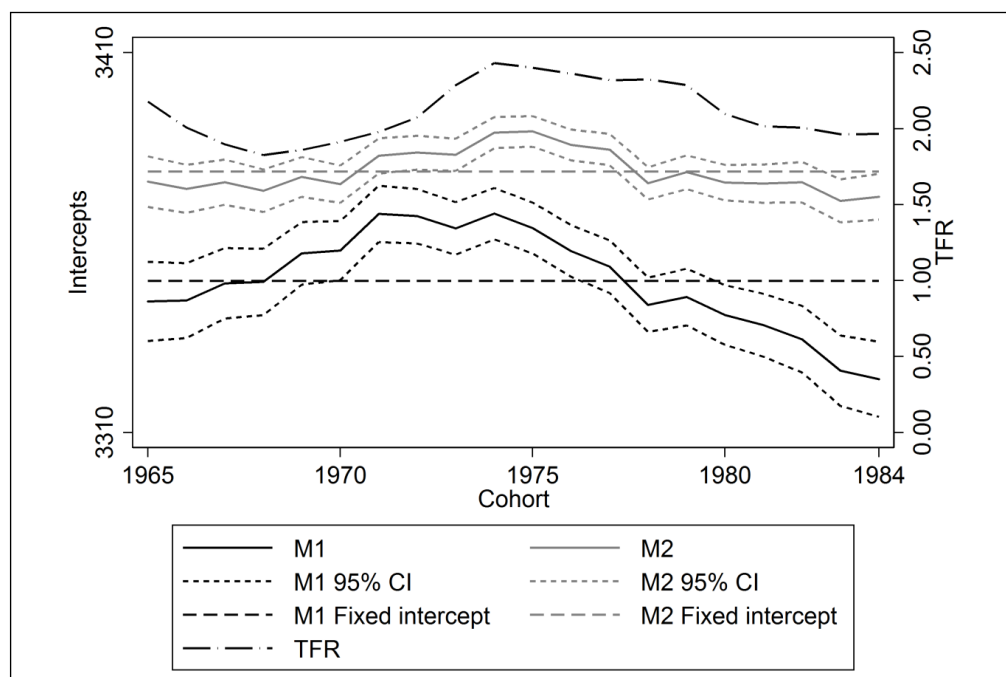
Source: Czech Statistical Office, author's computations

5.7   Conclusion

I tested the good start hypothesis that expected better birth outcomes among mothers from large cohorts of the 1970s who experienced generous family policies during their early life. Results support the hypothesis. Three main conclusions were reached. First, large maternal cohort size, had a positive effect on birth weight. The large cohorts born in the 1970s benefited from the generous family policy in terms of their health which translated in better outcomes of their birth when they became mothers. Second, although the early baby-boomers (but not the late ones) ended with lower education than

their antecedents and followers, the positive effect of the favourable early childhood experience prevailed. Third, the protective effect of large cohort size was only found among mothers with lower education and was strongest in the group with the lowest education. In summary, the results show that policies may effectively supress the negative consequences of uneven age structure and reduce health inequality. However, the costs of the Czech pronatalist policies were enormous and are hardly repeatable.

The finding of the favourable outcomes of the baby-boomers is in line with the literature that stresses the importance of early life conditions [Doblhammer, 2004; Beck et al., 2014] and extends it by showing that the health benefit can be transferred to the next generation through birth outcomes. However, the life experience of cohorts under study includes also other influential factors that shaped their health. Cohorts born since the mid-1970s made all the steps of the transition to adulthood after 1989. Their decisions regarding choice of education, school-to-work transition, and family formation took place under the new climate of freedom and self-actualisation on the one hand and economic uncertainty on the other. The data used in this analysis could only assess the role of education and marital status.

The educational gradient in birth outcomes in the Czech Republic is uneven. There is a large gap between the lowest (basic) and second-lowest (vocational) level. Gaps between the groups with higher than basic education are much smaller. Although the size of the educational disparities changes in time, the time trends are small relative to the large and persisting disadvantage of mothers with basic education [Koupilova et al., 1998; Štípková, Kreidl, 2011]. The present analysis shows that, although the educational opportunities expanded, the proportion of mothers with the lowest level of education remains almost constant across cohorts. Hence changes in the educational opportunities and returns to education did not have much influence on the birth outcomes of the studied cohorts.

Spread of non-marital childbearing, on the other hand, shaped the cohort effect substantially. Unmarried status is known to have a negative influence on birth outcomes [e.g. Shah et al., 2011]. The rapid spread of non-marital childbearing in the Czech Republic had a negative impact on the outcomes of younger cohorts. The rising proportion of unmarried mothers compromised the outcomes of the late baby-boomers and its influence prevailed over the protective effect of favourable early life conditions.

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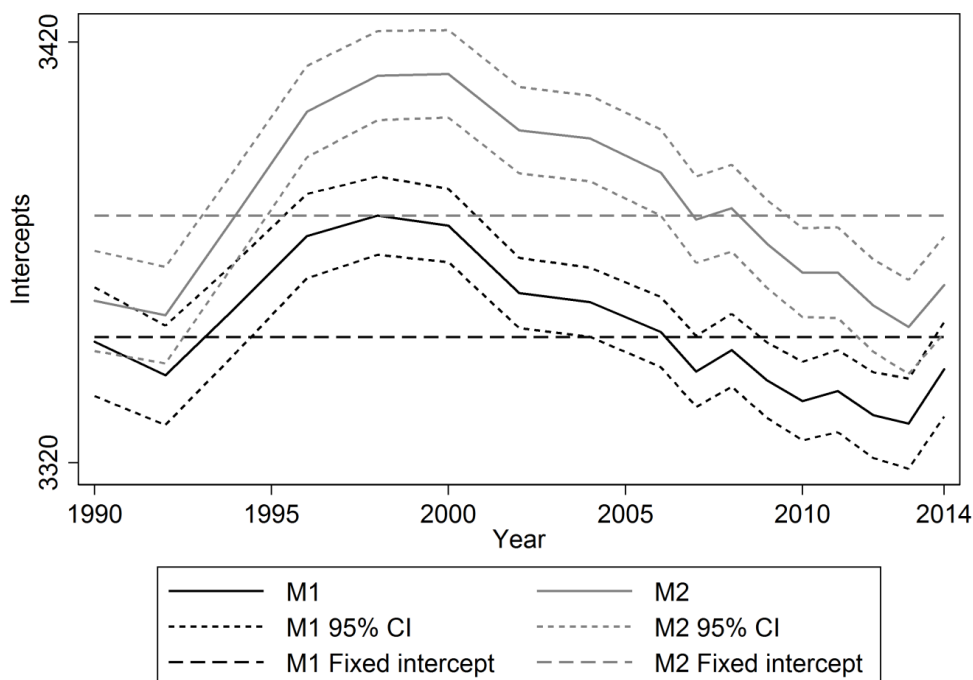
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Appendix. Estimated period effects

Figure 5.A1 | Period effects predicted by selected models.

Source: Czech Statistical Office, author's computations

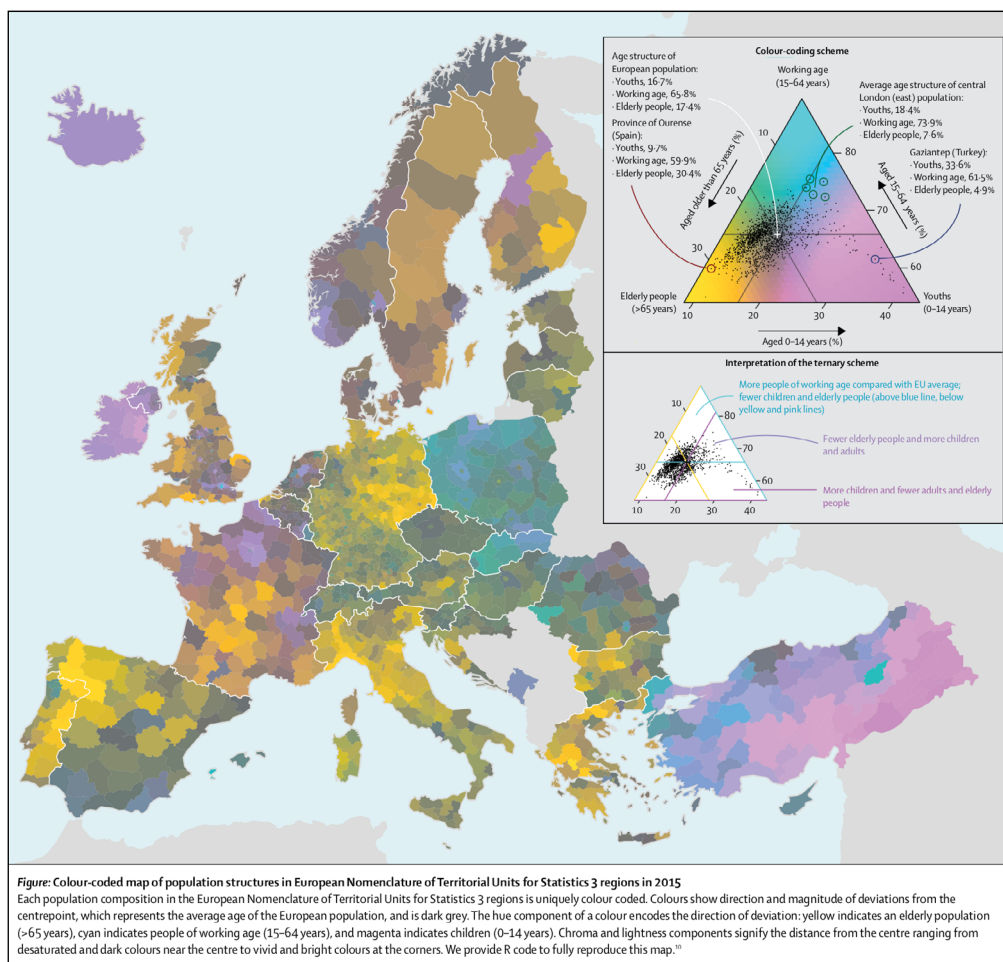# But Why? Design choices made while creating "Regional population structures at a glance"

Jonas Schöley, Ilya Kashnitsky

In the days following the publication of "Regional population structures at a glance" [Kashnitsky and Schöley, 2018] we were busy participating in the discussions of our article's main figure (reproduced in Fig. 6.1) on social media. Various groups were sharing their thoughts on the colorful map of Europe showing the population age-structure on a regional level publicly discussing topics like European immigration, abortion legislation in Ireland, Italy's low fertility, East-West migration in Germany and more. Meanwhile designers and visualization researchers debated the question "clever or too clever?". The hundreds of comments we received post-publication gave us plenty of opportunity to reflect on our design. In this essay we want to explain the design choices we made during the creation of the map, explore and discuss alternative designs and evaluate our visualization against the goals we had when starting this project. But first let's take a look at the map in question:

Figure 6.1 | Regional deviations from the average European age structure in 2015 as published in the Lancet letter "Regional population structures at a glance".

Figure: Colour-coded map of population structures in European Nomenclature of Territorial Units for Statistics 3 regions in 2015
Each population composition in the European Nomenclature of Territorial Units for Statistics 3 regions is uniquely colour coded. Colours show direction and magnitude of deviations from the centrepoint, which represents the average age of the European population, and is dark grey. The hue component of a colour encodes the direction of deviation: yellow indicates an elderly population (>65 years), cyan indicates people of working age (15–64 years), and magenta indicates children (0–14 years). Chroma and lightness components signify the distance from the centre ranging from desaturated and dark colours near the centre to vivid and bright colours at the corners. We provide R code to fully reproduce this map.[10]

Source: Kashnitsky and Schöley, 2018

In the year 2015 Europe's population was composed of 16.7% youths (ages 0–14), 65.8% working age (ages 15–64) and 17.4% elderly (65 years and above). The age structure of any given region however may differ substantially from the European average. Fig. 6.1 shows those regional deviations by the means of a (centered) ternary color scale: Regions close to the European average show as dark shades of grey, e.g. the Czech Republic or the south of Spain. The further a regions age structure deviates from the aggregate age structure, the brighter and more vivid it is colored with the hue of the color indicating the direction of deviation: Yellowish regions have a larger share of elderly, e.g. Eastern Germany or the north of Spain; pinkish regions are comparatively young and blueish regions have a larger than average share of working-age population.

Important choices in the design of this visualization were the use of a ternary color coding scheme, the expression of regional age structure as a deviation from

the European average, the use of continuous colors and the use of an equal-area map projection (vs. a cartogram). In the following we will explain these choices and demonstrate alternatives. The direct quotations spread throughout the text are taken from discussions of our map on social media.

6.1 But why ternary color-coding?

> *"The design took me a second to get used to but now I'm a fan."*
> Simon Kuestenmacher (@simongerman600), July 24, 2018

> *"Might be a red flag when your legend needs a legend."*
> Will Morris (@willmorris), July 25, 2018

Ternary diagrams are not widely used outside the fields of compositional data analysis, chemistry and geology – using a color coded ternary diagram as a legend for a map is mostly unheard of[27] and makes for a true *xenograph* [Lambrechts, 2018], i.e. a visualization that most viewers are completely unfamiliar with. So why did we choose such a weird technique, what did we achieve and what could we have done instead?

Our design process was informed by two overarching goals and one technical limitation:

1. *make people understand* how European regions differ in their age structures,
2. *reach a wide audience*, and
3. *do it in a single plot*[28].

Reach a wide audience: We knew that we had interesting data in our hands. Regional age-structures compared to the European average show very clear spatial patterns and provide a snapshot of the state of the demographic transition in Europe. The data has the potential to inform the public debate about population ageing in Europe – a debate that all too often simply invokes the image of an ageing continent without addressing the regional diversity of the demographic transition.

But having interesting data is not enough to catch people's attention – using a *novelty* viz-technique which shows clear global patterns at first sight as well as local detail may however successfully engage users [Hullman et al., 2011]. We had some prior experience using the ternary color scale [Schöley and Willekens, 2017] and found that it was a technique well suited to get the interest of fellow academics who, after a short introduction, were able to correctly infer information from the plot. So yes, we were both aware of the *flashiness* of ternary color-coding and capitalized on this very property to arrive at our secondary design goal. However, we wouldn't have chosen the ternary color coding technique if we found it to be ineffective at conveying information.

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27 For earlier examples of such maps see Brewer [1994], Dorling [2012, the corresponding PhD thesis was published in 1992], and Schöley and Willekens [2017].

28 Due to "The Lancet" only allowing a single plot for submitted letters.

Make people understand (in a single plot): Upon seeing the first crude version of our ternary color map (a playful experiment at this point) we were amazed by the sheer number of clearly visible spatial patterns, all of which related to meaningful differences in the underlying data. This good result was unexpected. Using color mixtures to represent multivariate data has experimentally been shown to be ineffective in situations where it is important to make accurate judgements about the numeric value of the involved quantities [Wainer and Francolini, 1980]. The main reason for that is the inability of people to separate a mixed color into their primary components, which is compounded by the difficulty of reading exact values from color encodings of even univariate data [Ware, 1988]. Luckily, exact quantitative judgements about the separate parts of the composition aren't at all necessary in order to achieve our first design goal, rather, the task of understanding the regional age-structure patterns is one of similarity judgements (which regions look similar, which look different), nominal judgements (does a region have more old, more young or more working age compared to the average), and ordinal judgements (among two regions, which is further away from the average), all of which can be performed effectively without requiring the impossible feat of primary decomposition:

Similarity judgements

> *"I'm surprised at the drastic difference between neighboring countries (e.g. Poland/Germany) I would have expected a more gradual transition"*
>
> LockRay July 23, 2018

A basic principle when using color for data visualization is that similar colors should represent similar data and colors perceived as dissimilar should represent dissimilar data [e.g. Silva et al., 2011]. Being guided by this simple rule a reader will be able to tell that East- and West-Germany feature greater similarities in their age structure then Turkey and Poland. This is because the color-coding technique we used assigns colors based on the magnitude and direction of deviation of a regional age structure from the European average. Regions which differ from the European average by similar degrees and in similar parts of the composition will feature similar colors. Ware and Beatty [1988] found that a multidimensional color encoding allows for such similarity judgements[29].

Nominal judgements

> *"Why is Ireland so young?[...]"*
>
> drodrey July 23, 2018

In order to make qualitative statements about a region's age-structure one simply needs to recognize the meaning of three colors: Yellowish colors mark a higher share of elderly people compared to the European average, blueish colors mark regions with a comparatively large share of working age population and pink regions mark relatively youthful regions. Reading the plot like this allows to correctly identify features such as the comparatively high share of working age population in Poland

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29 They tested whether subjects were able to identify clusters based on color similarity in a multi-dimensional data set.

as opposed to the high share of elderly in Germany. By using unique and distinct hues for each of the three directions of compositional deviation from the average we ensured that the ternary-balance scheme can be understood as a simple categorical color scale which is known to be an effective encoding for nominal data [e.g. Ware, 2013; Munzner, 2015].

Nominal-Ordinal judgements

> *"I'm wondering if the old East Germany thing is*
> *a side effect of the wall coming down."*
> PoorEdgarDerby July 23, 2018

The next level of understanding would be to recognize the significance of chroma and brightness: The closer a regions age structure is to the European average the darker and greyer it is colored. Using the chroma/brightness cue one can see that former East Germany deviates more from the European average than former West Germany and that while both Ireland and East Turkey have a young population, it is the Turkish population that deviates further from the European average. Regions in the Czech Republic and the south of Spain are quite representative of the European average in terms of their three component age structure. Burns and Sheep [1988] have shown that brightness and chroma are effective ordinal encodings even if hue is varying.

> *"[...]I'm struggling a bit with the intermediate colors.*
> *I would have preferred three maps with each of the variables*
> *in their own monochrome scale."*
> Bo Schwartz Madsen (@BoSchwartz) July 25, 2018

How does the ternary color-coded map fair when compared with a more conventional encoding? We pick up the suggestion above to show the three components of the composition in separate maps. As we are interested in deviations from the average European age structure, we use divergent color scales with a mid-point centered on the European share of the respective age-group.

Figure 6.2 | Instead of showing the deviations of a three-part composition from some average in a single map using the ternary-balance-scheme one can also show the deviations for each part on a separate map. This way it's easier to judge patterns relating to any single part of the composition but arguably harder to make holistic statements about the three-part composition.
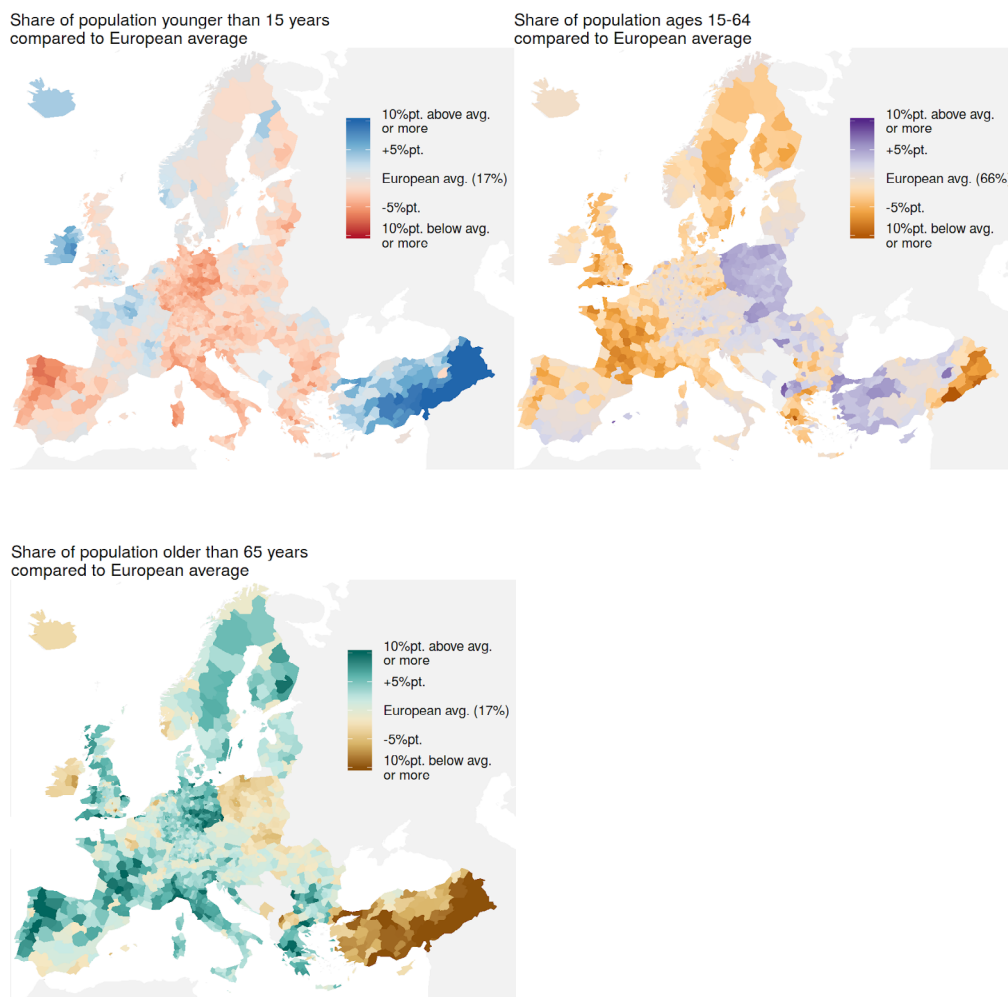
Share of population younger than 15 years
compared to European average

Share of population ages 15-64
compared to European average

Share of population older than 65 years
compared to European average

Source: Authors; Data: Eurostat, Population on 1 January 2015 by broad age group, sex and NUTS 3 region (table "demo_r_pjanaggr3")

Sadly, a small-multiples map as shown in Fig. 6.2 was out of the question as the publication format limited us to a single figure. A big strength of the repeated maps is the perfect separability of the three compositional components. This facilitates analytic judgements about each of the age-groups in separation from the others. On the other hand, holistic judgements about the joint three-part composition (representative/non-representative of European average, type of deviation from average) may be harder to make because they require the integration of information from all three maps.

Figure 6.3 | The color and orientation of a line encode the direction of deviation of a region's age structure from the European average: orange and forward leaning means more young, purple and backward leaning more old and pink horizontals represent more people in working ages. Two line symbols may be combined in a case where two groups have a higher than average representation. The magnitude of deviation from the average is encoded via line length and width with longer lines representing larger deviations.
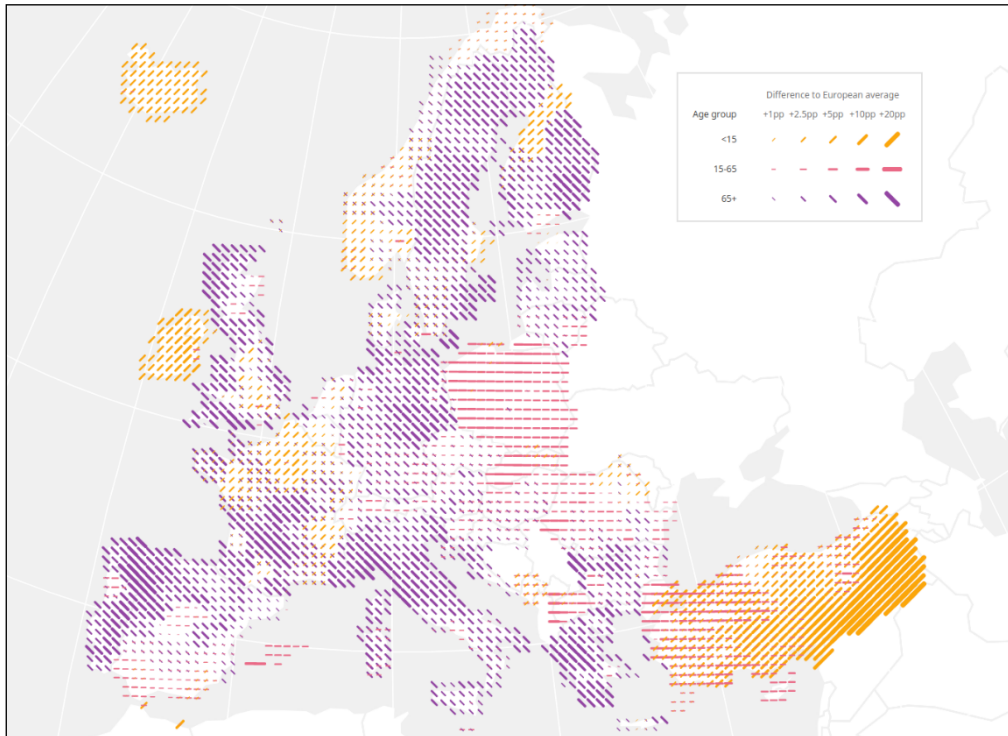
Source: Figure by Moritz Stefaner, reproduced with permission of the author; Data: Eurostat

Shortly after publication our map caught the interest of German information visualization designer *Moritz Stefaner*. He initiated a discussion among viz-professionals and researchers regarding the effectiveness of our ternary color-coding. A consensus emerged that the color encoding we used does not allow for accurate numeric estimates of the data at display. An interesting alternative, using line symbols, is shown in Fig. 6.3. The superimposed lines can indeed easily be judged separately and line length is known to be an accurate visual encoding [Cleveland, 1986]. Crossed lines are but one among many alternative solutions proposed by famous cartographer Bertin [2010, first edition 1967] for the problem of mapping multivariate data. Unfortunately, we did not explore these solutions. It would be interesting to compare the ternary balance scheme against these alternatives not only with regards to accuracy but also with regards to the nominal and ordinal judgement tasks stated above.

6.2   But why show deviations from an average?

"[...]Arguably only representing the differences in a trivariate rep. obscures the data more by obfuscating the underlying data.[...]"

Danielle Szafir (@dalbersszafir) July 26, 2018

Figure 6.4 | Europe's age compositions naturally is highly skewed towards the broadest age-group 15–65. Due to this narrow clustering using a regular ternary balance scheme (as seen on the left) makes it impossible to gain any insight into the regional variability of population structures. In order to see the internal variation of the data we shifted the grey-point of the ternary color scheme to the location of the average European age structure, thereby visualizing deviations from that average.
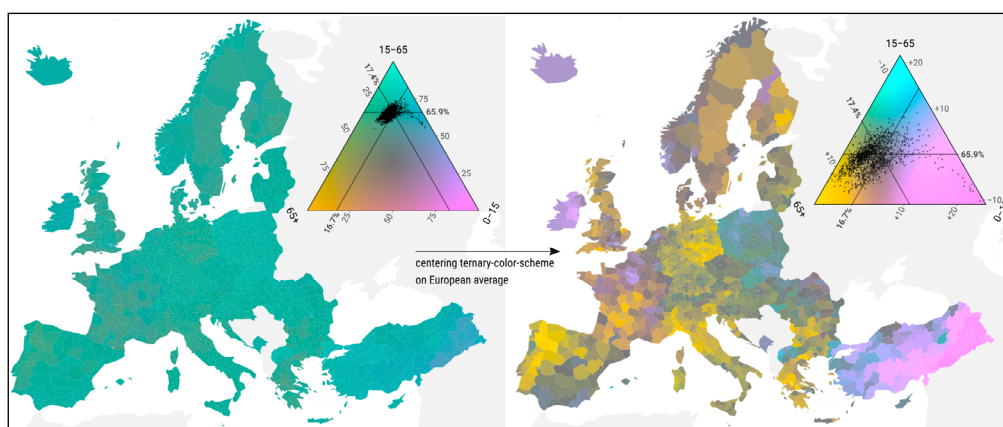
Source: Authors; Data: Eurostat, Population on 1 January 2015 by broad age group, sex and NUTS 3 region (table "demo_r_pjanaggr3")

A central question in data analysis is "compared to what?", e.g. does Poland have a high life-expectancy (compared to Russia, compared to other EU members, compared to other former Warsaw-Pact member states, compared to pre-1990 etc.). Changing the point of reference changes the question. Some visualization techniques implicitly define the comparison to take place: In case of the standard ternary balance scheme (Fig. 6.4 left) lightness and hue encode the magnitude and direction of deviation from a perfectly balanced composition. The resulting map is of little help, showing only that the age structure of every European region is far from balanced and skewed towards the working ages. By moving the grey-point of the ternary color scale from the location of perfect balance to the location of the average age structure in Europe in 2015, we change the comparison and research question to something much more interesting: How does the age structure of a region deviate from the European average?[30]

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30 We call this technique the "centered ternary balance scheme" and describe it in detail in Schöley [2018b].

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6.3   But why continuous colors?

"I have the impression that the 6 discrete color scheme shown on the lower legend would have already sufficed, and possibly make the figure clearer."

Selim Onat (@sel_onat) July 25, 2018

Selim Onat had a great idea on how to make the map more approachable: use only 6 colors. The resulting conventional choropleth map will be more familiar to the audience with the added advantage that each of the 6 colors represents a distinct and clear situation. Consequence of such a stark discretization though is a complete loss of subtlety and detail. Ireland, according to the discrete map, is just as young as Eastern Anatolia. Of course, other discretization schemes are possible but they all require a balancing act between clarity and detail. We opted for maximum detail.

Figure 6.5 | The six color scheme makes the map easier to understand as discrete color scales are widely used to encode qualitative information. The downside of this simplification is the introduction of substantial quantization bias. Compositional gradients become invisible, the age-structures of Eastern Anatolia and Ireland become indistinguishable while similar regions in Germany are assigned highly contrasting colors.
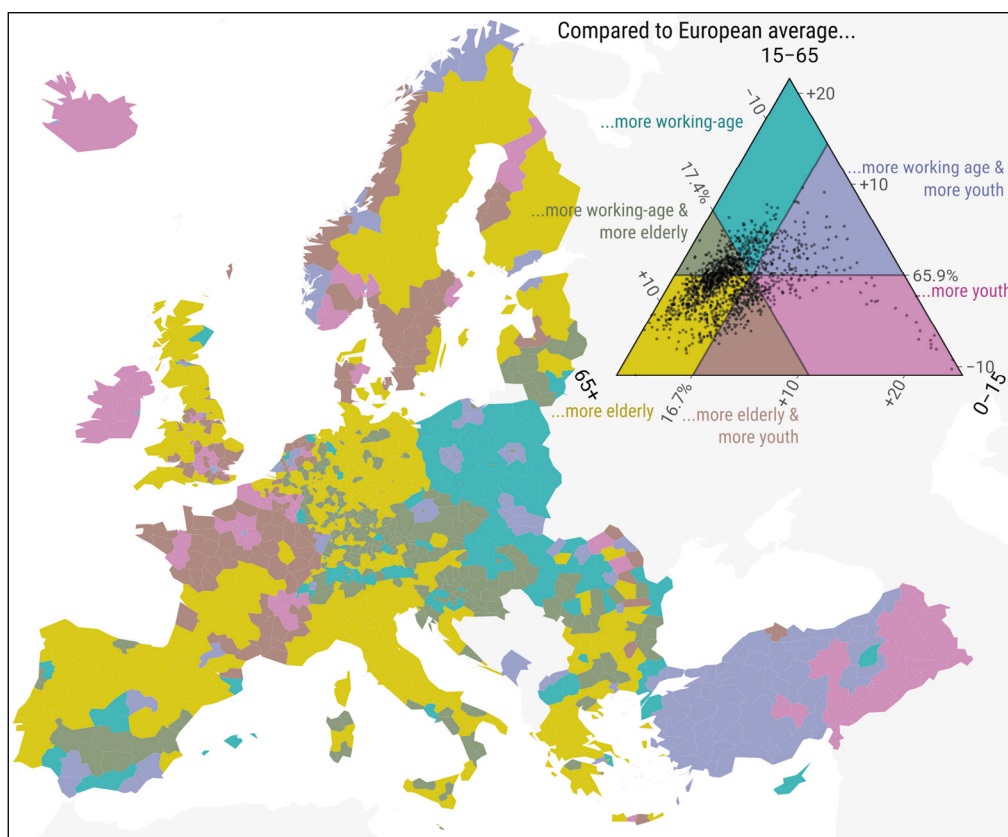
Source: Authors; Data: Eurostat, Population on 1 January 2015 by broad age group, sex and NUTS 3 region (table "demo_r_pjanaggr3")

6.4   But why no cartogram?

"Be careful over-interpreting this! Like all data maps,
it emphasizes large rural provinces and de-emphasizes cities.[...]
A lot of what we're seeing here is differences
in urbanism and youth mobility rather than age."

agate_ July 23, 2018

"[...]I actually thought that was the most interesting thing about the map – London
as a spot of youthfulness in a wider landscape of middle aged-to-elderly folk is
probably actually a pretty accurate and telling feature of the UK[...]"

-burrito- July 23, 2018

Whenever maps depict relative quantities like rates or, in our case, shares of a whole, information about the *size* of the affected population is lost. Instead attention is drawn to large, sparsely populated areas. This bias is very relevant for maps of the European continent given that *more than half of the territory of the European Union is uninhabited* and roughly 3/4 of the EU's population is concentrated in less than 6% of its area [European Union, 2016]. In consequence our map of European age structures over-represents sparse rural populations (e.g. large parts of Scandinavia) and under-represents the urban majority (e.g. London, Berlin, Paris etc.) – this bias can be corrected by using the *cartogram* technique.

Population cartograms distort geography in such a way that regions with equal population counts occupy the same area on a map [Dougenik, 1985]. Compared to a regular map of Europe a cartogram pulls attention away from the rural regions towards the densely populated urban centers as illustrated by the cartogram version of our age-structure map in Fig. 6.6: The shrunken regions of Scandinavia, rural France & Spain and Eastern Europe are balanced by magnified urban centers such as Paris, Berlin, Rome and Ankara.

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Figure 6.6 | Cartograms perturb the physical geography of a place by population size resulting in a map where regions occupy an area proportional to their populous. Notice that on this map Iceland and Scandinavia have largely disappeared while the larger cities are magnified.
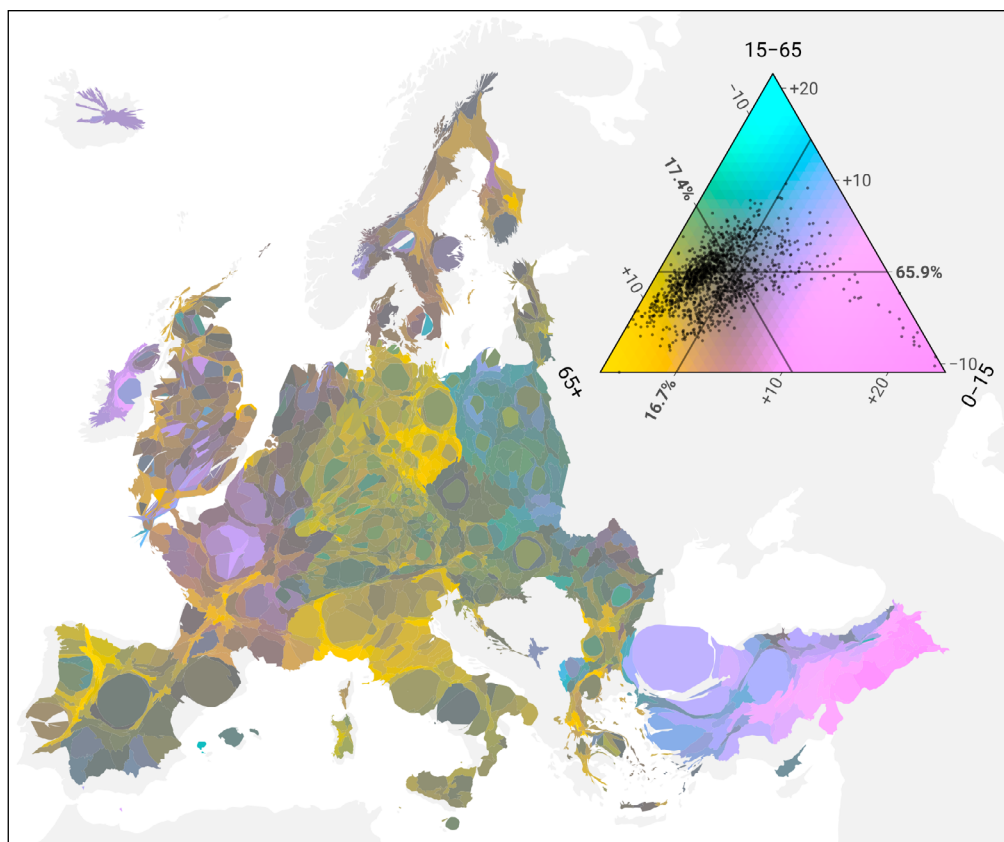
Source: Authors; Data: Eurostat, Population on 1 January 2015 by broad age group, sex and NUTS 3 region (table "demo_r_pjanaggr3")

Note: We used the continuous cartogram algorithm by Dougenik [1985]

> *"There are places I'll remember // All my life, though some have changed"*
> The Beatles 1965

Geography is personal. On a world-map we can locate the places we and our family and friends have lived and worked, the places we have visited, and places we have heard stories about. This makes statistical maps a very engaging form of data visualization. Showing regional level data for a whole continent gives the audience the opportunity to learn about places they care about – but only if they can locate them. The redrawn geography of a cartogram, while being the defining feature, is also its biggest drawback. With familiar coastlines being distorted and the space between capitals squashed and stretched orientation on a cartogram is no easy feat: note the difficulty

in recognizing the outlines of East Germany, Wales or Austria, also, where is London? Because we wanted the audience to recognize places of interest on the map we opted against the use of a cartogram. Also, we felt that having to explain the relatively unfamiliar cartogram technique in addition to the ternary balance scheme would probably overstretch the audience's patience.

6.5   What worked, what didn't?

"I find it amazing that there are such clear differences between regions. You could almost take away the national borders and still clearly know where they are."
kenbw2 July 23, 2018

"Wow! Heaps of „Elderly" across Europe!"
Rene Heim (@ReneHJHeim) Jul 24, 2018

We designed the map so that it would reach a wide audience and make them understand the regional diversity of European age-structures. Did we succeed? What worked, what did not and what have we learned?

We achieved our goal to reach a wide audience. In addition to the exposure gained by publishing in a high-impact medical journal our map of regional age structures in Europe was widely viewed, shared and discussed on social media. Within one day of publication close to 300,000 people have seen our map on reddit (an online discussion board) alone leaving hundreds of comments. We achieved similar exposure on twitter albeit over a longer time period. A few online news outlets reported on our article. The map inspired others to experiment with the centered ternary balance scheme, producing maps of municipal age structures in Finland, income distribution in Canadian cities and forecasted age structures of US counties (Fig. 6.7). We noticed that the map was polarizing. Many people felt engaged by our visualization and seemed to enjoy the complexity, others were appalled by the unfamiliar and dense encoding. While we reached a wide audience, it was also a very select audience of people who enjoy reading visualizations and are willing to invest some time engaging with them. Reaching to a more general audience would have possibly required a more well-known encoding, maybe even a simplification/categorization of the data.

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Figure 6.7 | By publishing all the data and code necessary to reproduce our map along with an R package implementation of our centered ternary color scale [Schöley, 2018a] we made it easy for others to produce their own maps. Here are some examples of work inspired by our publication: A) Municipal age structures in Finland 2017 (by Jani Miettinen, reproduced with permission of the author); B) Adjusted family income distribution in Vancouver 2016 (by Jens von Bergmann, reproduced with permission of the author); C) Adjusted family income distribution in Toronto 2016 (by Jens von Bergmann, reproduced with permission of the author).
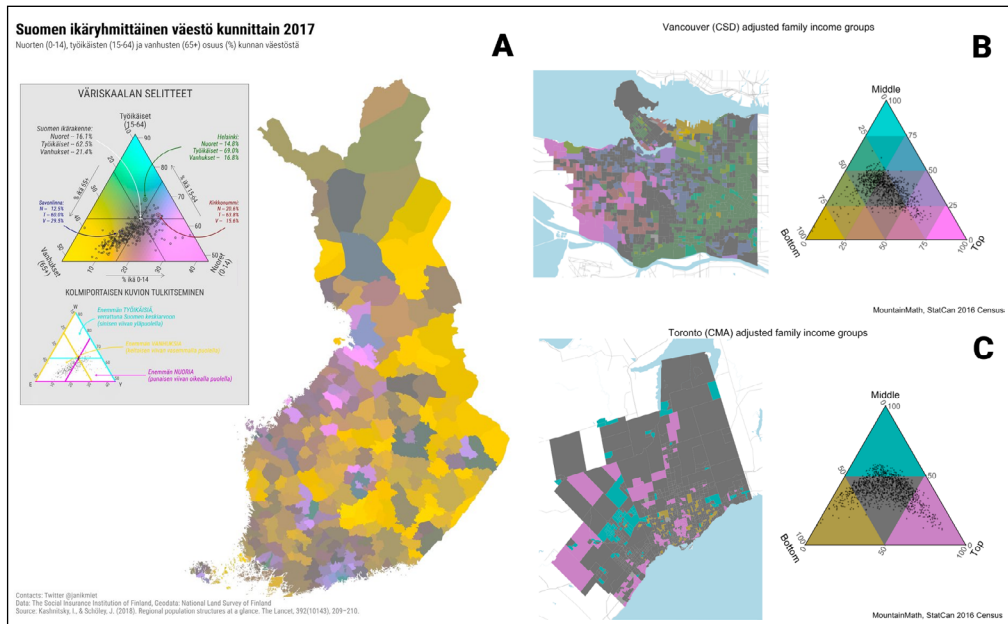
Have people been able to draw correct inferences from the map? Given the extensive discussions of the map on social media we were able to gain some anecdotal insight into how well the audience understood the visualization. Regions of Europe which are qualitatively different in terms of their age structure were reliably understood: People consistently pointed to Germany as an "old country" and to Turkey and Ireland as "young". The spatial discontinuity in age-composition at the German-Polish border was pointed out multiple times. Some also correctly interpreted more subtle differences between regions, such as the younger age structure of Ireland compared to Northern Ireland and the larger share of people aged 65+ in the East of Germany compared to the Western part.

When discussing features of the map people expressed them either in absolute terms (i.e. region X is very old) or in cross-regional comparisons (i.e. region X is younger than region Y). Rarely did anyone mention regional *deviations from the European average* age composition which was our intended reading of the map and the colour scale. In some cases, we observed gross misunderstandings such as judging Germany's population to be *mostly* elderly, or Ireland's population *mostly* young. We believe that the cause for these misinterpretations is not so much the ternary color coding as it is a design *flaw* of the legend: The color scale we used has annotations explaining how ternary diagrams work. What we should have focused on instead is to explain

how our color coding works. In Fig. 6.8 we show a re-design of the original legend that *emphasizes the deviation from the European average* and explicitly states how the color scale can be interpreted.

Figure 6.8 | While the original legend on the left explains how to read proportions from a ternary diagram, the redesigned legend on the right stresses the meaning of the colors and the percent point deviation from the European average.
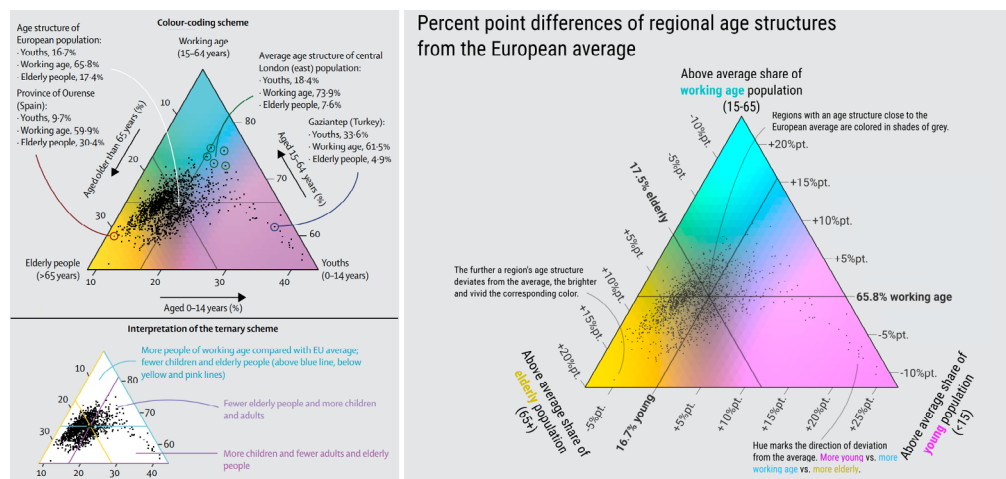
Source: Authors; Data: Eurostat, Population on 1 January 2015 by broad age group, sex and NUTS 3 region (table "demo_r_pjanaggr3")

6.6   Summary

In summer 2018 we published "Regional population structures at a glance" [Kashnitsky and Schöley, 2018] – a map showing how regions across Europe compare against the European average in terms of their population age structure. We spent half a year designing the map for the purposes of reaching a wide audience and making them understand regional age patterns in Europe. Our map was widely shared and discussed on social media which prompted us to reflect, post-hoc, on our design choices and their effectiveness with regards to the stated purpose of the map. While we are more than happy with the impact of our publication and the discussions of European demographics it sparked (spanning such diverse topics as Irish abortion legislation, the rural-urban divide, effects of the German reunification, European immigration policies, Poland's late second demographic transition, more traditional family structures among Kurds in Turkey...) reflecting on the feedback we were also able to identify some problems with our design ultimately stemming from too little user-testing and an incomplete consideration of alternatives.

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For every set of data there are countless ways to visualize it, some of which are more effective at conveying the intended message than others.[31] By trying out different alternatives, testing them on colleagues, reflecting on the collected feedback and finally sharing the result of our work alongside our reflections we would treat the practice of visualizing data just as we treat the practice of modelling data: as a *design process*.

6.7   One last note

When publishing a map showing European demographics one has to expect political discussion. We've seen people using our map to argue for more immigration, against immigration, for pro-natalist policies, against pro-natalist policies and so on… As stated above the map was designed to be engaging, interesting and consequently to invite discussion. Both of us gave our best to be available online, mostly on twitter and reddit, to answer questions, correct misunderstandings and dispel falsehoods regarding the demographics or the viz. Our most important task however was to keep the discussion free of hate. There were some attempts to infuse radical right side ideology into the discussion of the plot and the data and we saw it as our job to speak out against it. We believe that it is the responsibility of researchers to participate in the public discussion of their work. Especially in the age of social media, especially when the work is of public interest.

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31 In fact the situation is such that the space of possible designs is massive but contains only few effective solutions [Munzner, 2015].

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An introduction to agent-based modelling in demography

Francisco Villavicencio
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7.1   Introduction[32]

Demographers are modellers. Because direct observation is not enough to carry out a correct interpretation of population dynamics, theoretical tools and models are always necessary in demographic analysis to overcome the deficiencies of the data. As Nathan Keyfitz stated almost half a century ago, "[m]odels concentrate the interest of the profession and prevent the scattering to which empirical materials by themselves often lead" [Keyfitz, 1971, p. 574].

The Human Mortality Database and the United Nations (UN) *World Population Prospects* are two examples of high-quality demographic databases that are widely used in population studies [Human Mortality Database, 2018; United Nations, 2017a]. They both provide extensive protocols detailing the methods used and developed for data processing, which can give an idea of the complexities and challenges of moving from raw data collected in censuses or surveys, to data that can be efficiently analysed by anyone [United Nations, 2017b; Wilmoth et al., 2017].

Model life tables, for instance, have been extensively used by demographers when complete registration of vital events is not available. Several model life table systems have been developed along the years, the Coale-Demeny regional model life tables [Coale et al., 1983], the logit life table system by Brass [1971], and the UN models [United Nations, 1982] being some of the most popular. Often, the available data on the phenomenon under study are too sparse, and more complex methods not exclusive to demography are necessary. Recent decades have witnessed notable advancements in statistical methodology for handling all kinds of missing data in a wide range of disciplines. Some of these approaches include maximum likelihood estimation, Bayesian models, semi-parametric methods, and multiple imputation, to mention a few.

This chapter aims to offer an introduction to agent-based modelling (ABM) in demography by providing an overview of its theoretical foundations, strengths and weaknesses, followed by an example of application to the study of sex ratio at birth distortions. Agent-based models have drawn the attention of the scientific community in recent years thanks to their ability to deal with incomplete demographic data and with the complexity of social processes, and may present real challenges and research opportunities in the near future. Whilst the current review has inevitably omitted some important works, the hope is that it will help scholars to get a better

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understanding of the basic ideas and concepts behind the development of agent-based models and encourage them to apply these techniques to their own research.

7.2 The scientific study of population dynamics

The birth of demography as a scientific discipline has been traditionally identified with the figure of John Graunt (1620–1674) and the publication of his famous *Natural and Political Observations... Made Upon the Bills of Mortality* in 1662 [Graunt, 1662/1975]. As pointed out by Coale et al. [1983], even though death has always been a preoccupation among humans, it was not until Graunt's work that the patterns and regularities of mortality were subjected to scientific investigation. In the same line, Courgeau et al. [2017] highlight that Graunt was the first to analyse births, illnesses and deaths not as God's designs but as events occurring to statistical individuals. These events became fertility, morbidity and mortality, to be studied at the population level.

Graunt's foundational work aimed to estimate the population of London and provide a description of the causes of death of its inhabitants. It also represents a primitive sketch of what later became the life table, first constructed by the astronomer Edmond Halley in his study of the population of the city of Breslaw (currently in Poland) in the late 17th century [Halley, 1693]. Further, Graunt employed empirical observations to deduce probabilities of death, which is, according to Courgeau [2012], the first attempt to apply the concept of probability to the study of human populations. Although from a modern perspective most of Graunt's work was "purely conjectural" [Coale et al., 1983, p. 3], "highly approximative and his hypotheses extremely crude" [Courgeau, 2012, p. xix], it had a strong influence in the development of related disciplines such as epidemiology, economics, and political science. Most of all, it represents a starting point in the scientific study of populations and the mathematical formalisation of population dynamics, which has been traditionally defined as the "core of demography" [Lee, 2001]. Mathematical demography – also referred to as formal demography, pure demography, theoretical demography, or *démographie quantitative* in French – has been the subject of interest of a large body of literature and has been closely linked to the development of the discipline.

Notwithstanding this, it is worth mentioning that during the 17th and 18th centuries social sciences in general were labelled under the name of *political arithmetic*. The term *demography* was not introduced (in its French form *démographie*) until 1855 by Achille Guillard, almost 200 years after Graunt [Courgeau, 2012]. In fact, in early times demography was closely intertwined with statistics and actuarial science, but in the late 19th and early 20th centuries they separated when statistics began to focus on making inferences from small samples of data, and actuaries became a professional group and started to emphasise financial calculations.

Courgeau et al. [2017] suggest that the implementation of agent-based modelling in demography represents a paradigm shift in the development of the discipline. By providing an overview of the main methodological developments in demography since John Graunt's seminal work 350 years ago [Graunt, 1662/1975], they identify four methodological paradigms in demography: the period (cross-sectional) analysis that started with Graunt; the cohort analysis (longitudinal) developed in the 1950s; event-history analysis; and multilevel analysis, the latter two introduced in the 1980s. Subsequently, they argue that ABM "can form the foundation of the next step in the cumulative progression of demographic knowledge" [Courgeau et al., 2017,

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p. 29], given their ability to deal with the uncertainty and complexity of population phenomena. While at this time it is difficult to assert whether agent-based modelling will become a new theoretical paradigm, the following sections aim to illustrate its usefulness in the study of population dynamics.

7.3 Agent-based modelling

The seminal work by Schelling [1971] is probably one of the first examples of a dynamic model to analyse human behaviour. By developing a simplified agent-based model, he attempts to explain spatial segregation as the result of specific decision rules at the individual level. Nonetheless, the emergence of agent-based modelling (ABM) in population studies may be identified with the publication in 2003 of the ground-breaking volume *Agent-Based Computational Demography* [Billari and Prskawetz, 2003]. With a selection of papers from several scholars, that book aimed to introduce agent-based computational models in demography, given their flourishing development in related fields such as economics, political science, and sociology. Despite their capabilities, more than a decade later the application of ABM to the study of human behaviour remains limited, and the methodology has yet to become a standard tool for population scientists. The number of publications applying ABM specifically to demography during that time has been relatively low, although there are examples of some works focusing on family formation [Billari et al., 2007; Bijak et al., 2013], transition into parenthood [Aparicio Diaz et al., 2011], or migration [Kniveton et al., 2011]. In this context, a new volume on *Agent-Based Modelling in Population Studies* was recently published, seeking to enhance the methodological corpus of demography and discuss current and potential applications of ABM [Grow and Van Bavel, 2017].

7.3.1 Agent-based modelling in population studies

Borrowing from some of the works mentioned above, agent-based modelling may be defined as a class of computational models that implement theoretical rules of behaviour, decision-making and interaction among autonomous agents (that can represent individuals or groups) in a simulation, to help explain the emergence of macro-level patterns and potentially account for their feedback into the agents again. Adopting a bottom-up perspective, the main goal of ABM is to capture the complexity of social systems through the analysis of simulations and evaluate whether micro-based rules at the agent level can explain macroscopic regularities and social change.

Agent-based models are therefore embedded in what Axelrod [1997] defined as the "complexity theory", which involves the study of many actors and their interactions. As argued by him and other authors, this complexity may be difficult to analyse using standard mathematical and statistical methods, and computer simulations are an optimal choice. These ideas led Axelrod to consider ABM "a third way of doing science", comparable to the principles of induction and deduction: "Like deduction, it starts with a set of explicit assumptions. But unlike deduction, it does not prove theorems. Instead, an agent-based model generates simulated data that can be analyzed inductively. [...] Whereas the purpose of induction is to find patterns in data and that of deduction is to find consequences of assumptions, the purpose of agent-based modeling is to aid intuition" [Axelrod, 1997, p. 3–4]. Axelrod's claim may have been too ambitious given that 20 years later it is hard to assert whether ABM has become a new

way of doing science. However, agent-based models are undoubtedly a very powerful tool to understand the emergence of complex macro-level patterns as an aggregation and interaction of micro-level rules for which no empirical data are usually available. Moreover, there is a general agreement among scholars that ABM can also contribute to demography in the development of theories of human behaviour [Billari et al., 2003; Burch, 2003; Courgeau et al., 2017; Van Bavel and Grow, 2017; among others].

7.3.2   Agent-based modelling versus micro-simulation

A question that may arise naturally concerns the differences between agent-based modelling and micro-simulation. Both approaches take individuals as the unit of analysis and use computer algorithms to determine individual transitions between states, but their different goals have often been used to classify them separately. A general thought is that micro-simulation describes changes at the population level as outcomes of individual behaviour, without considering their possible feedback on the agents, whereas ABM focuses more on agents and adds individual decision rules to micro-simulation. Another common idea is that micro-simulation usually focuses on forecasting, while the main emphasis of ABM should be on explanation rather than prediction [Billari et al., 2003; Prskawetz, 2017].

Bijak et al. [2013] provide a detailed discussion about the similarities and differences of these two approaches. They add that micro-simulation is usually heavily data-driven and determined by empirical transition rates – which may certainly be useful in multiple applications – but it fails to capture the full complexity of processes underlying population dynamics, such as social networks, individual beliefs or spatial interactions. However, they also argue that the distinction between the two approaches in not clear-cut, at least when it concerns demographic applications, given that agent-based models in demography often use empirical transition rates to model fertility and mortality, and there are examples of micro-simulation models that also include behavioural rules and feedback mechanisms.

7.3.3   The micro and macro levels

In order to study the synergies between the micro (individual) and macro (aggregate) levels, Billari [2015] suggests a "two-stage view" of population dynamics. The first stage would concern the "discovery" of demographic regularities at the macro level, and their associations over time and space. Formal mathematical methods and summary measures of fertility, mortality and migration are necessary in this step. The second stage would focus on the "explanation" of those discoveries from a micro-level perspective, to show how population change emerges from individual behaviour and the interactions among individuals.

Agent-based models are useful to link these two stages of analysis, thanks to their ability to deal with complexity and to connect the individuals (agents) with the population level. Van Bavel and Grow [2017] summarise that ABM can help "bridging the gap" in two major steps: first, by developing a simulation model that includes an in-depth knowledge of the population of study, in combination with existing theoretical frameworks and rules of behaviour and interaction; and second, by simulating the micro and macro implications of hypothetical rules outside the original context, usually with real-world data. Being able to apply a model to a different context than the one for which it was originally designed is always necessary to prove its

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validity. Further, calibrating agent-based models with empirical data can make them more realistic and a more useful tool to understand observed demographic changes and their underlying mechanisms [Bijak et al., 2013; Courgeau et al., 2017].

7.3.4   Population heterogeneity

Van Bavel and Grow [2017] identify Billari's first stage with the concept of "closed" population, narrowly linked to the development of formal demography. On the other hand, the second stage refers to an "open" and more flexible, dynamic and complex concept of population that, in turn, can account for population heterogeneity very efficiently. Populations are heterogeneous, and there have been multiple advances in formalising the effect of individual and unobserved heterogeneity in population dynamics, with the frailty models introduced by Vaupel et al. [1979] as one of the most pioneering and noteworthy works on that matter. However, ABM provides more flexibility, allowing the simulation of scenarios that introduce heterogeneity at the agent level, and considering also the interactions of those agents within social networks and their evolution over time [Billari et al., 2003; Prskawetz, 2017; Van Bavel and Grow, 2017].

7.3.5   Demographic theory

In addition, several authors have highlighted the potential of agent-based models to contribute to the development of demographic theory. Accordingly, ABM needs theory for its implementation but can also generate theory. Billari et al. [2003], for instance, suggest that agent-based models can be conceived as "demographic laboratories" to study the effects at the macro level of rare events or factors that are hardly quantifiable, whereas Silverman et al. [2013] highlight the ability of agent-based models to be used as a theoretical exploration of different scenarios of policy-relevant problems.

One of the first authors who reflected extensively on the strength of modelling for theory generation in demography was Burch [2003], who claimed that, in order to become a true science and not a set of techniques, demography should overcome its apparent lack of theories. Adopting an original perspective – that some may even find controversial – Burch advocates a "liberal view" of theory and models, blurring any sharp distinction between the two. He argues that a theory does not necessarily have to be a generalisation across several scenarios, but it can deal with particular cases and address unique events. This point is supported by the fact that empirical generalisations in social science are rather uncommon. Therefore, a model that can explain a specific phenomenon is perfectly able to build a good theory. Accepting these premises, the model-based view allows considering a theory as a "tool-kit" of related models that can be used for different purposes. Burch concludes that this suggested approach to theory and models "enhances the stature of demography as a science, an autonomous, well-balanced scientific discipline, with a large body of good theory, as well as of techniques, data, and empirical findings" [Burch, 2003, p. 278].

7.3.6   Criticisms and possible solutions

Notwithstanding all the above, the use of agent-based modelling has some drawbacks, and criticisms have also arisen. Van Bavel and Grow [2017] note that the ability of a model to reproduce an empirical pattern is not enough to demonstrate its validity

and are alert to the risk that a given model turns into nothing more than a "good story" that illustrates a specific situation that could also be explained with "other stories". Several authors have expressed themselves along the same line, starting with Burch [2003] who highlights that models need to be stated clearly and rigorously to become valuable inputs in the development of theories.

For their part, Venturini et al. [2015] give what is probably one of the sharpest criticisms to agent-based modelling, claiming that in ABM the properties of micro-agents and the rules of interaction are simplified to conveniently fit the macro-level structures, and that the whole complexity of human behaviour is not captured. Instead, they suggest prioritising the development of mechanisms to exploit digital data as tools to study social phenomena. One could argue that these two approaches are not necessarily mutually exclusive, but complementary. Further, the potential use of digital data also poses methodological challenges to demographers and computer scientists and opens new research areas. The key point, however, is that of attempting to explain the complexity of a macro-level pattern in terms of a set of parsimonious rules at the micro-level, which generates a tension between parsimony and complexity that can hardly be solved. By definition, if a model is to aid intuition, there must be a simplification of some kind, and if it is to help support a theory and highlight its plausibility, it must also tell a good story. By being flexible, agent-based models can easily become very complex but make altogether unclear what is driving model results. In this regard, Venturini et al. [2015] are right when they state that agent-based models should not be designed at the researcher's convenience to fit the population dynamics.

To address these issues, two main workable solutions are presented in the literature. First, the use of meta-models that may help form a deeper understanding of the model behaviour, as well as its limitations. Meta-models, also called emulators or surrogate models, are simplified statistical representations of a simulation process that intend to quantify the sensitivity of the model outputs to the different parameters. Even though the use of meta-models in agent-based modelling in demography is rather scarce, two types of meta-models stand out: regression meta-models and Gaussian process emulators, examples of which can be found in Bijak et al. [2013], Grow [2017], Hilton and Bijak [2017] or Silverman et al. [2013], among others. On the other hand, in order to make agent-based models more transparent and useful for the target audience and facilitate their re-implementation, Groeneveld et al. [2017] suggest the use of the ODD+D (Overview, Design, Details + Decisions) protocol, a prescriptive model description originally implemented in ecology. Certainly, by generalising the use of meta-models and using a standard procedure in the model description, ABM would gain more credibility among researchers.

## 7.4 An agent-based model of sex ratio at birth distortions

To provide some intuition to all the theoretical concepts that have been introduced and illustrate the strengths of agent-based modelling, this section briefly discusses an example of application to the study of sex ratio at birth distortions by Kashyap and Villavicencio [2016; 2017]. For additional examples and discussion on ABM, the reader is referred to the monograph edited by Grow and Van Bavel [2017].

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7.4.1 The sex ratio transition

Across a number of countries in Asia and the Caucasus, fertility decline in recent decades has been accompanied by an unprecedented and anomalous rise in the sex ratio at birth (SRB), measured as the number of male births for every 100 female births. The causes, patterns, and demographic implications of imbalanced SRBs remain the subject of a large and growing body of research, but relatively little attention has been paid to understanding the micro-level dynamics underlying SRB trajectories.

Giulmoto [2009] understands macro-level SRB trajectories in terms of an "archetypal transition cycle" involving a rise, a levelling off, and eventual decline toward normalcy that he termed the "sex ratio transition". Fig. 7.1 shows the UN estimates for total fertility rates (TFR) and SRB trends from 1970 to 2020 for South Korea, China and India. Also reported is the example of Turkey, where the fertility decline has not been accompanied by a rise in SRB. The curves show that even as levels of fertility steadily declined in the 1980s and 1990s, distorted SRBs suggest the persistence of son preference and the practice of sex-selective abortions. Note that South Korea is the only country that has been through all three stages of the sex ratio transition.

Figure 7.1 | Total fertility rates (TFR) and sex ratios at birth (SRB) trends for several Asian and Caucasian countries, 1970–2020.
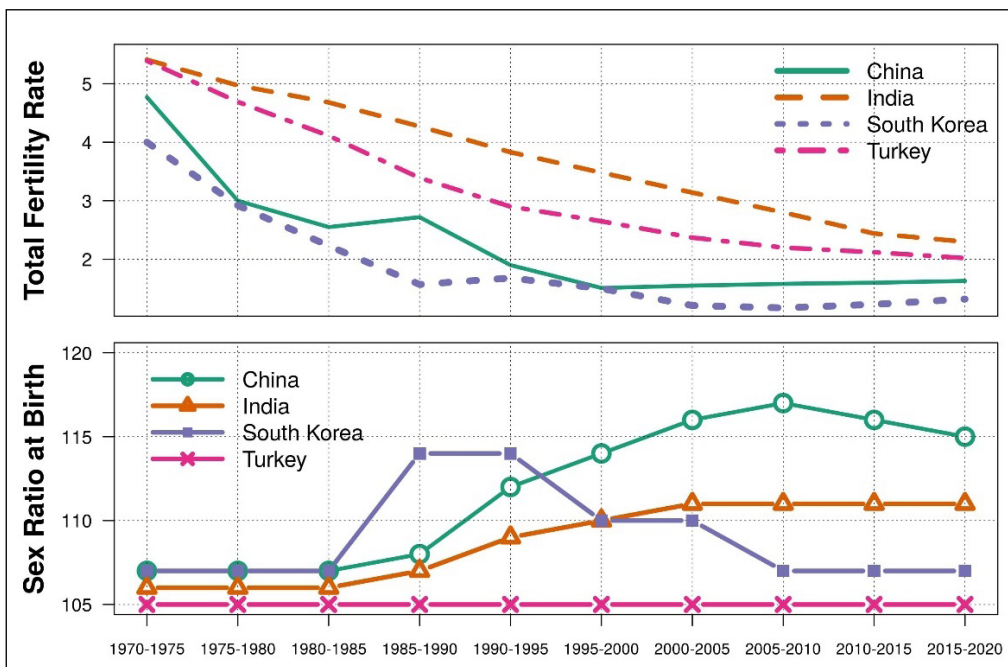
Source: United Nations 2017a

Guilmoto [2009] develops a framework for the three preconditions leading to the practice of prenatal sex selection: persistent son preference, declining total family size, and the spread of prenatal sex determination technology. However, the specific

levels, trends and interactions of these factors in explaining SRB trajectories are hard to discern with existing data and approaches. The work by Kashyap and Villavicencio [2016; 2017] aims to examine the contribution of each of them by calibrating an agent-based model to the South Korean and Indian scenarios.

7.4.2 Model description

The agent-based model simulates individual-level reproductive behaviours from the bottom-up to examine emergent population-level SRB trajectories. Individuals who desire a son practice differential stopping behaviour, conceived as the fertility behaviour in which couples continue childbearing until they reach a desired number of sons by regulating their contraceptive use based on the sex composition of their offspring. Although these individuals wish to control their total fertility levels over time, their son preference does not always allow them to stop childbearing at low parities. Prenatal sex determination technology then emerges as an exogenous stimulus that diffuses steadily, enabling growing proportions of individuals to reconcile their son preference with their aspirations for smaller families. The proportion of individuals desiring sons, their total fertility levels, and those with access to technology all change over time at differing rates, and their interactions produce aggregate SRB trajectories.

Following Guilmoto [2009], the model implements the "ready, willing and able" (RWA) framework to conceptualise the micro-level causal processes leading to the practice of sex selection. This approach adapts the RWA framework originally used by Coale [1973] to account for the European fertility decline in the 19th century. The practice of sex-selection from the agent's perspective can be seen as the outcome of three conditions: (1) *willingness* to consider sex-selection because of the persistence of cultural norms that reinforce the value of male offspring; (2) *ability* to seek sex-selection given the availability of affordable and accurate prenatal sex determination technology and relatively liberal abortion legislation; and (3) *readiness* to practice sex-selection as a consequence of the fertility squeeze wherein individuals wish to reconcile their sex preferences with a small total family size. The idea of readiness gains importance as fertility declines with the diffusion of norms towards smaller families, and prenatal sex-selection becomes preferable instead of additional births as the means to realise son preference.

7.4.3 Main findings

A detailed study of model behaviour, experiments and model calibration for South Korea is presented in Kashyap and Villavicencio [2016]. The article also includes some supplementary materials with the code to run the model and carry out a sensitivity analysis. As the only country that has been through all three stages of the archetypal sex ratio transition, calibrating the model to the South Korean case can shed light on the levels and rates of change in son preference, diffusion of technology, and probabilities of sex-selective abortion that plausibly underpinned different stages of the sex ratio transition.

The main findings in the works by Kashyap and Villavicencio [2016; 2017] can be summarised as follows: In South Korea, SRBs peaked at 114 at relatively low levels of son preference of around 30% wanting one son, due to the joint effect of technology diffusion combined with steady increases in the readiness to abort, including small increases even before the transition to first birth. In contrast, the Indian case in

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which SRB trajectories have been flatter and less peaked than South Korea suggests the plausibility of a slower technology diffusion combined with a lower readiness to abort due to a higher fertility context.

7.5 Discussion

Given the interest of social science in studying how individuals behave, their interactions and the effects at the macro level, agent-based models are a suitable approach. As has already been discussed, ABM describes population change as an outcome of rules of behaviour and interaction and, as a result of those interactions, these models can produce emergent properties that cannot be identified by simply aggregating individual characteristics. In agent-based modelling, agents are involved in one or more activities and act according to their social context and to some behavioural rules, but at the same time they have the autonomy to make independent decisions given the heterogeneity of individual attributes. Agent-based models can then be used to study complex dynamics in which mathematical analysis struggles, or when no empirical data are available to carry out a standard statistical analysis. In addition, agent-based modelling focuses on explanation rather than prediction, and therefore provides an opportunity to bridge theory and technique.

The agent-based model by Kashyap and Villavicencio [2016; 2017] aims to meet some of these goals. First, the model is built upon a theoretical framework that may explain the emergence of distorted sex ratios at birth [Guilmoto, 2009]. Next, some individual behavioural rules are implemented in a simulation in which autonomous agents make decisions at the micro level. The outcome of their decisions generates SRB trajectories at the macro level, which allows understanding the micro-level dynamics underlying those trajectories. Furthermore, a sensitivity analysis is carried out to evaluate the influence of each of the model parameters in the model output.

As it has already been mentioned, Courgeau et al. [2017] suggest that the implementation of agent-based modelling in demography can represent a paradigm shift in the development of the discipline. At this time, it is difficult to assert whether this will really happen. However, if modellers can overcome current challenges, formalise practical guidelines for the implementation, sensitivity analysis and description of models, be transparent about their limitations, and facilitate model replicability, ABM has good chances of becoming a standard tool for demographers and social scientists in the near future.

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Population aging as a current challenge for the world

Adéla Jodlová, Klára Hulíková Tesárková

8.1   Introduction[33]

The term "aging" could be explained from many points of view and could be defined from the perspectives of demography, sociology, psychology, or biology. Due to this fact, there are many possible meanings of this concept [Siegel, 2012]. Most often, the population aging is defined as a change in the age structure of the population, where the proportion of seniors is increasing [Calot and Sardon, 1999]. There could be many factors standing behind the traced change of the age structure.

Not only the process of population aging, but also the age group of seniors could be defined in many ways. Often the age of 65 and more years is used as a burden of old age [Calot and Sardon, 1999]. One important fact has to be mentioned in this relation – an absolute increase of the number of seniors does not necessarily lead to the increase of the proportion of seniors. This could be illustrated very simply: imagine a situation where the number of life births decreased in a studied population while numbers of people in all the other age groups remained unchanged. This would lead to the decrease of the proportion of the child age group in a population, or in other words, to the increase of the proportion of seniors in the population, however, the number of seniors did not change at all. On the other hand, the total number of seniors in a population may increase although its proportion remains unchanged or could even decrease – this can happen if the proportion of other age groups (children or adults) increase (number of children and adults increase in this case more than the number of seniors).

However, the absolute increase of the number of seniors as well as the increase of their relative proportion in population could have significant consequences and deserves attention in the study of population aging. Moreover, from the previous paragraph it could be concluded, that for the complex study of population aging both the perspectives should be considered – change of the absolute number of seniors as well as the change of the relative proportion of seniors in a population.

Although the population aging is often studied using only a rough division of population into three wide age groups (child, adult and seniors), it is worth working also with more detailed division above all of the oldest age group. Usually, as a consequence of age specific mortality improvements the proportions of the oldest age groups are the most rapidly growing ones [Rychtaříková, 2011].

There is one simple but perfectly illustrating tool usable for the analysis and visualization of population aging, it is the population pyramid. The population pyramid is a basic demographic instrument graphically presenting the age-sex structure of the population [Dupalová and Hulíková Tesárková, 2014]. Within this paper the population pyramid will be used in a specific manner, proposed below and suitable for illustration of the process of population aging.

The aim of this paper is to present briefly the most important trends in population aging in the world, to illustrate the increase of the relative proportion of seniors in the studied populations, and above all the absolute increase of the number of seniors in selected aging populations. The goal is, however, to use primarily the graphical methods, so as it enables to clearly present the process of population ageing to the public or non-demographers.

8.2   Roots of population aging

We can trace the population aging already to the demographic transition, where the high levels of mortality and natality were gradually replaced by low values of these processes. The beginning of the demographic transition could be dated mostly to the 19th century in developed countries, nowadays it is still in the process in the developing countries. Although the specific course of this process in all the countries could be significantly different, the process of demographic transition itself could be understood as nearly universal – the mortality decrease is followed by the decrease of fertility, in the meantime usually a significant increase of the population size occurs. As a consequence of the decrease of fertility, the more populous cohorts "are shifted" (grow older) gradually to higher ages, but they are usually not followed by similarly populous younger cohorts. Finally, those population segments grow old up to the senior age group. This leads to the change of the age pyramid, as more people are shifted to the higher age, unlike less children are born so the base of the pyramid becomes narrower [more about the demographic transition, its consequences and specifics could be found for example in Landry, 1987].

So as the demographic transition, also the course of the population aging could be different in particular affected populations. Usually, in relation to the course of the process of demographic transition, the demographic aging is more intensive and rapid in populations where it starts later [e.g. Dobriansky et al., 2007].

Not only the demographic development itself, but also the population aging is formatted by three main demographic processes – natality (or fertility), mortality and migration. In brief, the decrease of natality leads to the decrease of the number of life births and narrowing of the population pyramid. The population aging in this case starts *from the base of the pyramid* when more populous generations move to older ages and contribute to the population aging. On the other hand, decrease in mortality at adult and higher ages leads to relative widening of the top of the pyramid, this leads to the population aging *from the top of the pyramid*. The effect of migration is not so clear, migration does not have to lead to any change of population structure at all, or it could lead to population aging immediately (led by immigration of seniors or emigration of young people or children) or with some delay (aging of the young immigrants). Usually, the mutual process of aging from the top as well as from the base of the pyramid is observable. It is the consequence of mortality and fertility decreasing mutually underwent in the developed countries.

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Still, we have to keep in mind, that population aging might be a challenging problem for the affected populations, however, it is above all an important success of the population caused by the improved life conditions [Kinsella, 2000]. Although, almost all the countries in the world record the increase of the proportion of seniors, the tempo of population aging is significantly different in particular regions or countries.

The proportion of seniors is on average higher in developed countries, however, the tempo of population aging is (or likely will be in the future) higher in currently developing countries [Kinsella, 2000]. The first signs of population aging were traced in developed regions – Europe and the North America. In those regions also, the current proportion of seniors is the highest one. However, as a consequence of anticipated and already recorded decrease of fertility in Asia and Latin America, the doubling of the proportion of seniors in populations of those regions is expected in the first third of the 21st century [ibid.].

8.3   Measurement of population aging

Because the population age structure could be taken more important than the overall number of inhabitants, there is also a need of quantification of the intensity of population aging. As was said above, usually the increase of the number of seniors or increase of the proportion of seniors in a population could be used for illustration of the population aging. Although the burden of the senior age could be selected differently, we will work with the most common value nowadays – 65 years.

Usually a set of relatively simple measures is used for quantification of population aging, those measures are based on ratios of particular age groups (child-, adult-, and senior age group). Probably the simplest one could be the proportion of seniors itself [d'Albis and Collard, 2013]. Another measure could be e.g. the Aging index defined as the ratio of seniors and children (usually defined as people up to 20 years) in a population, or the Old age dependency ratio defined as the ratio of the number of seniors and population in the age of economic activity [those simple measures are often defined in basic demographic text books, see e.g. Pavlík et al., 1986, in Czech]. However, despite the simplicity of the mentioned measures of population aging, d'Albis and Collard [2013] pointed out that the senior population itself changes in time – as a consequence of developing life style or living conditions, working conditions and access to nutrition, people in a particular senior age are in a different condition in comparison to people in the same age in different generations.

8.4   Structure of the chapter

Although we can use many measures of population aging, from the simplest ones to the more sophisticated, it would be beyond the scope of this paper. As stated above, the aim here is to illustrate the process of population aging itself. For this purpose, we use the simple population pyramid and we will show, how flexible and usable tool the population pyramid would be.

At first, we will use some of the simple measures of aging, like the Old age dependency ratio, and point out the regional variances in the level as well as trends of population aging in the world. Then the overall tempo of the population aging on the national level will be presented. Within these two steps the oldest or most rapidly

aging regions or countries will be selected and studied more in-depth in the following part of the text.

For a deeper study, the regions of Europe and Africa were selected. Europe is currently the oldest region in the World, moreover, the tempo of population aging in Europe is still one of the highest ones. On the other hand, Africa is currently the youngest region and it will be probably also in the future. However, in the second half of the 21st century it is expected, that Africa will reach the highest tempo of population aging.

In the following part an intense description of the development of the three selected countries is introduced. Those countries are Japan, currently the oldest population in the World where the population aging is caused by the combination of very low fertility and mortality levels, Italy, the oldest population in Europe where population aging is a consequence of above all very low level of fertility, and the United Arab Emirates, where the tempo of population aging is expected to be extremely high in the 21st century and population aging in the country is driven primarily by the process of migration.

In the text, the population pyramids will be used for illustration of the changes in population age structure itself. This is a traditional manner of the usage of the pyramid. A less traditional way of usage is based on the presentation of the changes of the absolute number of seniors in the studied populations.

8.5 General trends of population aging in the world

Currently, Europe is the oldest region in the World. Using the Old age dependency ratio (ratio of the number of seniors to the population in productive age, presented in %) in Fig. 8.1, it is obvious, that in Europe, there are almost 30 seniors for each 100 people in the productive age. However, for the year 2015, the highest value of this measure was estimated for Japan (46.2). Other countries in this ranking were already the European ones – Italy (37.8) or Finland (35.0) followed by Germany, Portugal, Sweden or France and then most of the other countries from Europe [United Nations, 2017].

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Figure 8.1 | Old age dependency ratio, regions of the World, 1950–2015; estimate of the future development, 2015–2100, medium variant UN.
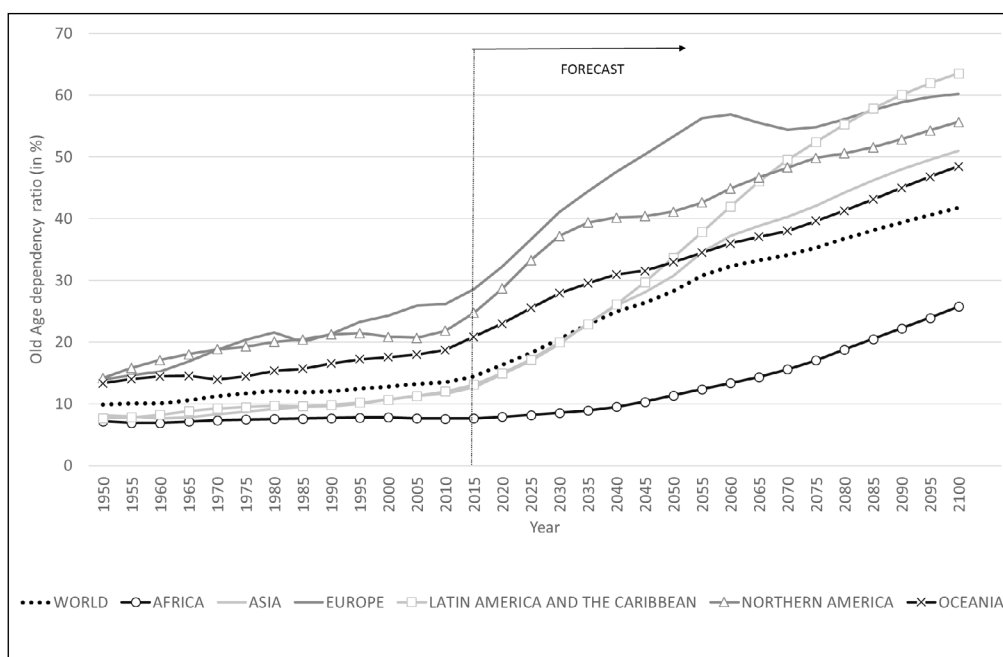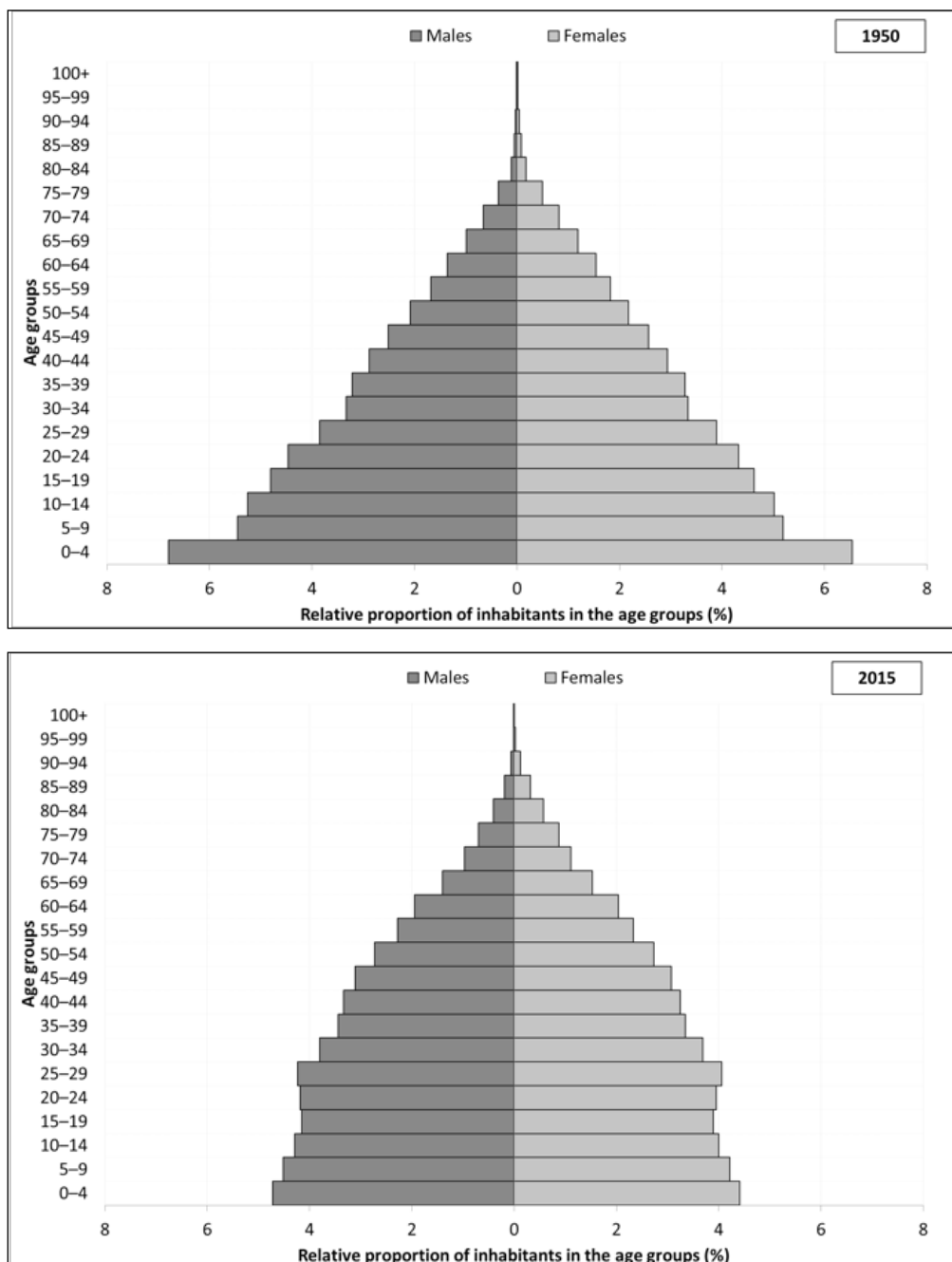

Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

The tempo of aging is expected even to increase during the 21st century (Fig. 8.1 and 8.2). This holds above all for the region of Latin America and the Caribbean. From this region the highest values in 2100 are expected in Jamaica (89.7) or Puerto Rico (81.2). However, these results for the end of the 21st century are based on many assumptions.

While nowadays, Africa is the youngest region where also the tempo of aging is the slowest one in the World, during the second half of the 21st century the situation is likely to be different and Africa may be the most rapidly aging region in the World (although still the youngest one). On the other hand, Europe is currently the oldest region in the World, and is likely to be also by the end of the century (together with Latin America and the Caribbean), however, the tempo of aging in Europe will probably fall down and be the slowest one in the World.

Figure 8.2 | 5-years relative changes (tempo of increase) of the Old age dependency ratio (in %), regions of the World, 1950–2015; estimate of the future development, 2015–2100, medium variant UN.
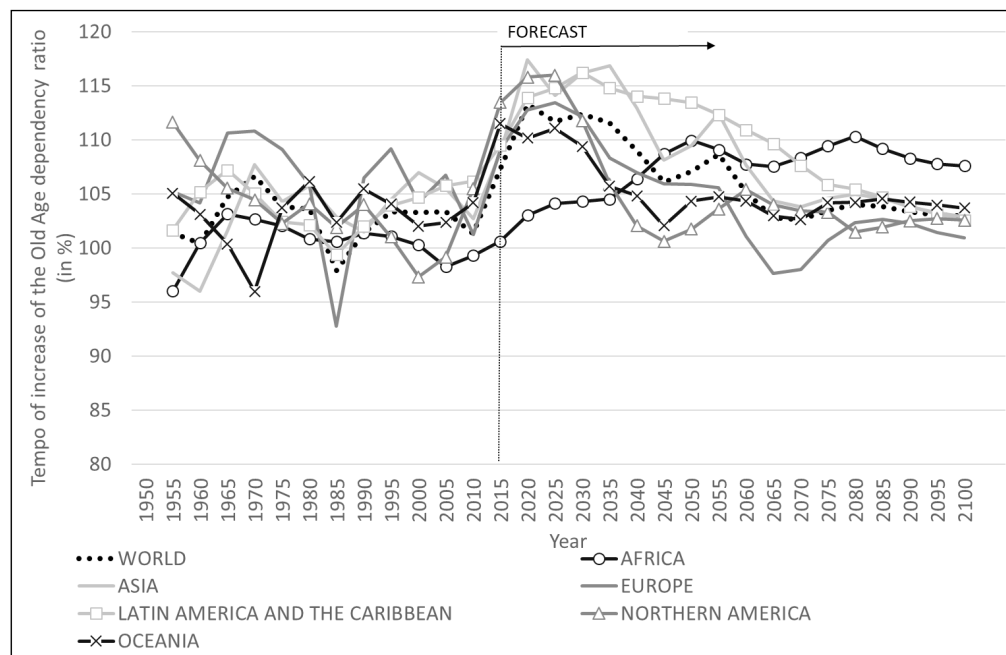
The estimations for the year 2050 could be taken as relatively secure. It is expected (Fig. 8.3), that also in the middle of the 21st century the oldest population will be in Japan (77.8 seniors for 100 people in a productive age). Italy is likely to remain among the oldest countries in the World (72.4), however, it will probably be on a similar level of aging as Spain (77.5), Greece (73.4) or Portugal (73.2). It is clear that the Southern Europe is likely to be the oldest region in the World within a few decades. This is caused by a long-term low level of fertility accompanied by the low mortality level in these countries. Japan or Republic of Korea are already nowadays old populations (in case of Japan) or rapidly aging countries (in case of Republic of Korea), which is caused (similarly to the Southern Europe) by low fertility as well as mortality levels.

Figure 8.3 | Changes in the Old age dependency ratios, 1950, 2015 and estimation for the year 2050; all the countries in the database of the United Nations are included.
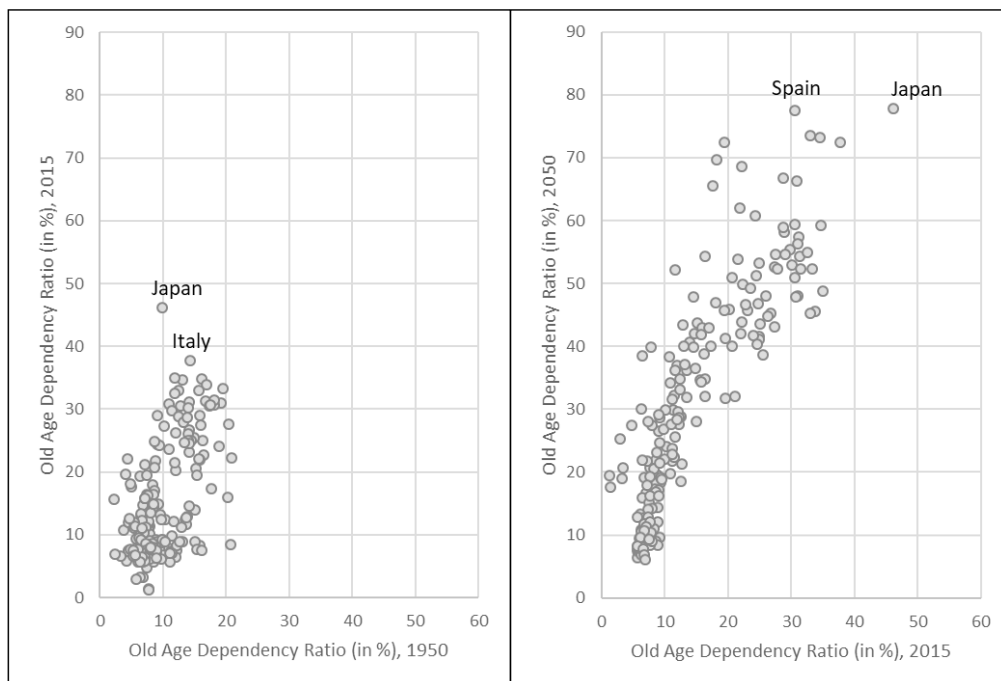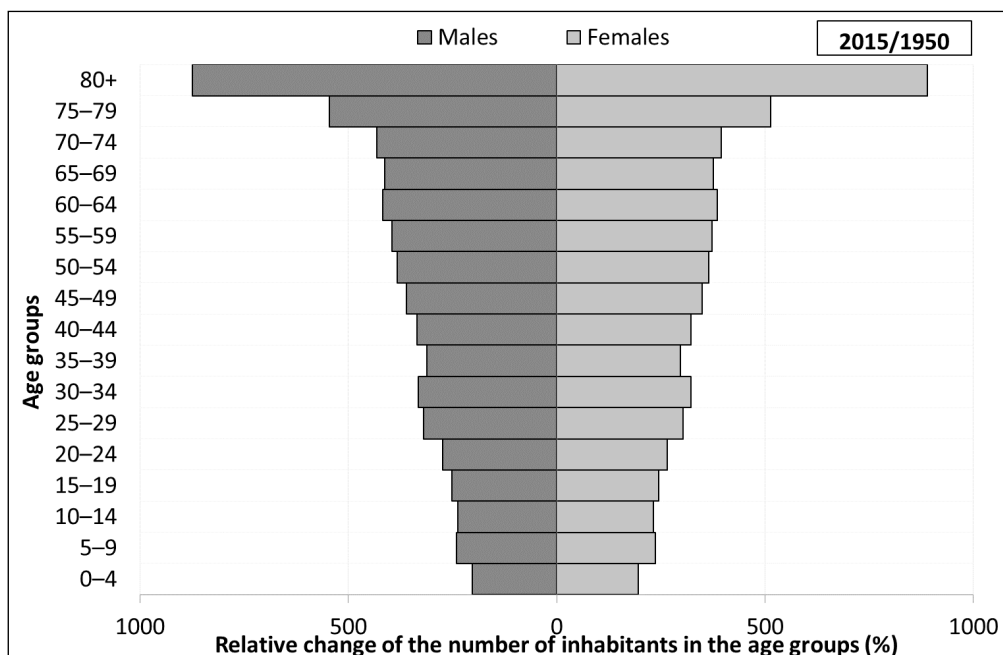

Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

8.6 Population aging in the world and in selected regions

In this part we will focus on the brief general description of the population aging and the increase of the number of seniors in the World and specifically in selected regions corresponding to the Fig. 8.1 or 8.2. Europe and Africa were selected for the general comparison – Europe as the currently oldest region in the World, Africa as the youngest one. Moreover, the process of population aging will be described according to its expected tempo also in the second half of the 21st century. In that time, Europe is expected to be the region with the slowest aging rate, Africa will be among the most rapidly aging regions.

The age structure of the world changed visibly during the second half of the 20th century (Fig. 8.4). Above all the proportion of the youngest (child) age group decreased in the population, in 1950 there were 43.7% of population at age below 20 years, in 2015 this proportion was 34.2%. On the other hand, the proportion of seniors increased from 5.1% in 1950 to 8.3% in 2015. During this time the overall population increased by some 4.8 billion of inhabitants, the increase occurred in all the age groups, however, the oldest age groups grew the most as an expression of population aging (Fig. 8.5).

Figure 8.4 | Relative age structure, 1950, 2015, World, in %.

Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

Figure 8.5 | Expected relative age structure, 2050, 2100, World, in %, medium variant UN.
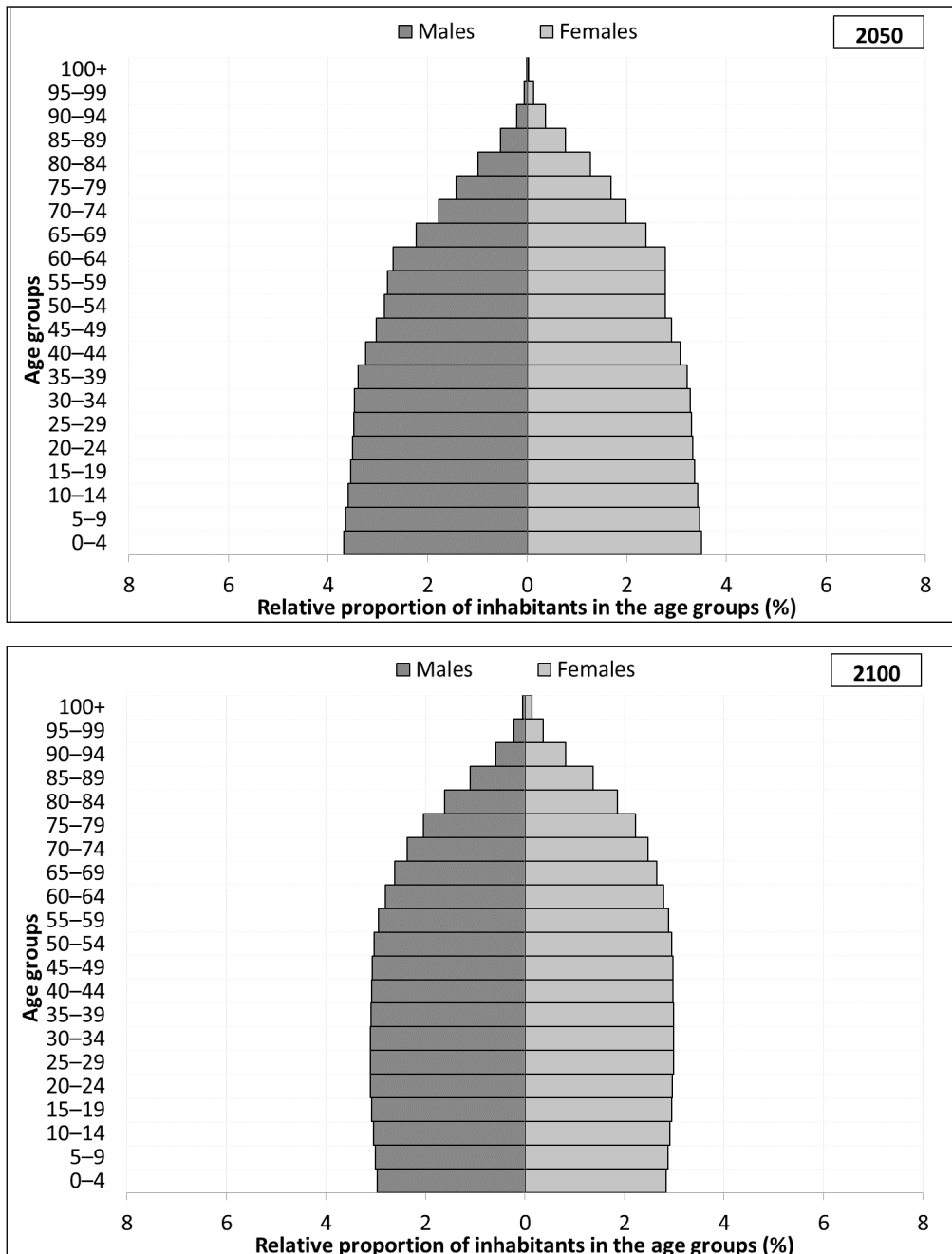
Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

Figure 8.6 | Relative (for later period expected) change of the number of inhabitants in all the age groups between 1950 and 2015 (up) and between 2015 and 2050 (down), World, in %.
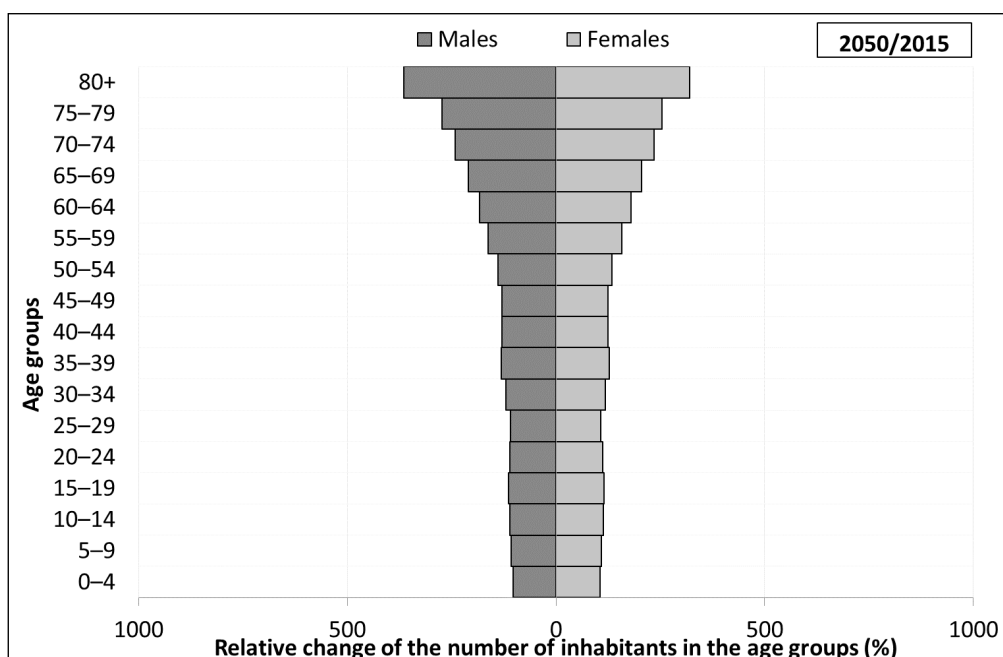
Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

In Fig. 8.6 (and the other corresponding figures),[34] the last age group is defined by the age 80 and more years, the reason lays only in the rough estimations of the number of inhabitants at the highest age groups in the middle of the 20th century, otherwise it would be possible to work with more detailed age distribution. Nevertheless, it is clear that during the studied period the number of inhabitants at the age of 80 and more years increased more than 8-fold in the World. However, as stated above, the tempo of population aging was different in different parts of the World. As it is clear from the previous text, the World population aging was driven above all by Europe.

It could be expected, that in the second half of the 21st century the population of the World will become significantly older in comparison to the current situation – the numbers of the oldest seniors (80+) are expected to increase more than 3-times (Fig. 8.6). Also, the population pyramid is likely to change from progressive to the regressive one (Fig. 8.5). As it was stated, the tempo of population aging will be likely driven above all by the Latin America and partly also by Africa. These expected regional differences will be described in the following text.

From Fig. 8.1 it is clear that Europe grew old very rapidly in the second half of the 20th century and in 2015 this continent was the oldest one (according to the value of the Old age dependency ratio) in the World. In 1950 the proportion of seniors (65 and more years) in European population reached almost 8%, in 2015 this proportion was 17.6%. During that period the population of Europe increased by almost 191.5 million inhabitants, however, at ages under 25 years the continent lost more than 42 million people. That means, that the population growth was concentrated only at ages 25 and more years, and above all at ages 75 and more years (Fig. 8.7, 8.9) as at this age group the number of inhabitants increased more than 3-times (age group 75–79 years), resp. nearly 6-times (age group 80 and more years).

According to the UN forecast it is expected that the proportion of seniors (65+) in Europe will grow to nearly 28% in the middle of the 21st century and 30% at the end of the century (Fig. 8.8). In the meantime, the population size is expected to decrease to around 653 million at the end of the century. The decrease of the population size will be driven mainly by the population decrease in younger age groups – until the year 2015 (from 1950), "only" the age groups under 25 years have numerically decreased, for the first half of the 21st century it is expected that the size of most of the age groups will decrease except for the age groups above 60. In other words, until 2050 the age group of seniors is likely to be the only growing one (Fig. 8.9).

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34 In the Fig. 8.6, 8.9, 8.12, 8.14, 8.17, 8.20, 8.22, 8.24 and 8.26 the value of 100 does mean no change of the number of inhabitants in the age groups, value equal to 200 represent doubling of the number of inhabitants. The hatched columns represent age groups where the number of inhabitants decreased during the studied period (the change in the total number of inhabitants within the particular age group is lower than 100%).

Figure 8.7 | Relative age structure, 1950, 2015, Europe, in %.
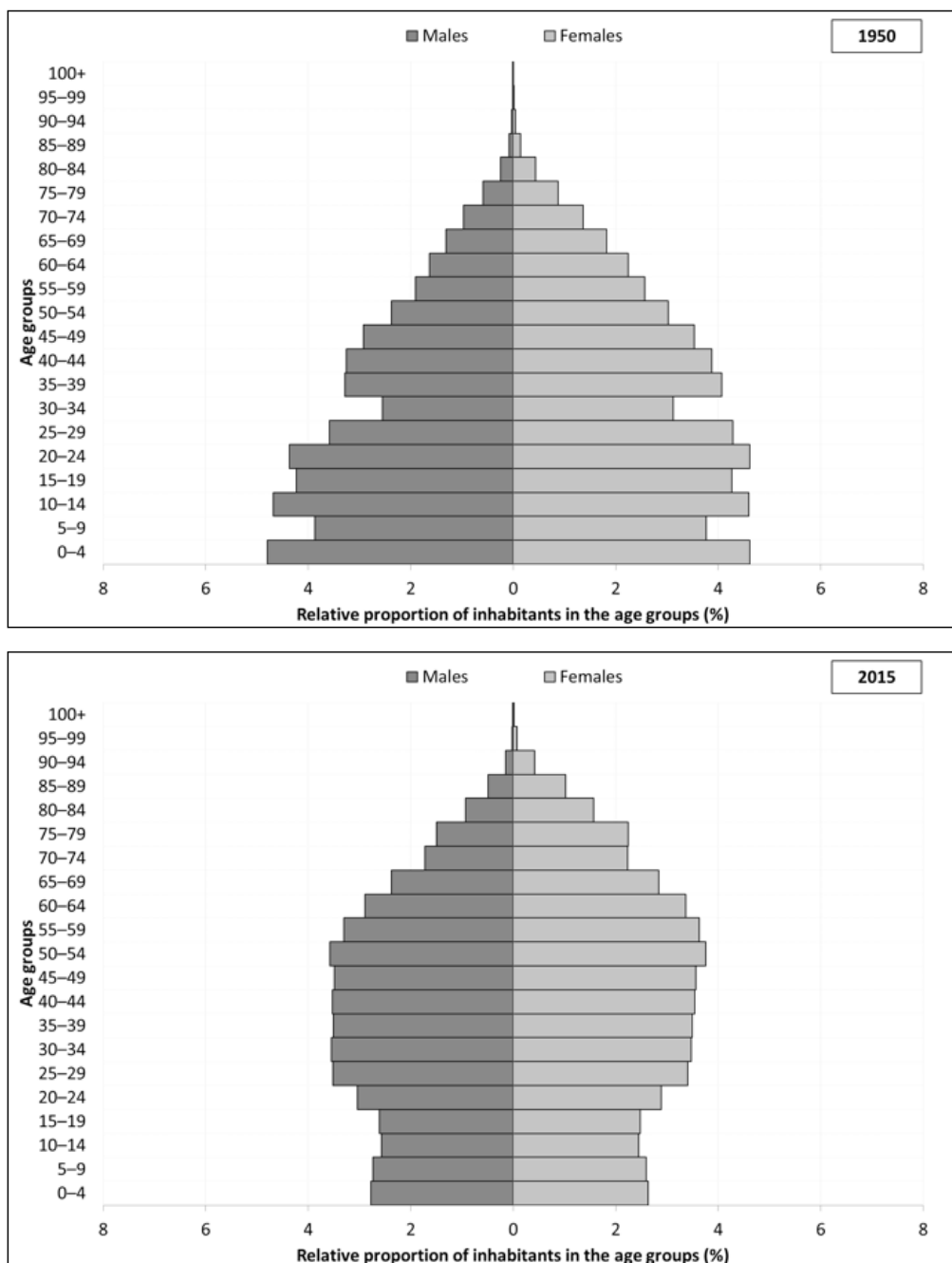
Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

Note: The dent in the population pyramid of the year 1950 at ages 30–34 years is the consequence of the natality decrease during the World War I.

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Figure 8.8 | Estimated relative age structure, 2050, 2100, Europe, in %.

Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

Figure 8.9 | Relative (for later period expected) change of the number of inhabitants in all the age groups between 1950 and 2015 (up) and between 2015 and 2050 (down), Europe, in %.
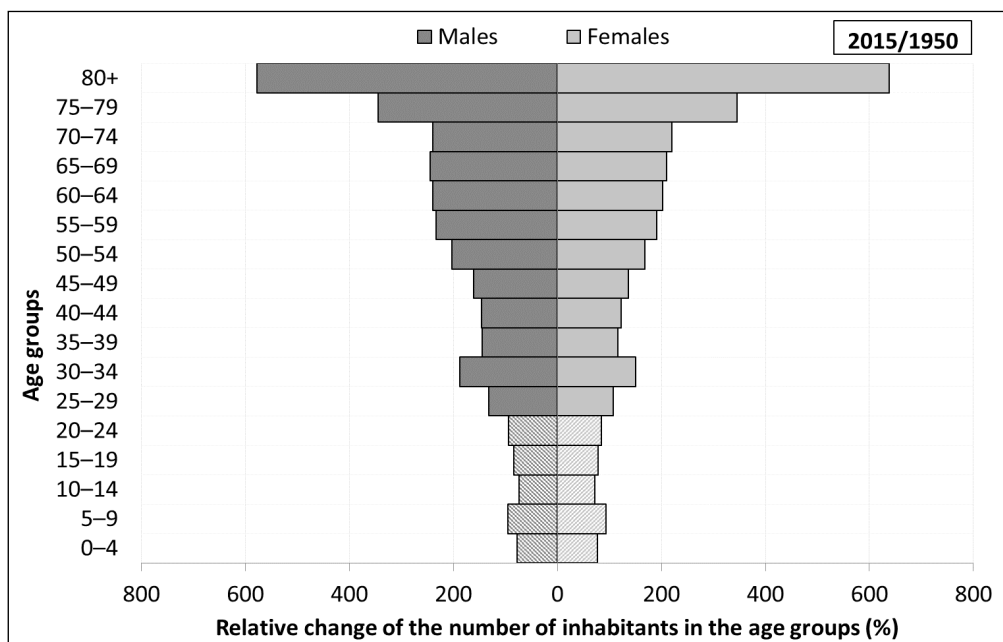
Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

Note: The hatched columns represent age groups where the number of inhabitants decreased during the studied period.

Figure 8.10 | Relative age structure, 1950, 2015, Africa, in %.
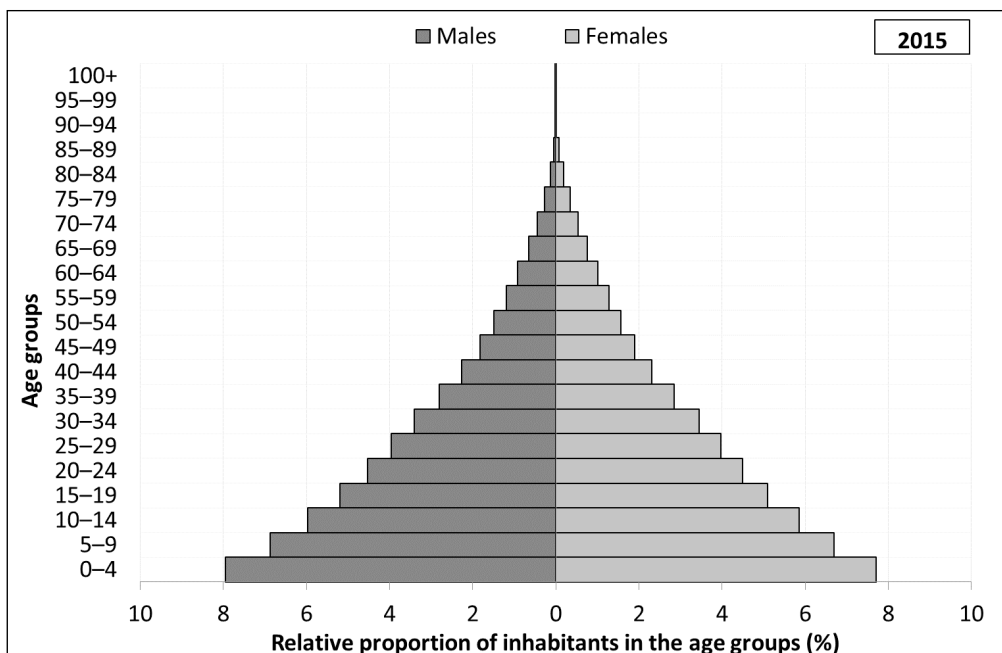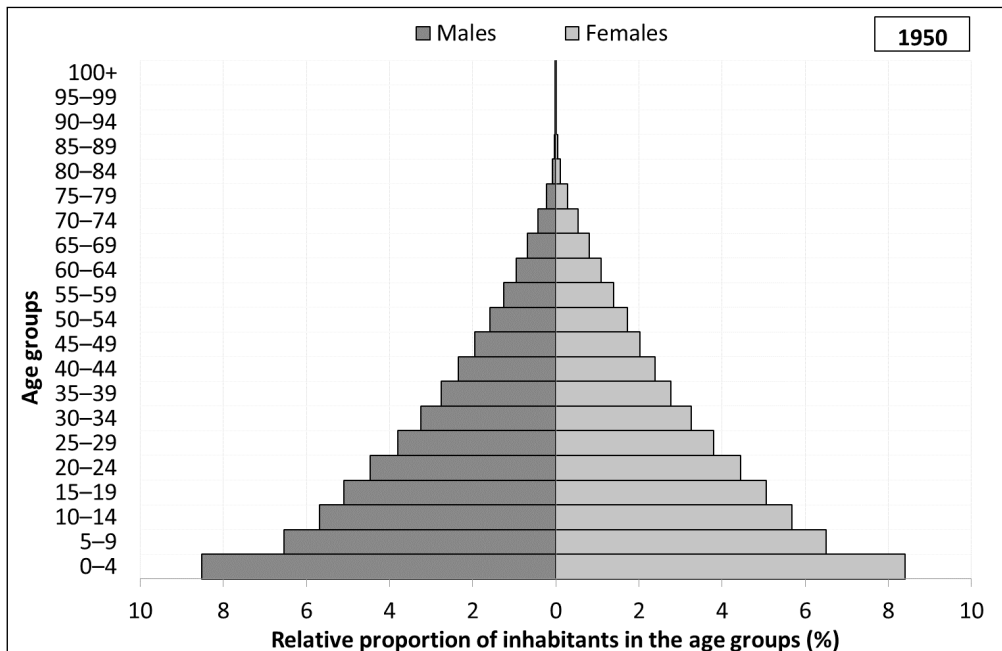
Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

Figure 8.11 | Estimated relative age structure, 2050, 2100, Africa, in %.
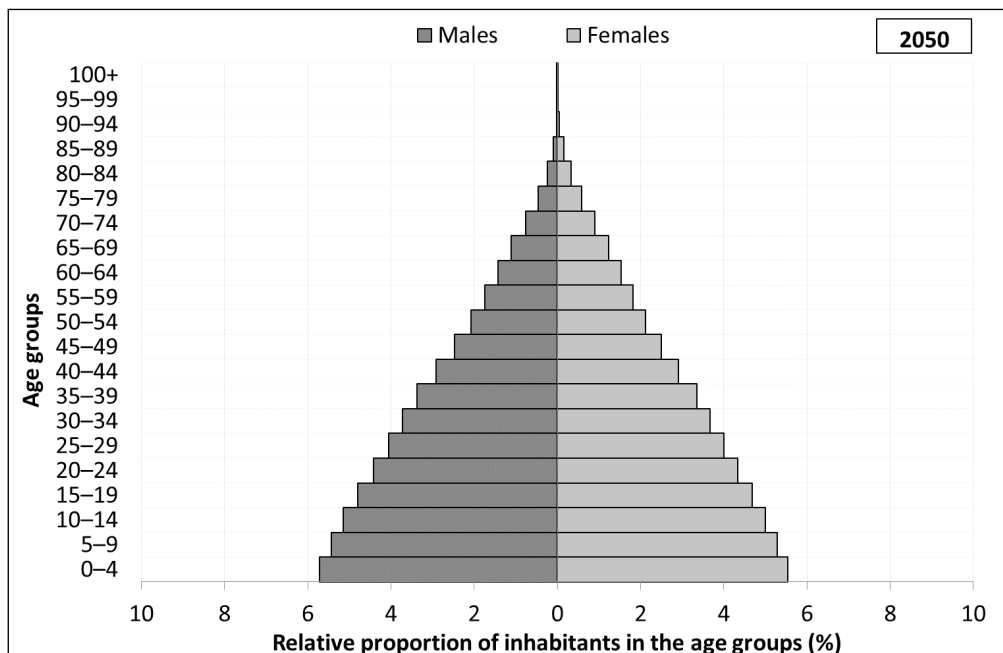
Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

From the shown above it may seem that the process of population aging in Europe is driven primarily by the decrease of the proportion of young people in the population, number of older seniors (80+) increased more than 8-times in the World and "only" around 6-times in Europe; number of seniors aged 65 and more years more than doubled in Europe between 1950 and 2015 and in the population of the whole World was the number of seniors at this age in 2015 more than 4-times higher than in 1950. This difference is clearly given by the mortality decrease in the World.

During the studied period, Africa is the youngest region in the World. Moreover, until the year 2015, there was almost no change in the age structure of the African population (Fig. 8.10). From 1950 to 2015 the population size of Africa increased from nearly 230 million to 1.2 billion. This enormous increase of the population size occurred in all the age groups, the size of all the age groups increased at least 4-times during the period, however, number of seniors (80+) increased 8-times (Fig. 8.12). Despite this increase, the proportion of seniors (65+) in the African population reached only 3.5% in 2015.

The process of population aging in Africa reached a higher intensity with the start of the 21st century (Fig. 8.2). However, it will be more significant in the second half of the century. Only that time the population structure is likely to start to change visibly (Fig. 8.11). This fully corresponds to the expected tempo of population aging, which is supposed to be the highest in Africa during the second half of the century (Fig. 8.2). By the year 2050 the African population is likely to reach 2.5 billion of inhabitants and almost 4.4 billion by the end of the century. This increase will not be concentrated only in a limited age range but it will be spread in all age groups. During the 21st century, however, the biggest increase of the population size will move to the higher age groups. Until the end of the century, there probably will not be any age group where the population size decreases (Fig. 8.12).

From the presented comparison of the youngest (Africa) and oldest (Europe) region it is clear that the relatively young age structure of the World is maintained above all thanks to developing countries. The development of the age structure of developed countries (here represented by Europe) is significantly different. Europe is undergoing the population decline, where the only rising age groups are the oldest ones. This development is expected to hold at least until the middle of the century. Then the tempo of population aging is likely to slow down. On the other hand, in many developing countries (e.g. in Africa) the process of population aging has not started yet or not with a high intensity. During the second half of the 20th century the African population grew as a whole, in all the age groups. This will probably hold also for the whole 21st century, however, more rapid grow is likely to move to higher age groups. This is the reason why Africa will probably become the fastest aging region in the second half of the 21st century.

Figure 8.12 | Relative (for later period expected) change of the number of inhabitants in all the age groups between 1950 and 2015 (up) and between 2015 and 2050 (down), Africa, in %.
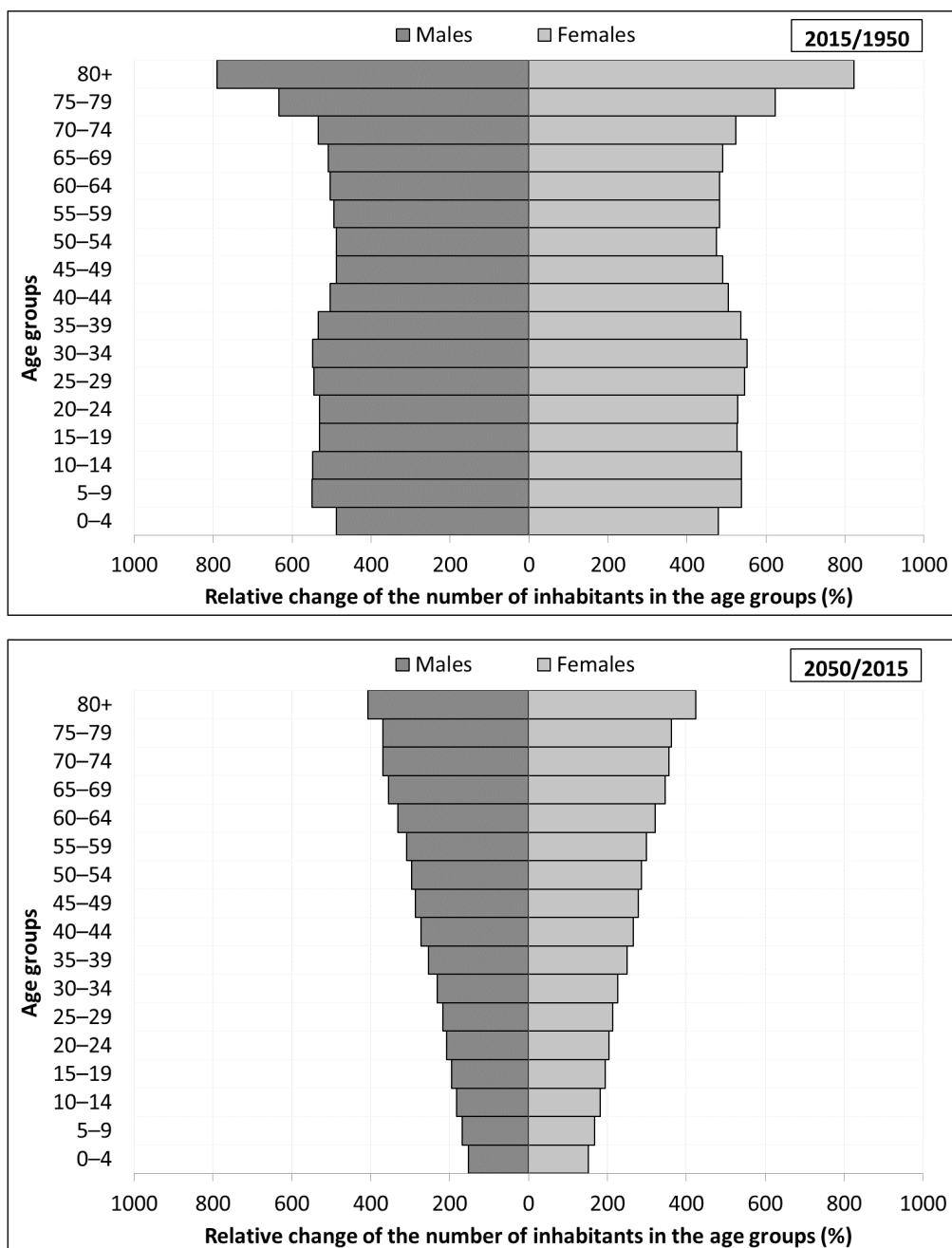
Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

Note: The hatched columns represent age groups where the number of inhabitants decreased during the studied period.

8.7 Population aging in some selected specific countries

If one focus only on some selected specific countries, the picture of the process of population aging could be significantly different than it was presented in the previous part of the chapter. It was stated above, that there is a group of countries characterized by high level of population aging (high proportion of seniors in the population, high value of the Old age dependency ratio, etc.). Using the simple graphical analysis of population aging in those countries based on the usage of population pyramids may reveal some of the reasons of the specific development.

One of these specific countries is Japan – in Japan the proportion of seniors (65 years old and older) reached 4.9% in 1950 and this proportion increased to 26.0% in 2015 [United Nations, 2017]. It might seem that the reason for this development lies in the fertility decrease, because the proportion of children under 20 years decreased from 45.6% in 1950 to only 17.7% in 2015. Although the fertility (and also the number of life births) decreased rapidly after the World War II, an important role in population aging in Japan was played also by the mortality decrease and also by "shifting" of the more populous cohorts to higher ages.

The extreme depth of the change of Japan's age structure could be illustrated by the increase of the size of the oldest age group in the population. While in Europe the age group of 80 years old and older people increased approximately 6-times, in Japan it was 27-times (Fig. 8.14). In 1950 in Japan, only around 0.4% of the population was aged 80 and more years, in 2015 it was already 7.6% of the population, the absolute increase was more than 9 million people older than 80 years.

As it was assumed above, the reasons of the rapid population aging could be found in the initial young age structure of the Japan population just after the end of the World War II. This young age structure was typical by relatively wide base of the age pyramid, i.e. by high proportion of children (45.6% of the population). These populous age groups were later "shifted" to higher ages and at the beginning of the 21st century they reached the age of 60 or 65 years and started to contribute to the increase of the proportion of seniors in the population. At the same time, the mortality level decreased rapidly, so the average length of life (life expectancy at birth, Fig. 8.15) increased by around 20 years for males as well as females between 1950 and 2015. Thanks to that, higher proportions of all the cohorts reached the senior age. And simultaneously, the total fertility rate drops quickly after the World War II – from values around three children per woman to less than two during the 1970s, from the 1990s the measure is relatively stable below the very low level of 1.5 children per woman.

Combination of the very low mortality level, relatively stable and low level of fertility and populous cohorts entering the senior age are not only the reasons of the rapid population aging and already very old age structure, but also of the continuation of the process of population aging in the 21st century.

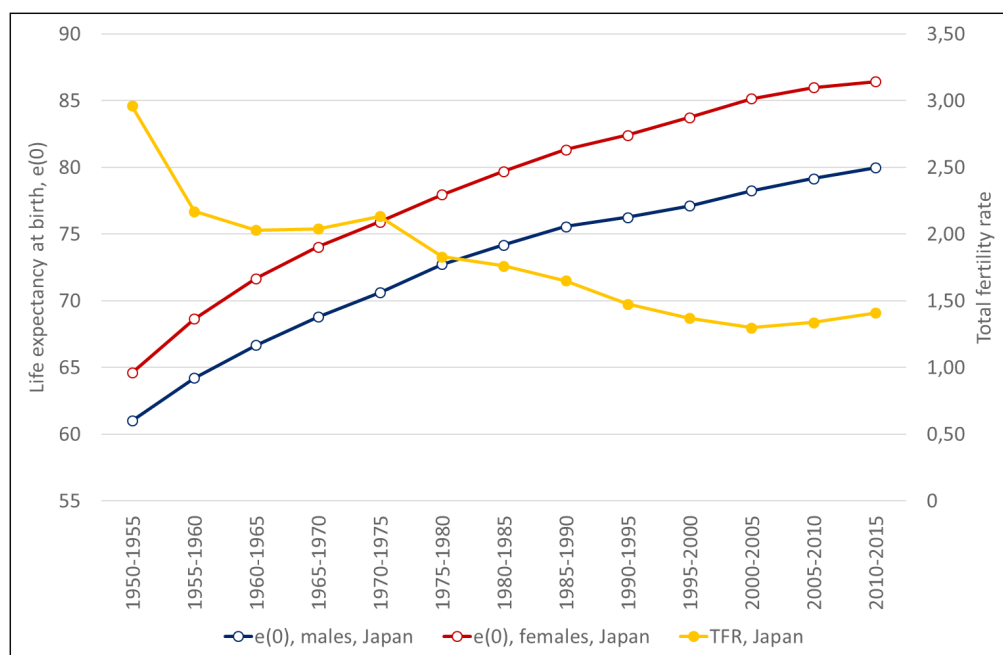**Figure 8.13 | Relative age structure, 1950, 2015, Japan, in %.**
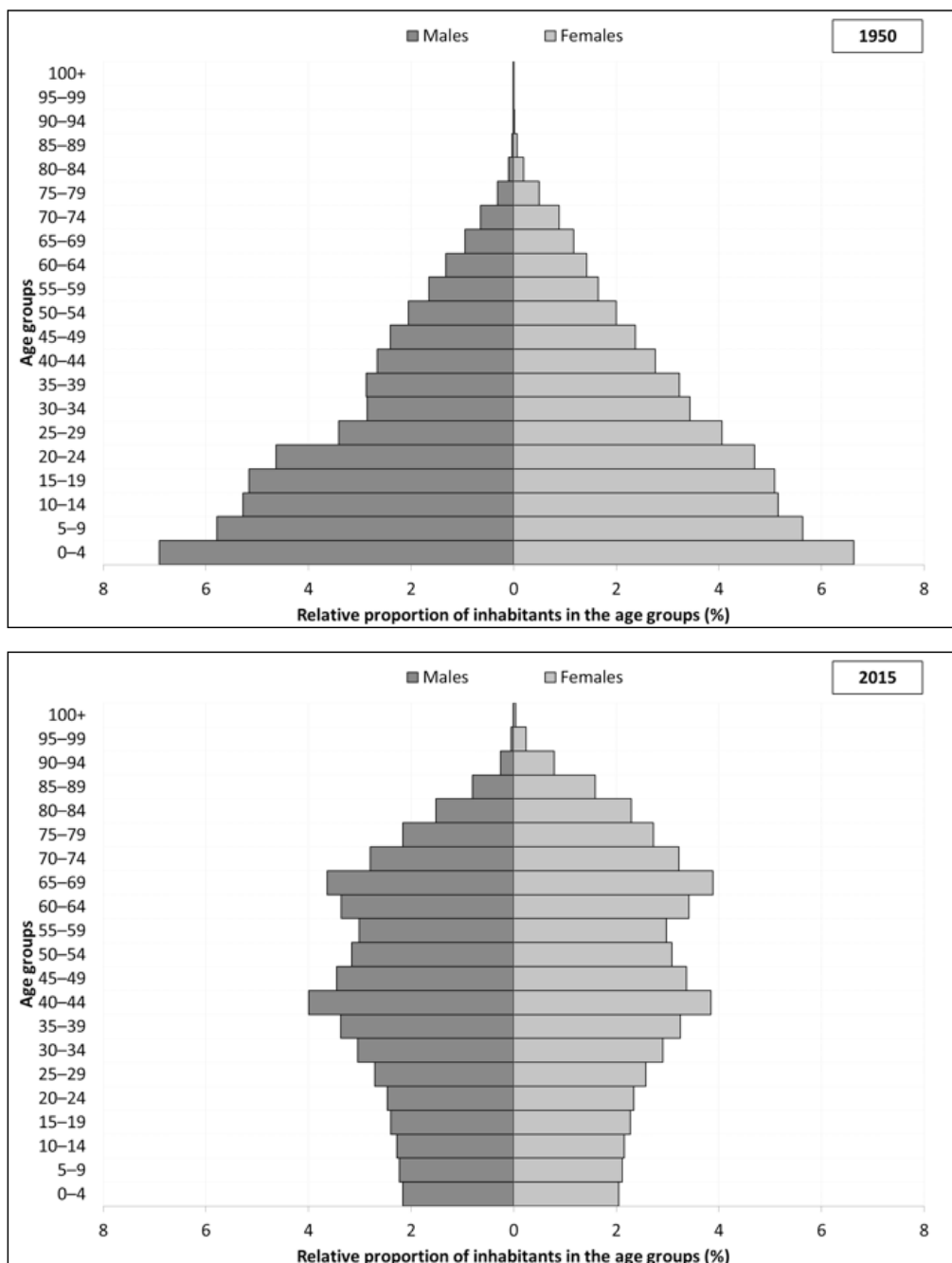
Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.
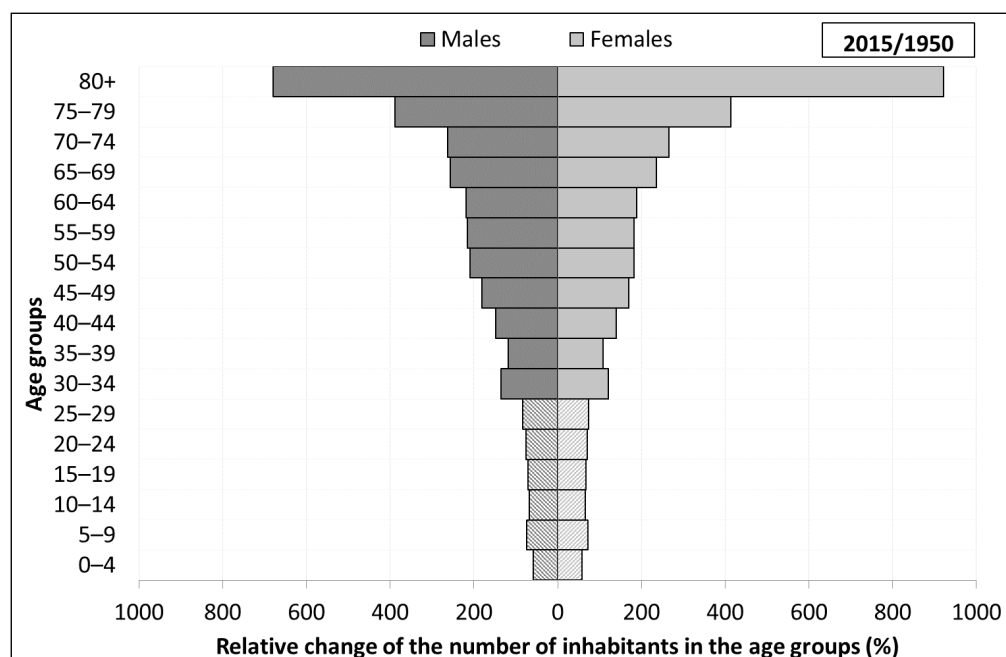
Figure 8.14 | Relative change of the number of inhabitants in all the age groups between 1950 and 2015, Japan, in %.
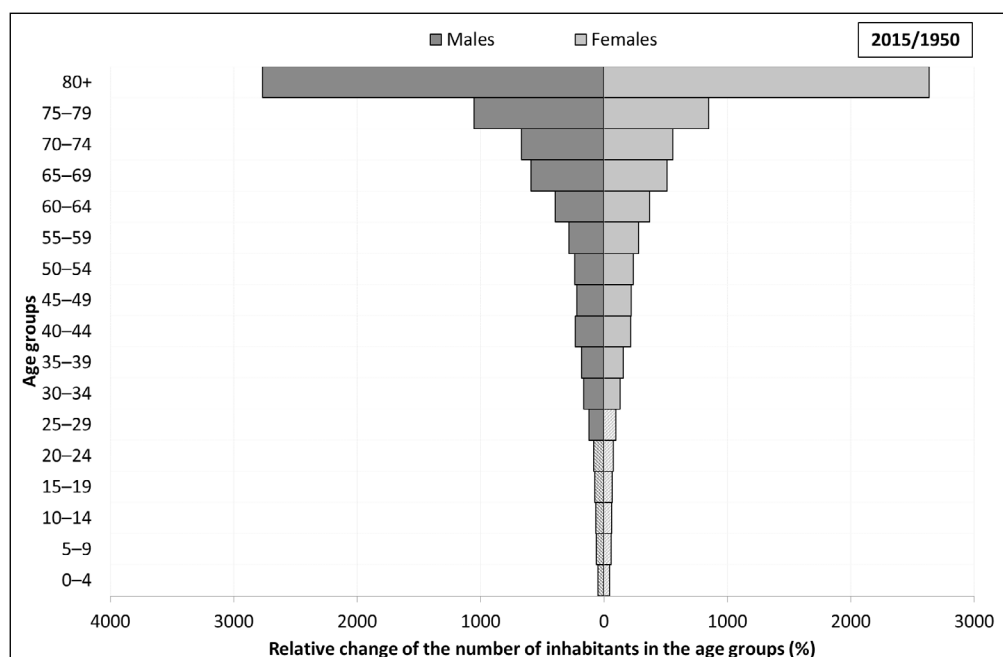
Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

Note: The hatched columns represent age groups where the number of inhabitants decreased during the studied period.

Japan was selected for the deeper analysis as the currently oldest population in the World. It enables to illustrate the rapid development of population aging supported not only by the low level of mortality and fertility, but also by the initial age structure, where the populous cohorts (usually born just after the World War II) grow older and reach the senior age not followed by other similarly populous cohorts.

Figure 8.15 | Development of the life expectancy at birth, e(0), males, females, and total fertility rate , TFR, between 1950 and 2015, Japan.

Another representant of very intensive population aging is Italy. Italy is currently the oldest population in Europe and also represents an extreme change of the age structure, although, Italian population was relatively older in comparison to Japan already in the middle of the 20th century. In 1950 the proportion of seniors (65+) in the Italian population was around 8.1%, in 2015 it was 22.4%. In the meantime, the proportion of children (under 20 years) decreased from 35.4% to 18.4%. Also in this case the increase of the number of inhabitants aged 80 and more years is extremely high (although lower than in Japan) – between the years 1950 and 2015 the oldest age group (80+) increased nearly 7-times in case of males and more than 9-times in case of females (Fig. 8.16 and 8.17).

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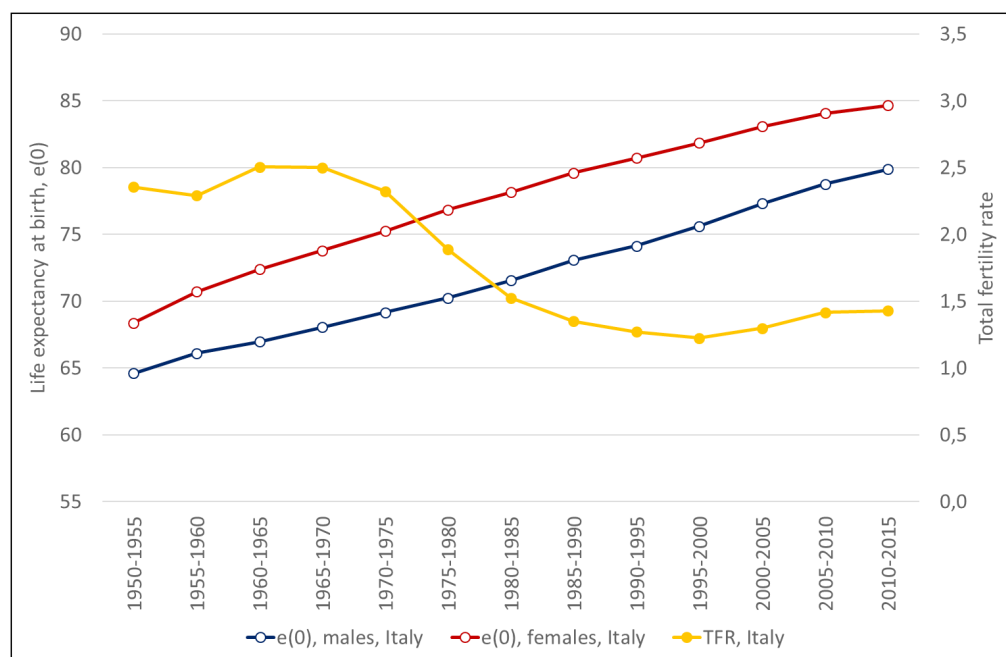**Figure 8.16 | Relative age structure, 1950, 2015, Italy, in %.**
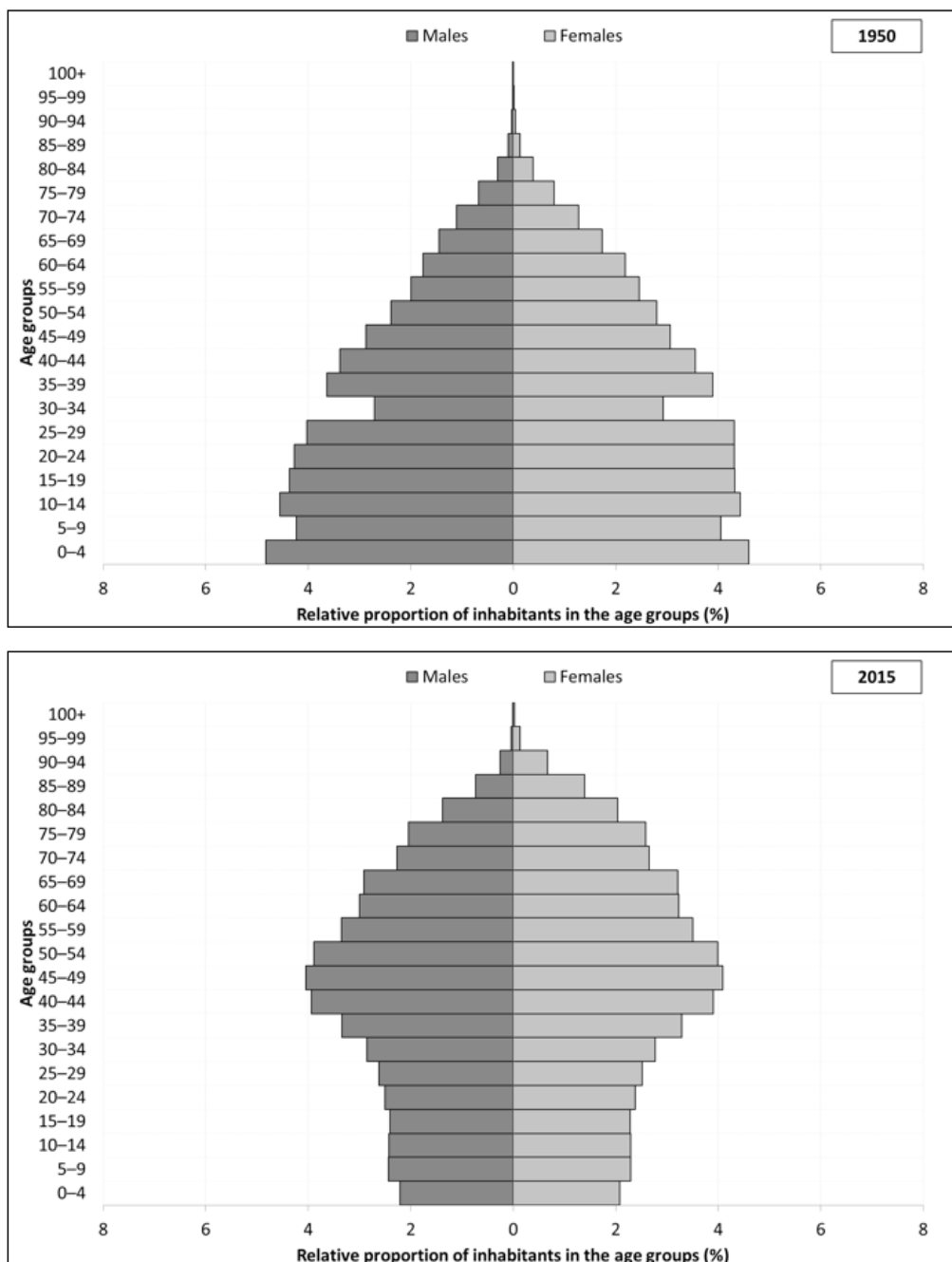
Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

Figure 8.17 | Relative change of the number of inhabitants in all the age groups between 1950 and 2015, Italy, in %.

Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

Note: The hatched columns represent age groups where the number of inhabitants decreased during the studied period.

In case of Italy, similarly as in Japan, the process of population aging is significantly supported by the mortality decrease (here represented by the increase of the life expectancy at birth, Fig. 8.18), although the overall increase of life expectancy in Italy is a bit lower than in Japan. On the other hand, the fertility decrease in Italy during the 1970s, 1980s and 1990s was an almost extreme one. Currently, since the beginning of the 1980s (longer than in Japan), the total fertility rate in Italy is below the value of 1.5 children per woman. Alike in Japan, also in Italy one cannot expect anything else than the continuation of the process of population aging.

A special case of aging population according to United Nations [2017] could be found among the oil-producing countries. We selected the United Arab Emirates as an example, however, other countries from the same region could be characterized in a similar manner. In the middle of the 20th century, the population age structure of the country was an average one corresponding to developing countries in that time (Fig. 8.19). In 2015 the situation was completely different as the role of migration was strengthened during the last decades of the 20th century with the development of the oil industry (Fig. 8.19). Not only the age structure, but also the sex composition of the population was strongly affected by migration, so as the migrants were mostly young men.

Because of that extremely special role of migration and its contribution to the overall grow of population size between 1950 and 2015 (rapid grow from around 70 thousand to more than 9 million) also the relative change of the population size in all the age groups is very special (Fig. 8.20). The extreme increase is visible above all in the middle age groups, typical for migration. For males in the ages from 30 to 45 the population increase was the highest one – the population size increased around 550-times. The number of inhabitants at ages above 65 years increased as well (for males even around 60-times), however, as a consequence of the development at lower ages the proportion of seniors (65+) in the population decreased from 3.4% in 1950 to only 1.0% in 2015). As a result, the United Arab Emirates is an example of a country, where the total number of seniors significantly increased, although the proportion of seniors decreased so as the values of the indicators of population aging. However, in case of this country, the future development of the population may be seriously affected by the population aging as the populous age groups grow older.

Figure 8.19 | Relative age structure, 1950, 2015, United Arab Emirates, in %.
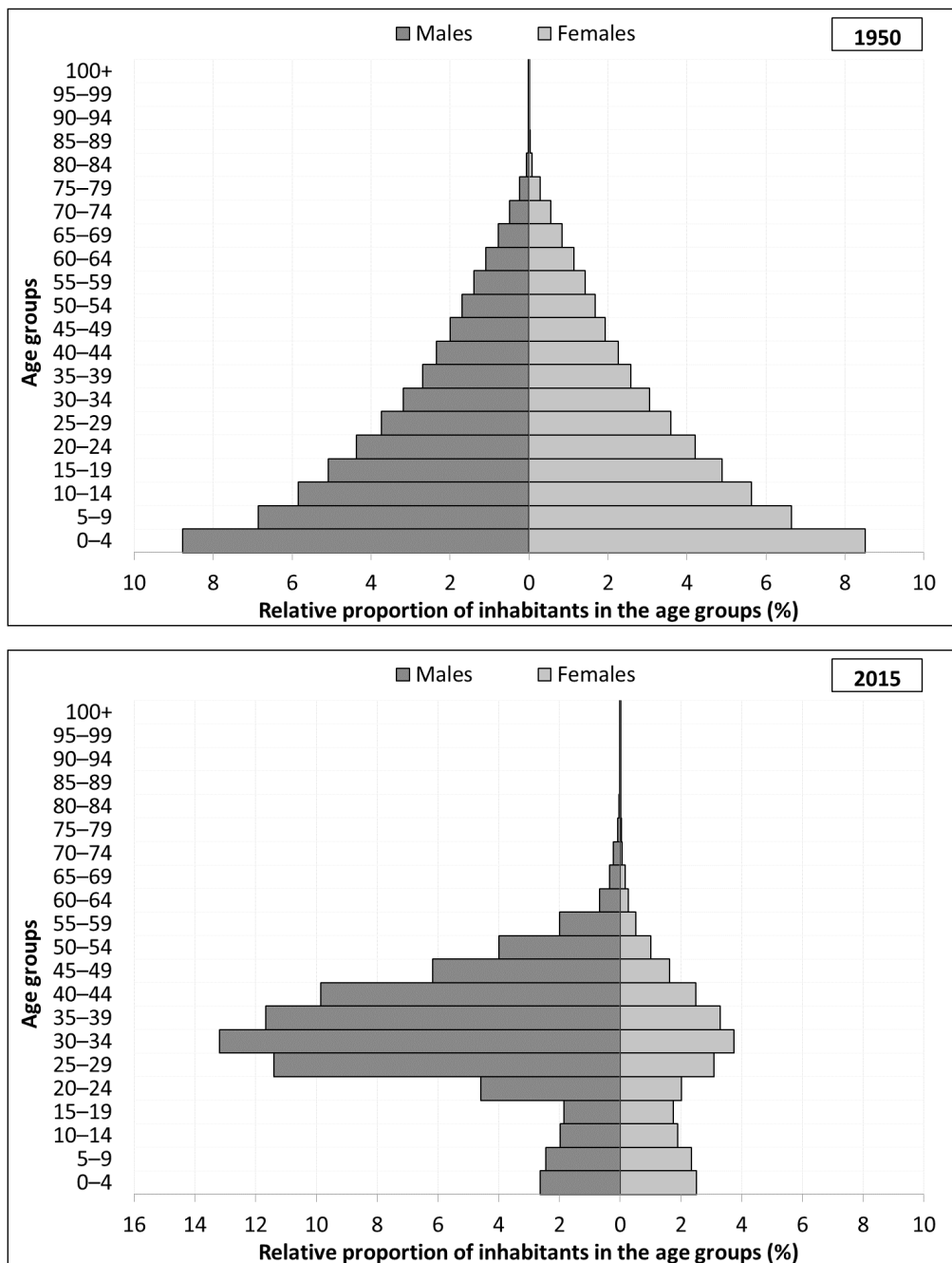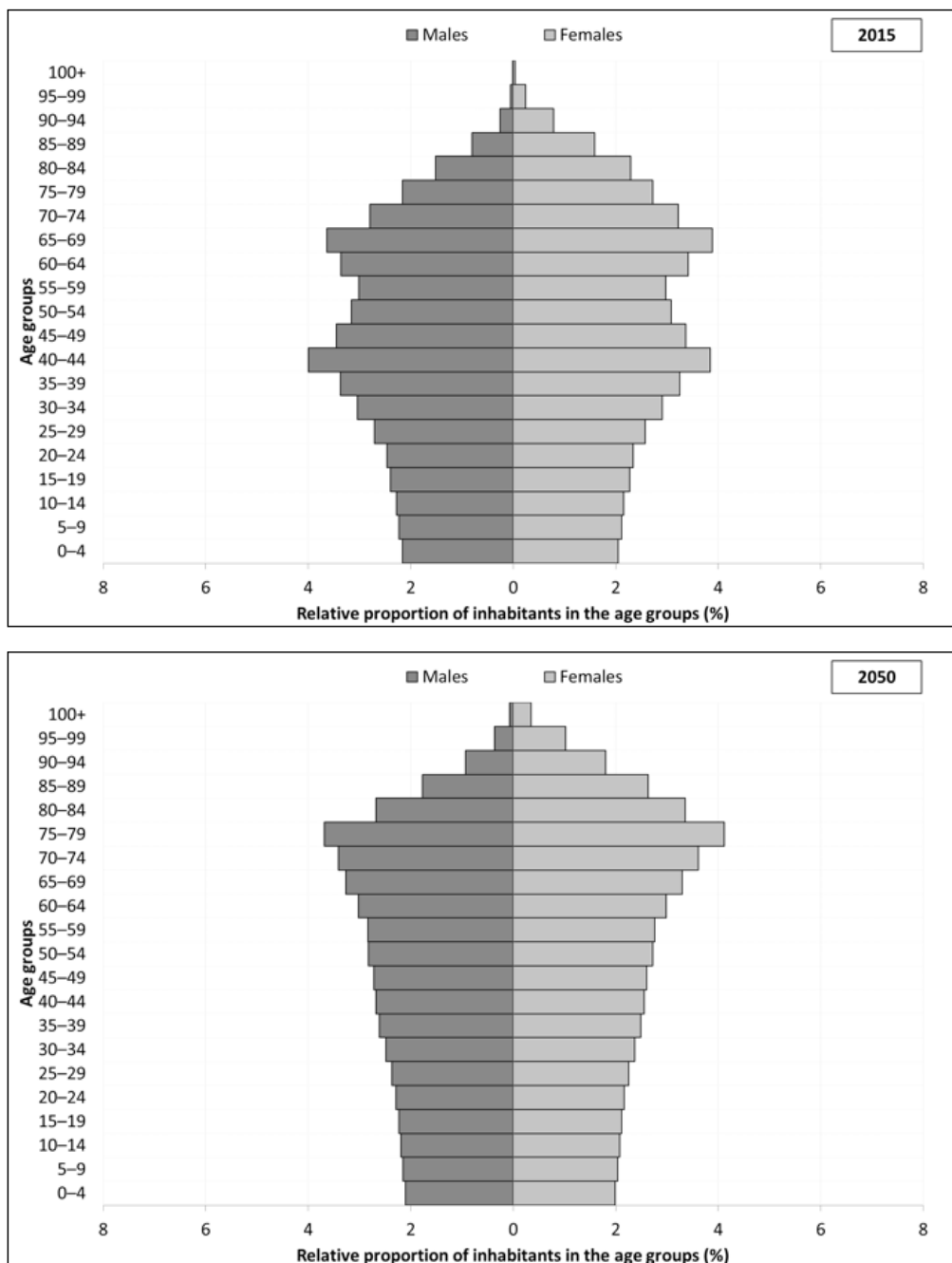

Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.
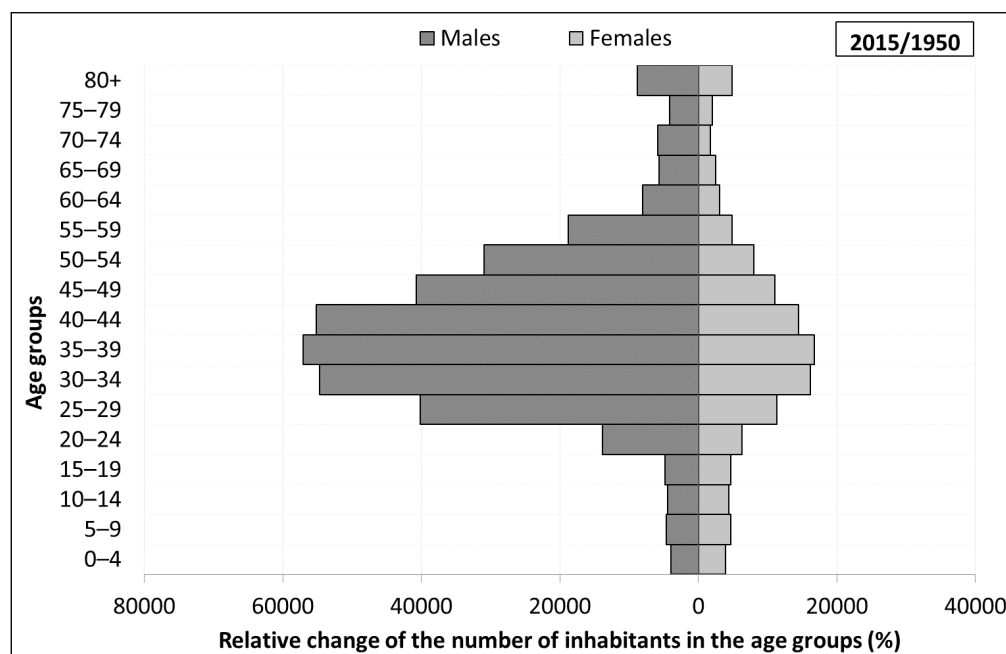
Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

8.8 Expected aging of population of the selected countries in the 21ˢᵗ century

From the presented results and figures it is clear that the case of Japan is really an extreme one, because its population could be described by a rapid population aging characterized not only by the increase of the proportion of seniors in a population, but also by the absolute increase of the oldest population. Moreover, in Fig. 8.3 it was presented, that a high tempo of population aging is expected in Japan also in the 1ˢᵗ half of the 21ˢᵗ century.
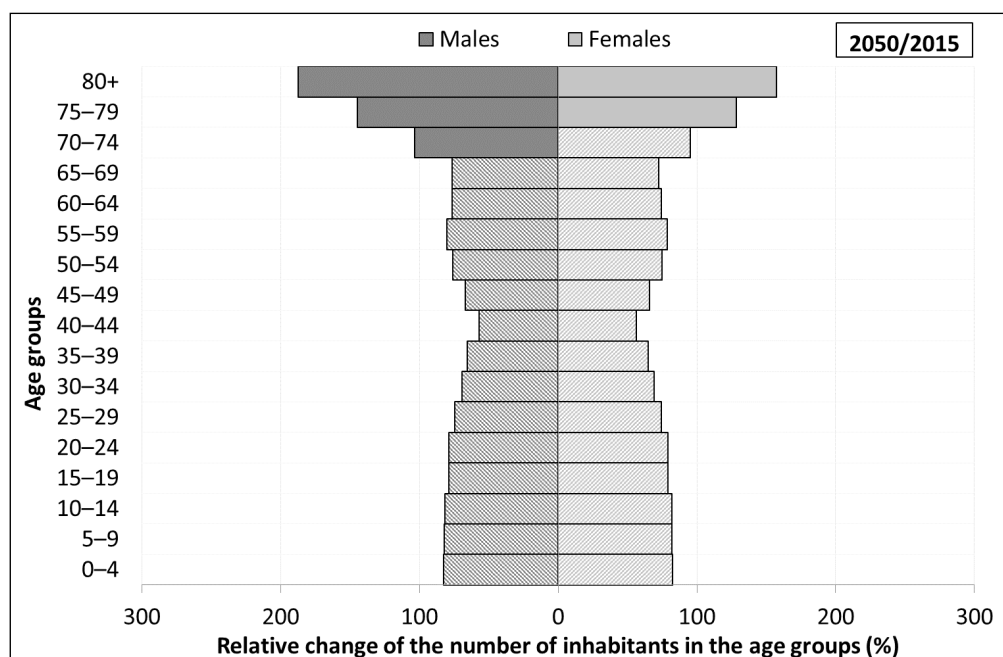
From Fig. 8.21 it is clear that the population aging in Japan during the 1ˢᵗ half of the 21ˢᵗ century would be likely driven by the "shift" of the populous cohorts to older ages. If the fertility level (measured using the total fertility rate) remains under the value around 2, then there will be no future generation populous enough to replace numerically the older cohorts. Based on the forecast of United Nations [2017] it is expected, that the Japan population would decrease by some 19 million between the years 2015 and 2050, however, the population aged 75 and more years is likely to increase by nearly 9 million. As a result, the oldest age group may increase approximately 1.5-times while the size of younger age groups is expected to decrease. The size of the population aged 40–44 years might decrease by almost one half.

Figure 8.21 | (Estimated) relative age structure, 2015, 2050, Japan, in %.

Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

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Note: The hatched columns represent age groups where the number of inhabitants decreased during the studied period.

Similar situation could be expected also for Italy, the oldest country in Europe. In Italy the proportion of seniors aged 65 and more years in the population is expected to increase to more than 34% in 2050. This would be the consequence of (above all) the shift of populous age groups to higher ages not being replaced or followed by similarly populous cohorts (Fig. 8.23). The population size is expected to decrease between 2015 and 2050 by some 4.5 million of inhabitants, however, the senior population size is likely to increase, e.g. the population aged 80 and more years is expected to increase more than 2-times in case of males and nearly 2-times in case of females (Fig. 8.24).
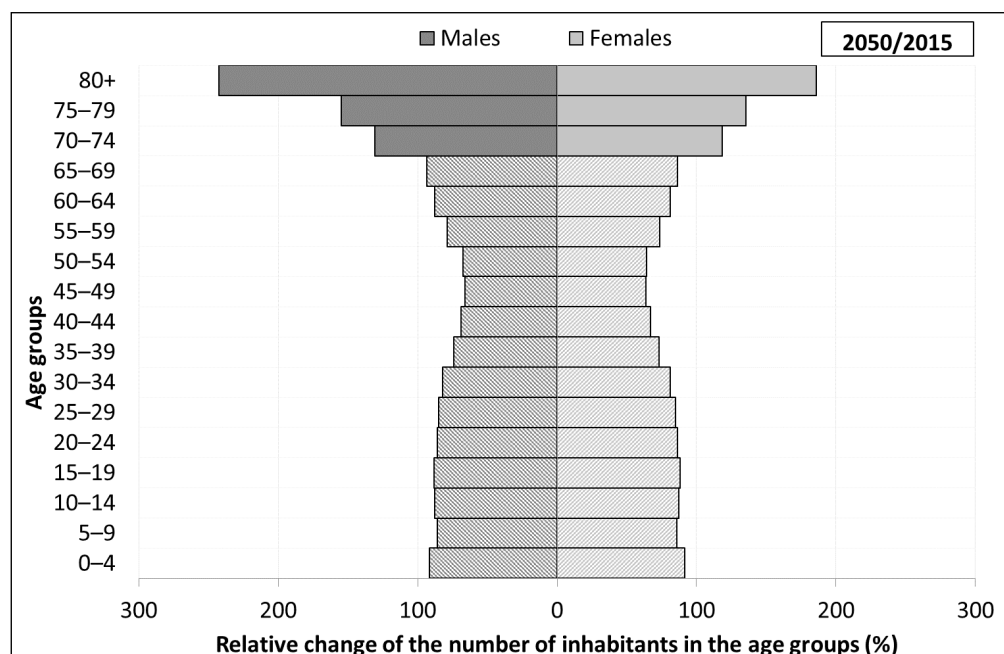
Figure 8.23 | (Estimated) relative age structure, 2015, 2050, Italy, in %.

Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

Figure 8.24 | Estimated relative change of the number of inhabitants in all the age groups between 2015 and 2050, Italy, in %.
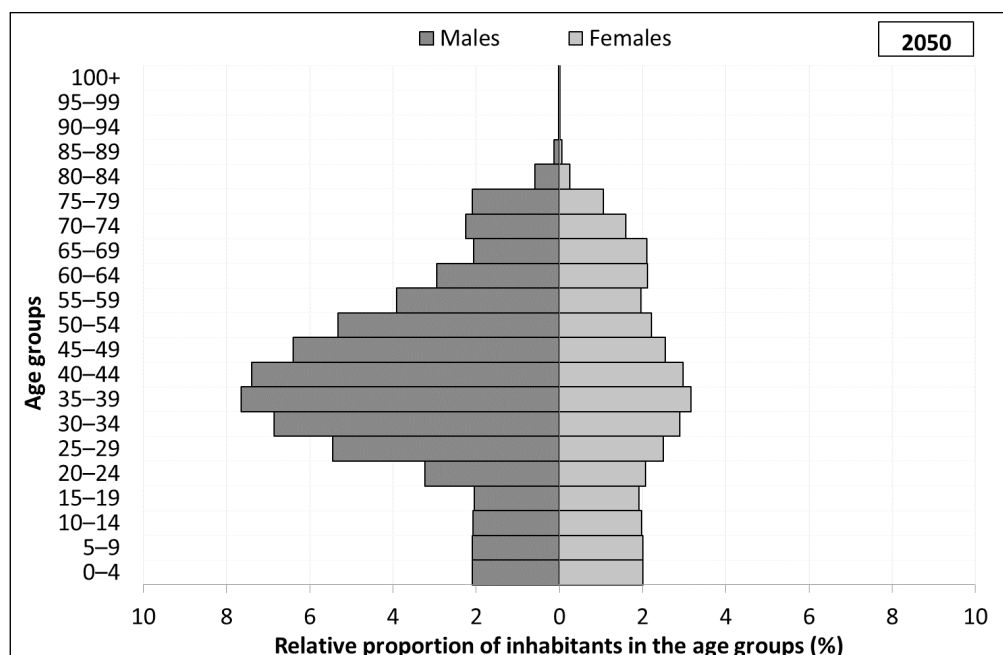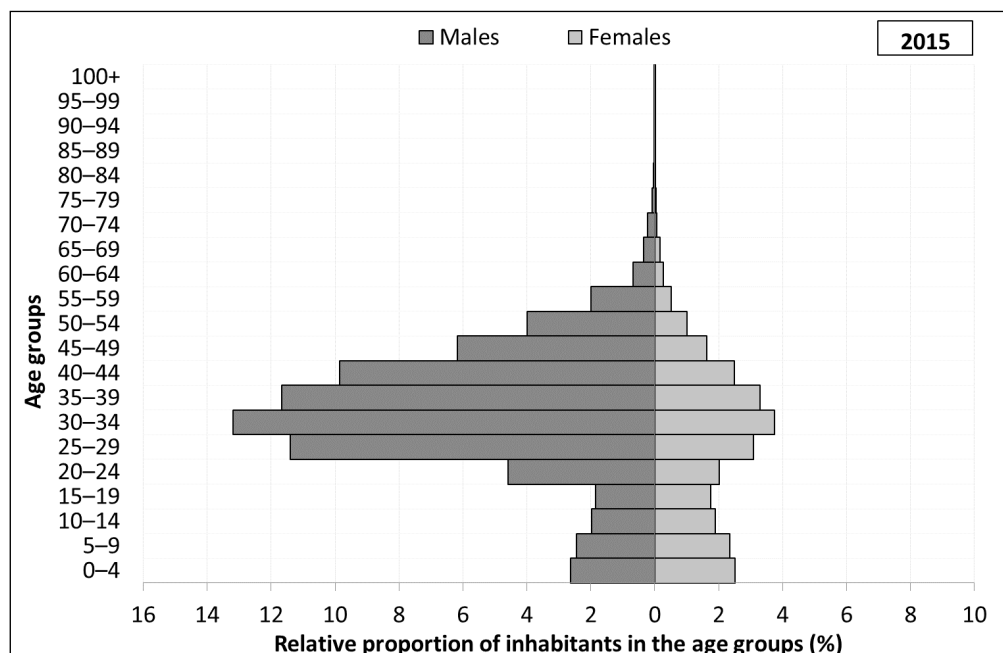

Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

Note: The hatched columns represent age groups where the number of inhabitants decreased during the studied period.

The last country described above was the United Arab Emirates where the specific development is affected above all by the development of migration. It could be expected that the populous groups of migrants from the end of the 20th century will gradually grow old and in that manner contribute to the process of population aging in the country. On the other hand, currently the most populous age groups are those in the age of reproduction, this will probably lead to the increase of the numbers of life births and emergence of another group of populous cohorts (Fig. 8.25).

Figure 8.25 | (Estimated) relative age structure, 2015, 2050, United Arab Emirates, in %.

Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

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Figure 8.26 | Estimated relative change of the number of inhabitants in all the age groups between 2015 and 2050, United Arab Emirates, in %.
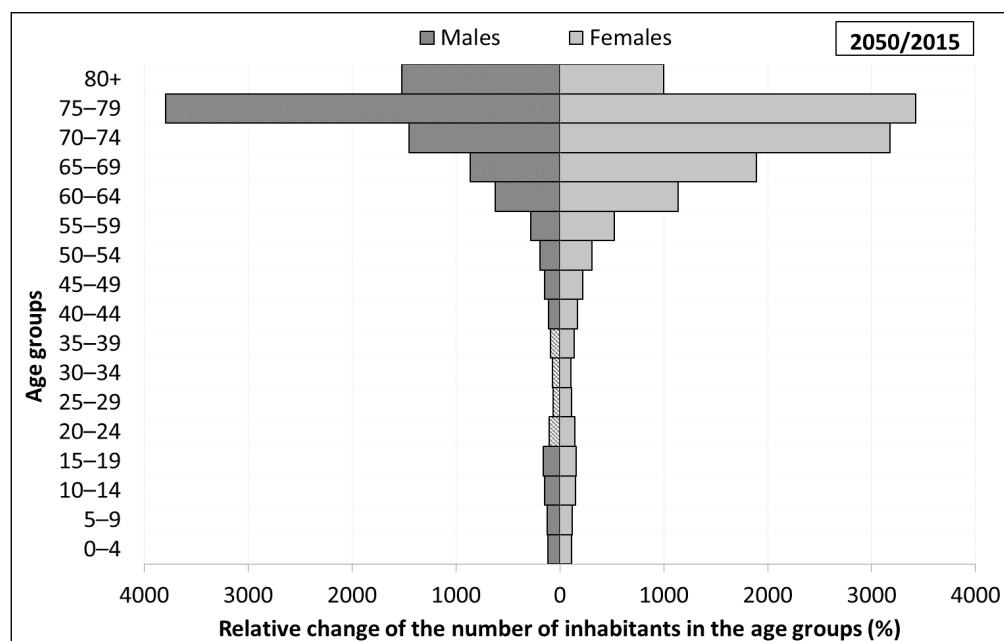
Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

Note: The hatched columns represent age groups where the number of inhabitants decreased during the studied period.

Although even in 2050 the population pyramid of the United Arab Emirates does not look similarly as the pyramids of other aging countries (see Japan or Italy above), it is the most rapidly aging country between the years 2015 and 2050 (measured using the relative increase of the Old age dependency ratio, in 2015 the ratio reached value of only 1.25 seniors per 100 inhabitants at the age of economic activity, this value will probably increase to 19.5 in 2050, what is a 14.56-times higher value of the indicator, the highest value of the relative increase in the studied period, United Nations, 2017, Fig. 8.26).

8.9   Conclusion

The aim of this paper was not to present the issue of population aging in-depth, nor to propose some alternative methods of measuring of the process, the aim was rather to show an easy and simple way how the population aging could be illustrated so as it is understandable also by the public. Moreover, using the simple tools, like the population pyramid, it is clearly visible how strong the process could be in seriously affected countries like Italy in Europe and above all in Japan, currently the oldest country in the World, or United Arab Emirates, the country with the expected highest tempo of population aging during the first half of the 21st century.

It was shown, that the process of demographic aging could be defined (among other) as the increase of the proportion of seniors in the studied population or the increase of the absolute number of seniors in the population. If the overall age structure

of the population is of the major importance, the relative proportion of seniors could be presented. If the absolute number of seniors is important, e.g. for planning of the financial demands of the pension or social systems, it is easy to show the rapid increase of such a number. From the figures above, it was clear that the oldest age groups are those most intensively rising – today the size of the oldest age groups is several times higher in comparison to the middle of the 20th century. In an extremely rapidly aging population, Japan, the increase of the size of the oldest age group was 27-times. The volume of this increase is almost not comparable to e.g. Italy, although it is the oldest country in Europe nowadays. On the other hand, it is comparable to the expected development of another studied country, the United Arab Emirates. From the selected countries described above, in Italy the population aging is driven above all by the rapid decrease of fertility and its very low level. In Japan the influence of low fertility is accompanied by the very low mortality level (although mortality level in Italy is also very low). The United Arab Emirates could be taken as an example of country where the population aging is significantly supported, or even caused, by migration.

For the future, the population aging in already extremely old countries, like Italy or Japan, will be driven above all by the decrease of the size of younger cohorts. This is the consequence of the long-term low level of fertility in those countries. In developing countries, however, the population aging will likely reach its maximal tempo, and we feel as important to spread the information about the challenges or potential steps in relation to population aging so as it could be understood as not only a negative phenomenon, but rather as an achievement and potential for the future.

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Short period (or cohort) mortality shifts and estimation of their effect on life expectancy: formal expression using the biometric functions with practical application

Petr Mazouch, Klára Hulíková Tesárková

9.1   Introduction[35]

It may seem that demography is focused above all on contemporary population trends: topics like population aging, health status, low fertility, infertility, issues tied to developing countries, evolving new methods, availability and usage of new types of data (e.g. panel data, large social surveys or so-called big data), etc. Although this is all true, there is still a part of demography (historical demography) and a subgroup of demographers (historical demographers) who devote their attention to the past, studying historical trends and developing methods appropriate for solving issues tied to past population trends. Historical demographers are not, however, the only ones who use historical trends in their studies.

A concrete example of the necessity to go into the past more in-depth within contemporary demographic analysis is the construction of cohort life tables. For construction of cohort life tables within the analysis of mortality, it is needed to study the historical mortality trends deeply. Moreover, the historical data (data for older cohorts) may be affected by some structural changes, incompleteness or periods of lower reliability.

During the years 2012–2017 the research project "*Cohort life tables for the Czech Republic: data, biometric functions, and trends*"[36] was completed for the Czech

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Republic. As members of the grant team, we reached many experiences and challenges working with historical and rather problematic data. When completing the mortality data for cohorts 1870−1920, its completeness was particularly disrupted by World War II, where only estimates of the age structure and total numbers of deaths were available. It was impossible to use these estimates of the total numbers for any further demographic analysis – e.g. for calculation of the probabilities of death and construction of the cohort life tables. Moreover, just after the end of World War II, the national structure of the population was changed radically, as the German population moved from the area of the republic [Mazouch–Hulíková Tesárková, 2018; Metodika tvorby …, 2018].

For reconstruction of usable cohort data sets, we had to develop several approaches or methods for how to cope with data incompleteness and low reliability [e.g. Zimmermann, 2017; Zimmermann et al., 2014; Mazouch, 2016a; Mazouch, 2016b; Zimmermann et at., 2013; Mazouch, 2013; Mazouch, 2016c; Zimmermann, 2016]. One of these methods will be presented and illustrated below together with its selected results. The aim of the approach described below is to estimate the potential impact of mortality in a short-term period or age-limited cohort changes to the value of life expectancy at birth. Because such short-time or age-limited mortality changes are common above all during wars and other periods with limited data quality and reliability, it could be useful to quantify the role of the mortality change for any overall mortality indicators. Estimations of mortality development during periods of limited data quality are often based on significant simplifications. If the role of a temporary mortality change for the overall indicator is rather marginal, then it could be taken as a justification and defense of those simplifications which have to be done.

9.2 Theoretical background

The crucial question could be stated as: what is the effect of some temporary mortality change limited to only some age(s) (e.g. a mortality increase during a war period) on the overall value of life expectancy at birth in the studied population. A very similar question can be found (with a corresponding solution) in an article by Vaupel [1986] where the author seeks the effect on life expectancy under the one percent reduction of the number of deaths during any decade of life. Pollard [1988] also expressed the effect of change of mortality level in a particular age group to the overall level of life expectancy. A comprehensive summary of similar approaches can be found in an article by Wrycza and Baudisch [2012] where the authors present and prove the central relationship between a change in mortality and the resulting change in life expectancy at birth.

A similar question was also answered by Keyfitz [1971, 1977], who took a more general approach. He studied the effects of changes in birth as well as mortality rates on selected parameters of a stable population. Another interesting approach, based on the usage of decomposition, was presented by Vaupel and Canudas Romo [2003].

Our approach follows up these previous studies, particularly Vaupel [1986] and Wrycza and Baudisch [2012], and offers a simple formal expression of the effect of a temporary change in mortality on life expectancy at birth. The expressions were derived simply from the traditional life table functions (biometric functions) and cover

more scenarios of the mortality change described below. Numerical illustration is also included in this article.

The aim of the chapter is to quantify the effect of mortality changes typically observed during specific periods like wars on the general mortality measures and to present an approach which could be used for such an estimation. This could help answer a crucial question: whether the significant (or serious) age- or time-limited mortality changes also have a serious and significant effect on the general measure of mortality (here represented by the life expectancy at birth) or whether the effect of a temporary mortality change could be said to "split" over the ages without any deep response in the values of the overall indicators.

As was stated, this question could arise when analyzing specific periods like wars, where the level of mortality is typically changed for a limited time period (period of the war) or age groups (during wars, young men are typically affected the most). For these specific time periods (e.g. wars), the available data are usually limited or less reliable. That supports the need of a formal estimation of the relation between a temporary mortality change and overall mortality measure. Using the partial information for such a period (e.g. estimation of the temporary mortality change or the overall life expectancy level, respectively), it could be possible to estimate the unknown or unreliable information (overall mortality development or age-specific mortality change, respectively).

9.3   Basic assumptions of the proposed approach and its formal expression

Although we use the cohort perspective for the estimation below, the same relations could also be derived for the period perspective. In the cohort approach, we study the (short term) period effect – for example, temporary mortality increase tied to a war and its effect on the overall cohort life expectancy at birth, calculated for the cohorts affected by the war. This period effect is supposed to affect, above all, only some ages (age groups) from the studied cohorts (of course, it affects different ages in different cohorts). In the period approach, the supposed mortality change would be represented by the cohort effect where only a limited number of cohorts are characterized by a significantly different behaviour. Also, in such a case the period life table functions would be affected only in some age(s) and life tables related to different time periods would be affected in different age(s) (related to the affected cohorts).

Figure 9.1 | Illustration of a model temporary increase of the mortality rate by 100% for age group 60–64 – e.g. in this model example in the graph the age-specific mortality rates for a selected cohort (or period) are depicted. Only five ages were affected by the mortality increase (it might be the effect of a 5-year-long war period that this model cohort went through at the affected ages).
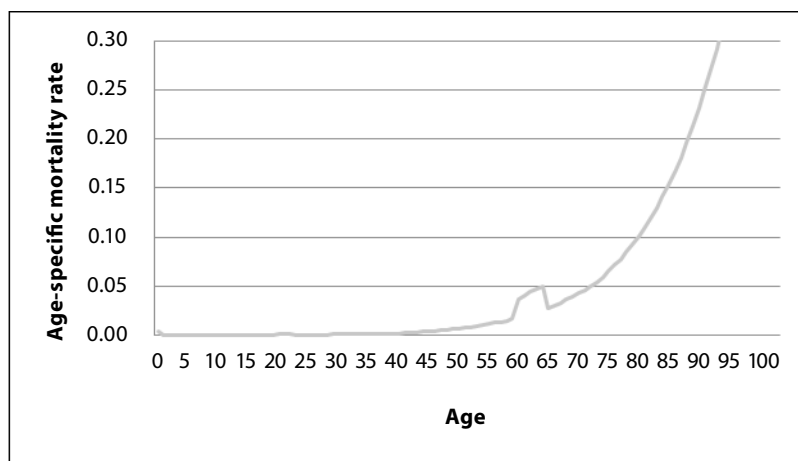
Source: Authors

One important assumption has to be mentioned: for simplicity and clarity of the expression, we assume, as shown in the Fig. 9.1, that the temporary mortality change affects only the limited age-range, with mortality rates at any other ages being held constant/unchanged. There is also no assumed compensation effect following the mortality change (e.g. subsequent improvements at ages following the ages affected by the mortality increase). However, this might happen, e.g. for populations during and after the war when a mortality increase could be followed by some mortality reduction in the following ages or years (a compensation effect as it was proved and explained in depth for the case of fertility by Van Bavel and Reher [2013]). We neglect this potential compensation of mortality change so that it is possible to illustrate and study the pure effect of war (period effect leading to mortality increase affecting, above all, the younger ages) on the life expectancy of the cohorts born before the war.

In general, there are three steps in the described approach. First, there is the estimation of mortality development without the effect of war, i.e. what mortality development would look like if there wasn't a war or other mortality change. This unaffected mortality development could be estimated using many potential methods, however, one of the simplest is probably the interpolation for the war period using the data observed before and after the war. This approach was used also in the example below.

In the second step, the mortality change itself has to be estimated. In this step, many other sources of information have to be used in order to quantify the overall increase in the number of deaths, the distribution across time, cohorts, etc. This leads to the estimate of the relative mortality change used in the third step of the calculation.

Finally, the third step is the application of the relations developed below. These relations lead to the estimate of the overall effect of the temporary mortality change for the general measure (e.g. the life expectancy).

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Formally, a relative change of mortality could be expressed as:

$$A = \frac{p_x^*}{p_x} => p_x^* = A \times p_x,$$

where p_x is probability of surviving from the exact age x to the exact age $x + 1$, and A is the relative change of probability of surviving, i.e. p_x^* is the changed (higher or lower) probability of surviving; p_x is the unchanged (original) value.

There are several assumptions for the formal expression which enable us to simplify the relations below:

1. $l_0 = 1$, what is the radix of the life table
2. $a > 0$, where a represents the age (or age-group) affected by the mortality change (i.e. we do not assume a change in infant mortality rate here because we concentrated solely on higher age groups)
3. Distribution of deaths within an interval of one year of age is supposed to be equal. Because we concentrate on 1-year age intervals, this assumption can be justified.

In the expressions below, we assumed various scenarios for the mortality change. Using these scenarios (from the simplest one on), it is possible to follow the derivation of the equations, i.e. we assume that the mortality change could happen:

A. In the interval of one age or age group (we study the period change of the mortality in one year and its effect on the cohort life expectancy at birth)
B. In interval of two ages (age-groups)
C. In the interval of more than two ages (age groups)

A. Starting from the first approach (change of mortality level in interval of one age or age group), it could be seen that a change in (only *one*) age group (labeled as a) leads to an absolute change in life expectancy at birth ($e_0 - e_0^*$) equal to:

$$e_0 - e_0^* = l_{a+1} \times (1 - A) \times e_{a+1} + p_a \times (1 - A) \times \frac{l_a}{2},$$

where the first part of the addend expresses the effect that increased/decreased number of persons surviving to age $a + 1$ has on the life expectancy of the total population because those higher/lower number of persons will live more (or less) years than the whole generation. The second part of the addend shows direct increase of years lived in the age category a. Both effects can be found in moderately different expressions as the Indirect and Direct effect in life expectancy decomposition method by Arriaga [see Arriaga, 1984]. Summation of both effects can reduce the whole formula as:

$$e_0 - e_0^* = l_{a+1} \times (1 - A) \times e_{a+1} + p_a \times (1 - A) \times \frac{l_a}{2}$$
$$= (e_{a+1} + 0,5) \times l_{a+1} \times (1 - A)$$

B. Change in *two* age groups *a*; *a* + 1 (we can distinguish *two* different relative changes equal to A_a and A_{a+1}):

$$e_0 - e_0^* = l_{a+2} \times \left(1 - A_a \times A_{a+1}\right) \times e_{a+2}$$
$$+ \left(p_a \times \left(1 - A_a\right) + p_a \times p_{a+1} \times \left(1 - A_a \times A_{a+1}\right) \times 0.5\right) \times l_a$$
$$= \left(e_{a+2} + 0.5\right) \times l_{a+2} \times \left(1 - A_a \times A_{a+1}\right) + l_{a+1} \times \left(1 - A_a\right)$$

C. Short period mortality shift in <u>more than two</u> age groups (*a*; *a* + 1; …; *b* − 1; *b*) and its impact on cohort mortality (a general approach):

$$e_0 - e_0^* = l_{b+1} \times \left(1 - A_a \times A_{a+1} \ldots A_{b-1} \times A_b\right) \times e_{b+1}$$
$$+ \left(p_a \times \left(1 - A_a\right) + p_a \times p_{a+1} \times \left(1 - A_a \times A_{a+1}\right) + \ldots\right.$$
$$+ p_a \times p_{a+1} \ldots p_{b-1} \times \left(1 - A_a \times A_{a+1} \ldots A_{b-1}\right)$$
$$\left. + p_a \times p_{a+1} \ldots p_{b-1} \times p_b \left(1 - A_a \times A_{a+1} \ldots A_{b-1} \times A_b\right) \times 0.5\right) \times l_a$$
$$= \left(e_{b+1} + 0.5\right) \times l_{b+1} \times \left(1 - \prod_{i=a}^{b} A_i\right)$$
$$+ \sum_{i=a+1}^{b} \left(l_i \times \left(1 - \prod_{s=a+1}^{i} A_{s-1}\right)\right)$$

In both variants B and C, the same effect as in variant A can be found before reduction. The first part of the addend is indirect effect and the second part is the direct effect related to the years where the mortality change occurred.

9.4 Example of potential application of the proposed approach – estimation of the effect of mortality increase during the period of World War II

For the construction of the cohort life tables for the Czech Republic, the most complicated period was probably the period of World War II. For that period, it was very difficult to estimate numbers of deaths as well as population size (population structure) according to age. In that period (1938–1945), it is necessary to cope with the problem of territorial delimitation [Mazouch–Hulíková Tesárková, 2018]. Because of this problem, it was decided not to estimate those raw data (absolute numbers of deaths and age-structure) from which the biometric functions had to be estimated in the following step, but rather to estimate the age-specific probabilities of death themselves. Although the problematic period is bordered by the years 1938 and 1945, the period of estimated probabilities of death was widened to nine years because for the life table construction, the first primary sets of events were used and each of these covers two calendar years [Hulíková Tesárková – Kurtinová, 2018]. As a result, for each analyzed cohort (cohorts 1870–1920), nine total years of age were modelled, corresponding to years 1938–1946 [see the description in Mazouch–Hulíková Tesárková, 2018].

1938 is the first year where the empirical data of numbers of deaths could be treated as completely problematic. For the year 1937, the data are only partially unavailable because of the construction of the first primary sets. In those primary sets, the lower triangle (elementary set) is characterized by deaths recorded at age x and at calendar year t for cohort z and upper triangle of deaths recorded at age x and at calendar year $t + 1$ for the same cohort z. In other words, the first primary set covering the beginning of World War II covers the year 1938, but also the previous year, 1937. For the first primary set (covering the beginning of the war), only partial information could be potentially used, which does not suit the construction of the probability of death for this primary set.

The same situation happened at the end of the war period where the first primary set corresponding to the war period consists of the years 1945 and 1946, the first primary set after the end of the war with unproblematic data being for the years 1946 and 1947.

In practice, this situation means that, for example, for the cohort born in 1916, the last useful data before the war period was for the age 20 (period 1936/37). For the age of 21, a combination of calendar years 1937 and 1938 would be needed. The first useful data after the war period correspond to age 30 (period 1946/47). For age 29, a combination of years 1945 and 1946 would be needed and it is not completely covered by the available data. This is the reason why nine years in total have to be estimated for all the cohort measures. For more details, see Mazouch–Hulíková Tesárková [2018].

In the following part, the three steps described above are used. First, a simple interpolation for the war period is used, which leads to the estimation of the mortality development without the effect of war. Then, the mortality increase during the war years is estimated. The last step is the application of the relations derived above and introduced within this text.

In the interval of nine years, where the mortality level was not possible to calculate directly, a simple interpolation was used for estimation of the potential mortality development if there was no war effect. It assumes constant increase of mortality level with age. For a more detailed description, see Mazouch–Hulíková Tesárková [2018]:

$$q_{x+n}^z = \overline{q_x^z} \times k_z^n, \text{ pro } n = 1, 2, \ldots, 9,$$

where n stands for the 9-year-long period (where it is not possible to calculate the mortality level directly from the data) and $\overline{q_x^z}$ is the estimate of the last known probability of death related to the cohort (generation) z. This probability was estimated rather than calculated directly from the data because of the volatility and natural irregularity in the data. The weighted geometric mean of the last three known values was used for the estimation:

$$\overline{q_x^z} = \sqrt[16]{q_{x-2}^z \times \left(q_{x-1}^z\right)^5 \times \left(q_x^z\right)^{10}},$$

and k_z is the coefficient of increase of the probabilities of death with age in the cohort z calculated using the equation:

$$k_z = \sqrt[9]{\frac{\overline{q_{x+10}^z}}{\overline{q_x^z}}},$$

where $\overline{q_{x+10}^z}$ is the estimate of the first known probability of death from the cohort z after the war period and this is calculated again as a weighted geometric mean from the three first known values:

$$\overline{q_{x+10}^z} = \sqrt[16]{\left(q_{x+12}^z\right) \times \left(q_{x+11}^z\right)^5 \times \left(q_{x+10}^z\right)^{10}} \ .$$

As was mentioned above, in the first step the war period was bridged by a simple interpolation. The estimated values could be understood as corresponding to a model situation of no war at all (or not existence of any mortality increase, in general). It could also be taken as a basal mortality level in the period of war. All the equations presented above and related to the basal mortality are explained more deeply in Mazouch–Hulíková Tesárková [2018].

To estimate the real mortality development during the war, this basal mortality has to be increased by any indicator of mortality increase during the studied period. Estimation of this mortality is the second step of the calculation (mentioned above). For the purposes of the presented case, we used the indicators of mortality increase during World War II. This estimated mortality increase is then simply added to the basal mortality level for estimation of the likely mortality development during the war.

For the estimation of the mortality increase during World War II, we can use the assumption that the overall increase of the number of deaths is caused by (1) the increase of the mortality level related to war crimes and other factors directly related to the war conflict, and (2) mortality increase related to other causes of death, i.e. indirectly tied to the war conflict (e.g. worsened nutrition, increase of accidents and injuries, etc.).

For the period of World War II in the Czech population, some estimates of mortality increase were already done in the 1940s. Soon after the end of the war, authors like Korčák [1946], Srb [1946] and Sekera [1947] estimated crude mortality rates and the increase of the total number of deaths with no information about age or sex distribution. Decades later, Kučera [1994] and Srb [2004] estimated the mortality increase during World War II including the distinction of a direct and indirect effect of war. For more details, see Mazouch–Hulíková Tesárková [2018].

The basic assumption for estimation of the coefficients of the increase of probability of death during the war is that an indirect increase affected all cohorts relatively equally, i.e. the increase was constant in relative expression and the absolute impact then differs by age groups and their level of mortality. Absolute change was lower for age groups with lower initial mortality level and higher for age groups with higher initial level of mortality. This reflects the assumption of a different sensitivity to worse living conditions by different age groups during the war, with seniors and small children plausibly being negatively affected more seriously than active adults.

The direct effect was supposed to affect some age categories more deeply. The age distribution of deaths in this case is difficult to estimate. It is known that the biggest group of unrecorded deaths was the Jewish population (more than half of unrecorded deaths, see Srb [2004]). Age distribution of deaths of this subgroup is close to the distribution of deaths of the whole population. The rest of unrecorded deaths is a combination of Czech citizens in Nazi concentration camps or prisons, executions, deaths of involuntary Czech workers in Germany, partisans, and victims of the rebellion in May 1945 [Srb, 2004]. In these cases, because of the types of reasons for a mortality increase (war conflict), a higher risk of death is expected for males rather than females and primarily for younger age groups (i.e. age categories where more risky behavior is typical). In the results of Kučera [1994] where some estimates of distribution of deaths during the period of war were also done, there is an assumption of higher concentration of deaths in the later stage of the war.

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For each calendar year, the estimation of mortality increase caused by indirect effect was done (general increase of mortality) based on previous publications cited above. Then for each age group (0; 1−4; 5−14; 15−19; 20−34; 35−49; 50−64; 65+), the increase caused by the direct effect of war was estimated. For categories 0 and 1−4 and 65+ the direct effect was not included at the first period (1938–1941) of war. Direct effect to the other age groups was estimated with respect to the assumption of higher risk of mortality increase at younger ages and men (as mentioned above).

As stated above, the total number of deaths increased by around two-hundred thousand for direct and indirect effects together, according to Kučera [1994] and Srb [2004]. The estimation of the coefficients of mortality increase was done with the aim to spread the estimated numbers of deaths during the war period and among the cohorts as realistically as possible. A table with the estimated coefficients for years 1938−1945 can be found in Mazouch–Hulíková Tesárková [2018]. Because there are no detailed estimates of distribution of the effect of war to specific age categories and only fragments of data from the war period could be used for indirect (and partly for direct) effect calculation, the proposed indicators of mortality increase during the war could be understand as one of many possible scenarios. It is used below for a demonstration of the potential total war effect to the life expectancy of individual cohorts. We can assume that even though the proposed indicators of mortality increase are only certain potential quantifications of the war effect and the reality could have differed more or less, if the overall war effect on life expectancy is rather low then this simplification can be justified. As it will be shown below, this assumption could be taken as fulfilled because both the sensitivity from cohorts perspective and the war effect on the value of the overall mortality indicator (life expectancy) is very low.

Figure 9.2 | Coefficients of the increase of probability of death for cohorts 1870 (age interval 67–75) and 1920 (age interval 17–25).
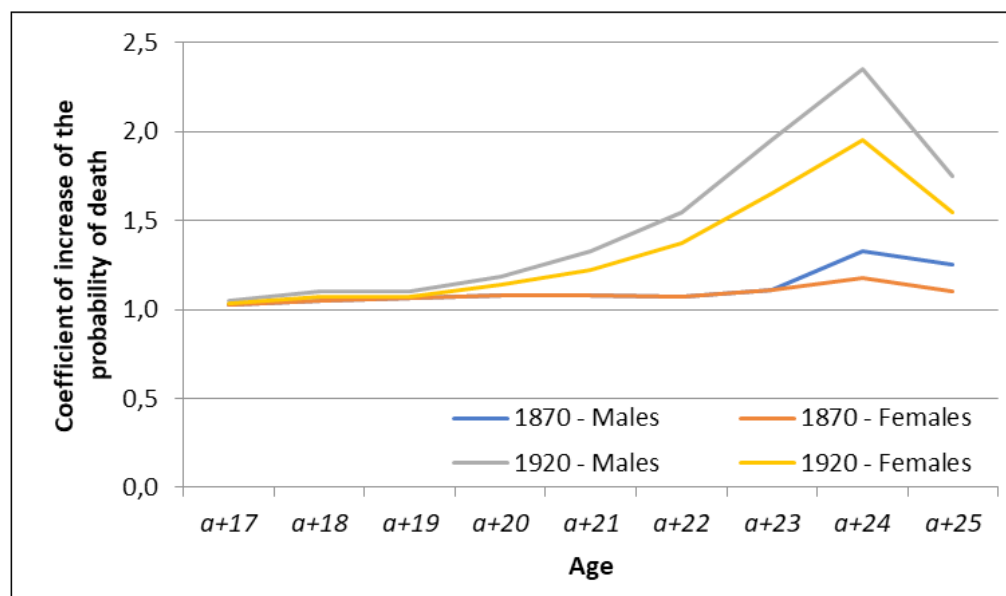
Source: Authors

Note: Where *a* for cohort 1920 = 0 and for cohort 1870 = 50.

Based on the results of previous studies cited above and estimations of the total increase of deaths, the distribution of the increased numbers of deaths to cohorts 1870−1920 and to all age categories during the war period was calculated. In Fig. 9.2, an example of selected cohorts from 1870–1920 is presented. For the first period of the war, only a small mortality increase is found, with a higher increase concentrated in the later period of the war. Decline of the coefficients for the last age category is caused by the combination of year 1945 and 1946 (to which the last coefficient is corresponding to). In the calculation of the 1st primary set (for the cohort born in 1920, this corresponds to the age of 25), a significant mortality improvement occurred in the year 1946 when the war was already over. Coefficients for all relevant cohorts and age categories are in Tab. 9.1 and 9.2.

Table 9.1 | Coefficients of the relative increase of probability of death for cohorts 1870−1920, males.

Cohort	Age								
	a+17	a+18	a+19	a+20	a+21	a+22	a+23	a+24	a+25
1870−1872	1.025	1.050	1.065	1.080	1.080	1.075	1.110	1.325	1.250
1873	1.045	1.050	1.065	1.080	1.080	1.075	1.110	1.325	1.250
1874	1.045	1.090	1.065	1.080	1.080	1.075	1.110	1.325	1.250
1875	1.045	1.090	1.090	1.080	1.080	1.075	1.110	1.325	1.250
1876	1.045	1.090	1.090	1.145	1.080	1.075	1.110	1.325	1.250
1877	1.045	1.090	1.090	1.145	1.225	1.075	1.110	1.325	1.250
1878	1.045	1.090	1.090	1.145	1.225	1.350	1.110	1.325	1.250
1879	1.045	1.090	1.090	1.145	1.225	1.350	1.725	1.325	1.250
1880	1.045	1.090	1.090	1.145	1.225	1.350	1.725	2.250	1.250
1881−1887	1.045	1.090	1.090	1.145	1.225	1.350	1.725	2.250	1.750
1888	1.065	1.090	1.090	1.145	1.225	1.350	1.725	2.250	1.750
1889	1.065	1.130	1.090	1.145	1.225	1.350	1.725	2.250	1.750
1890	1.065	1.130	1.130	1.145	1.225	1.350	1.725	2.250	1.750
1891	1.065	1.130	1.130	1.190	1.225	1.350	1.725	2.250	1.750
1892	1.065	1.130	1.130	1.190	1.325	1.350	1.725	2.250	1.750
1893	1.065	1.130	1.130	1.190	1.325	1.550	1.725	2.250	1.750
1894	1.065	1.130	1.130	1.190	1.325	1.550	1.950	2.250	1.750
1895−1902	1.065	1.130	1.130	1.190	1.325	1.550	1.950	2.350	1.750
1903	1.060	1.130	1.130	1.190	1.325	1.550	1.950	2.350	1.750
1904	1.060	1.120	1.130	1.190	1.325	1.550	1.950	2.350	1.750
1905	1.060	1.120	1.120	1.190	1.325	1.550	1.950	2.350	1.750
1906−1917	1.060	1.120	1.120	1.185	1.325	1.550	1.950	2.350	1.750
1918	1.050	1.120	1.120	1.185	1.325	1.550	1.950	2.350	1.750
1919	1.050	1.100	1.120	1.185	1.325	1.550	1.950	2.350	1.750
1920	1.050	1.100	1.100	1.185	1.325	1.550	1.950	2.350	1.750

Note: Where a for cohort 1920 = 0, 1919 = 1, 1918 = 2, … and 1870 = 50.

Table 9.2 | Coefficients of the relative increase of probability of death for cohorts 1870−1920, females.

| Cohort	Age								
	a+17	*a*+18	*a*+19	*a*+20	*a*+21	*a*+22	*a*+23	*a*+24	*a*+25
1870−1872	1.025	1.050	1.065	1.080	1.080	1.075	1.110	1.175	1.100
1873	1.035	1.050	1.065	1.080	1.090	1.120	1.145	1.175	1.100
1874	1.035	1.070	1.065	1.080	1.090	1.120	1.145	1.175	1.100
1875	1.035	1.070	1.070	1.080	1.090	1.120	1.145	1.175	1.100
1876	1.035	1.070	1.070	1.110	1.090	1.120	1.145	1.175	1.100
1877	1.035	1.070	1.070	1.110	1.175	1.120	1.145	1.175	1.100
1878	1.035	1.070	1.070	1.110	1.175	1.300	1.145	1.175	1.100
1879	1.035	1.070	1.070	1.110	1.175	1.300	1.550	1.175	1.100
1880	1.035	1.070	1.070	1.110	1.175	1.300	1.550	1.750	1.100
1881−1887	1.035	1.070	1.070	1.110	1.175	1.300	1.550	1.750	1.400
1888	1.045	1.070	1.070	1.110	1.175	1.300	1.550	1.750	1.400
1889	1.045	1.090	1.070	1.110	1.175	1.300	1.550	1.750	1.400
1890	1.045	1.090	1.090	1.110	1.175	1.300	1.550	1.750	1.400
1891	1.045	1.090	1.090	1.145	1.175	1.300	1.550	1.750	1.400
1892	1.045	1.090	1.090	1.145	1.225	1.300	1.550	1.750	1.400
1893	1.045	1.090	1.090	1.145	1.225	1.325	1.550	1.750	1.400
1894	1.045	1.090	1.090	1.145	1.225	1.325	1.525	1.750	1.400
1895	1.045	1.090	1.090	1.145	1.225	1.325	1.525	1.825	1.400
1896−1902	1.045	1.090	1.090	1.145	1.225	1.325	1.525	1.825	1.500
1903	1.040	1.090	1.090	1.145	1.225	1.325	1.525	1.825	1.500
1904	1.040	1.080	1.090	1.145	1.225	1.325	1.525	1.825	1.500
1905	1.040	1.080	1.080	1.145	1.225	1.325	1.525	1.825	1.500
1906−1907	1.040	1.080	1.080	1.140	1.225	1.325	1.525	1.825	1.500
1908	1.040	1.080	1.080	1.140	1.225	1.375	1.525	1.825	1.500
1909	1.040	1.080	1.080	1.140	1.225	1.375	1.650	1.825	1.500
1910	1.040	1.080	1.080	1.140	1.225	1.375	1.650	1.950	1.500
1911−1917	1.040	1.080	1.080	1.140	1.225	1.375	1.650	1.950	1.550
1918	1.035	1.080	1.080	1.140	1.225	1.375	1.650	1.950	1.550
1919	1.035	1.070	1.080	1.140	1.225	1.375	1.650	1.950	1.550
1920	1.035	1.070	1.070	1.140	1.225	1.375	1.650	1.950	1.550

Note: Where *a* for cohort 1920 = 0, 1919 = 1, 1918 = 2, … and 1870 = 50.

Since life tables based on interpolated levels of probabilities of death (based on the formulas above) were constructed we can estimate the effect of World War II on life expectancy at birth for all the analyzed cohorts 1870−1920. The effect is calculated

with respect to the formula where a short-period mortality shift occurred in more than two age groups (scenario "C" of the formula above). It is obvious that the effect is stronger for males than for females. The strongest effect of the war is estimated for the cohorts 1881 and 1882, at the age category 56−64 and 55−63 years of age, respectively. In those ages, the total number of deaths is logically very high. Our results show that the effect increases with increasing number of deaths according to age, which corresponds with the results of Vaupel [1986]. The total effect of World War II for the life expectancy at birth for males is between −0.4 to −0.5 year and −0.3 to −0.2 year for females (Fig. 9.3).

Figure 9.3 | The estimated effect of World War II to life expectancy at birth (e0) for cohorts 1870–1920, males and females, Czech Republic.
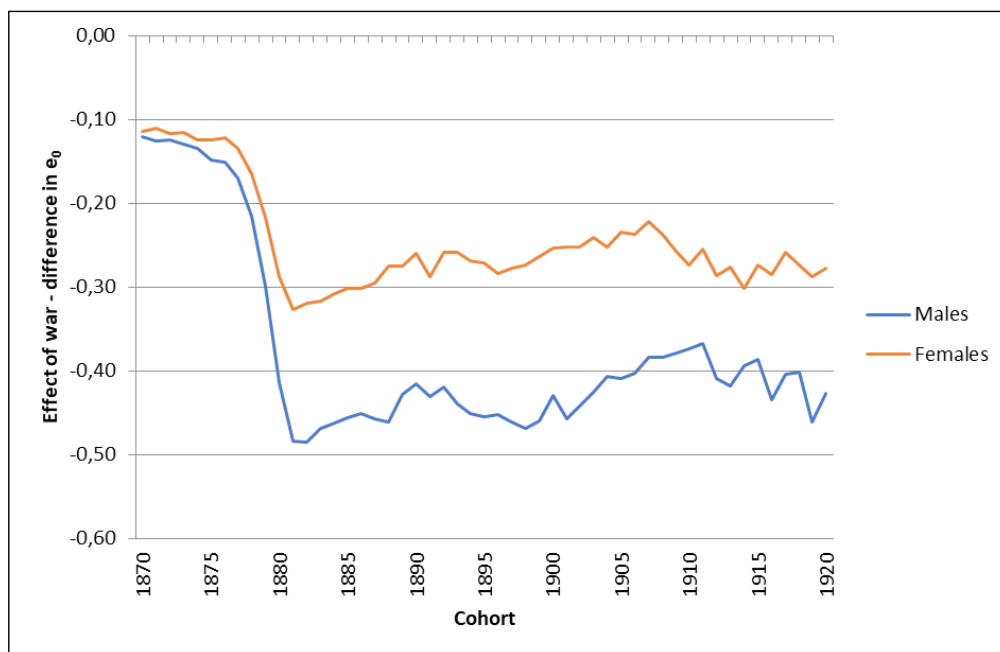
Source: Authors

9.5   Conclusion

To our knowledge, there are no previous studies focused specifically on estimating the effect of temporary mortality change on the life expectancy using the life table functions for its expression. The approach presented in this chapter is a practical application using only limited information about mortality change during a short period where we can easily estimate the potential effect of this mortality change on life expectancy at birth.

Using the knowledge of a temporary mortality change (e.g. during the war or any mortality crisis), it would be possible to estimate the overall effect on life expectancy (or other summarizing indicators). It would also be possible to estimate the unknown mortality increase during the war using at least approximate values of life expectancy of some cohorts affected by the war.

In the presented example, the effect of temporary mortality increase on the overall values of life expectancy at birth was estimated for the Czech cohorts living through the period of World War II. During this period, almost no reliable data about the numbers and age structure of deaths as well as population size were available. It was possible to estimate those numbers, however, with an alternative approach – to model and estimate the probability of death itself (rather than its nominators and denominators).

Only a very simple method was used for the World War II period. Potential mortality development was estimated using the simple interpolation of the values of probabilities of death observed before and after the war. This was described above as a basal mortality level corresponding to the theoretical development, assuming the elimination of the war conflict. Then, based on the results and estimates of previous demographers dealing with the topic, the indicators of mortality increase during the war were estimated. This corresponds to the direct and indirect effects of war. These indicators are constructed as age- and cohort-specific (see the Tab. 9.1 and 9.2 above). Using those, it was possible to estimate the overall mortality increase during the war. Of course, there could be many other estimations of mortality increase during the war, with the examples presented above simply being one representation of them. Moreover, as it was proved, the overall effect of the estimated temporary mortality increase on the life expectancy at birth is rather small and it could be assumed that the result would be similar using any other assumption (corresponding with reality and verified facts) about the mortality increase during the war.

As seen in the results, the distribution of an extra two-hundred thousand deaths during World War II for the population of the Czech Republic (around 8.5 million inhabitants in total in the Czech Republic during World War II), the highest effect on life expectancy at birth is observable for cohorts of males born in 1881 and 1882, being slightly less than half a year.

Through the application of the relations above, it was confirmed that the overall effect of the war for the studied cohorts was rather small. In proving such a marginal negative effect of the war conflict (and estimated values of the related mortality increase) on the overall value of life expectancy at birth, the usage of some simplifications in modelling the conflict's effect is justified. We suppose that an easy tool of estimation of the effect of short period (or cohort) mortality shift based on the life table functions, as presented in this chapter, can help directly evaluate a particular effect easily. Then, it is possible to compare different scenarios of estimates simply using the life table functions. The only necessity is the estimation of the basal life table (under the assumption of elimination of the war effect, estimated above simply using the interpolation) and coefficients of mortality increase during the studied period (optimally estimated based on validated and relevant information in other studies or based on at least partial knowledge of the data or historical context).

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Meet the Young Demographers

<div style="text-align: right">**10**</div>

10.1 Introduction

This book is devoted to the introduction of new generations in demography – new generations of topics as well as new generations of scientists. In total, nine young (or a bit older) scientists contributed to this book. This last chapter is focused on them: their careers, education, and plans for the future.

All the authors wrote their own introduction and tried to answer the questions relevant for them:

- Where did you discover demography? Why did you decide to study it?
- Where have you worked in demography? What is your research focused on?
- What do you like most about demography and your work?
- What are your personal interests?
- Can you briefly describe your family or how do you reach a work-family balance?

10.2 Daniela Arsenović

I was born in 1983 in Woerden, Netherlands, and I am Assistant Professor at University of Novi Sad, Faculty of Sciences. Demography as a scientific discipline was my interest since the Bachelor's studies in geography. Recognizing demography as an applied science in society during my Master's and Doctoral studies, I focused my research interests on population ageing, mortality and climate change-related population, as well as population policy.

I have engaged in several national projects dealing with main population issues in Serbia, e.g. concerning the demographic transition and depopulation in Serbia.

Currently, I am involved in an international, cross-border project related to climate change and population in cities. I consider the main contributions of my research in demography to be the possibility of mitigating negative population processes and improving public policies.

I am a mountain lover, enjoying in hiking and climbing.

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10.3 Jakub Fischer

I live in Prague since my birth in 1978. When I was young, I have been fascinated by math, numbers and so on. I studied at the primary and secondary schools which were focused on math and then I had to decide between studying math at the Faculty of Mathematics and Physics at the Charles University and statistics at the Faculty of Informatics of Statistics at the University of Economics, Prague. I chose the second one as it is more applied discipline.

Demography is an integral part of the statistical studies at our Faculty. As it is described in chapter 3 of this book, it is strongly related to economic statistics and I am interested, together with Petr Mazouch, in searching for these relations in my teaching and research activities. One of our key topics is the issue of human capital: how to measure it, how to analyse its impact on the society and economy, how to forecast it. Apart from this topic, my research activities are focused on national accounts (reconstruction of the historical time series of GDP for the communist era and the transition of this series from the historical methodology to the current methodology; data regionalisation; revision policies), total factor productivity analysis and education policy issues.

Work-family balance is a very hard issue for me: besides teaching and research, I also work for the University and Faculty management (currently as the Dean of the Faculty of Informatics and Statistics, previously for 8 years as the Vice-Rector of the University). However, I spend some time with my personal interests. They consist of sports (hiking, cross-country skiing, tennis, table-tennis and chess) and classical music (from the classicistic era in particular). Last Christmas I got my first musical instrument (ukulele) so one of my plans for personal development in 2019 is to try to learn to play :)

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10.4 Klára Hulíková Tesárková

I was born in 1980 and grew up in Prague, the Czech Republic. I attended primary and secondary schools focused on mathematics. For my university studies I originally planned to study in a field like psychology, sociology or journalism, however, my plan changed. I was looking for a field where I could combine my interest in people and society, communication, mathematics and the possibility of working with people. Since I did not know about demography that time, I decided to study Statistics and Econometrics at the University of Economics in Prague. This is where I discovered demographics. I had great teachers there who (unfortunately, they are not alive anymore) actually directed me to demography. That is why I have graduated from the Master's and Doctoral studies at the Faculty of Science (Charles University) and I have worked there since 2008.

In my research, I focus above all on demographic methodology and models (applied usually on the process of mortality). I also participate in projects focused on other fields like historical demography. Besides research, I am mainly devoted to teaching. I lead courses focused on analysis, programming and applied demography, while tutoring many Bachelor's and Master's students. In addition, I focus on popularization of demographics, preparing lessons and activities presenting population issues to the public and occasionally lecturing at high schools. This variety is also what I like most about my work, together with everyday communication with people.

I have been married since 2010 and in September 2017, I became the mother of my daughter, Vanda. My husband and I are both trying to combine our family and work life. Still this is an extremely difficult challenge for us. On the other hand, thanks to the possibility to work at least partially from home, we can spend time the three of us together more than most other parents. I simply love those moments.

Since a young age, an integral part of my life has been dancing. I helped with dancing courses, which were my first pedagogical experiences. I won the Republic Championship in dance formations and in a special competition in the Czech dance polka several times. I have always loved this combination of sport and music, which I simply need for my life. Apart from that, I like traveling, which for me is tied to learning about society and life all around the world. I particularly appreciated several months spent with my husband in the U.S., among others in California and Hawaii.

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10.5 Adéla Jodlová

I am a Master's student in Demography. I was born in Neratovice in 1996 but now live in Řevnice, to the west of Prague. I came across demography during graduation year by accident because we did not learn about demography at high school at all. Luckily, I found some information on the internet and decided to try it. I can now say that this field is really interesting and enriching for me. Not only do we learn about population history, present and future, but we also get to know how to analyse data in depth and this is useful even for other fields.

I do not have much experience in demography research so far but when writing my bachelor thesis, I realised how interesting and catchy demography is. I learned many new things and experienced the feeling of creating my own work for the first time which was very enriching and satisfying.

The advantage of demography is that there are always some important and relevant topics. We can focus on fertility or mortality – its past, development, present and we can make forecasts as well. Moreover, nowadays the topic of migration is very hot and there are many more trends we can analyse, such as decreasing number of marriages or rising number of divorces which both influence the population.

In my spare time, I tend to be with my family as well as prepare for school. Since I'm a student, I can also dedicate myself to some hobbies such as playing the saxophone in a band and travelling. Finally, I can concentrate on demographic study since this field has so much to offer and I would like to discover it.

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10.6 Olga Kurtinová

I was born in 1982 in Bohumín, Czech Republic. In high school, I was looking for a study programme and university that could be interesting for me. The word "demography" captured my attention in the list of the study programmes available in the Czech Republic. Because I didn't know the exact meaning of "demography", I searched for more information. From what I learned, I decided I had to study demography. Then, I passed the entrance exam to the bachelor programme of demography at the Department of Demography and Geodemography at the Charles University, where I work currently.

My research is focused on fertility, family demography, and the relationship between population and economic development in the present day. However, sometimes my research overlaps with other fields in demography.

What I like about demography is how interdisciplinary it is. To understand demographic reproduction, it is necessary to know parts of history, statistics, mathematics, geography, economics, sociology, etc. There is always something new to learn.

In my spare time, besides spending time with my lovely family, I am interested in beekeeping. I currently take care of eight beehives.

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10.7 Petr Mazouch

I was born in 1981 in the very southeastern corner of the Czech Republic. From a young age, I remember loving numbers and mathematics. At university, I studied statistics with a special focus on economic statistics as the area of application of general statistical methods. More than difficult models, I was interested in data and its relationships. I also found that (macro)economy as theory should be understood as a result of behavior of population and that was why I started to look for demography courses during my studies at the University of Economics in Prague.

I finished my studies in 2005 and my final thesis was about human capital, a topic that combines statistics, economics and demography. I had found that at the time in the Czech Republic, there was no complex study about human capital, especially about the quantification of human capital itself and the impact of human capital on the other socio-economic indicators. I had decided to continue with the Ph.D. studies and the goal was clear: to set up some study about human capital. The Ph.D. project was defended in 2010. During that time, I wanted to increase my knowledge of demography and decided to start other studies – this time, directly about demography. In 2013, I finished studies of Demography at the Charles University in Prague. My final thesis was about mortality, mortality modelling, and estimates of mortality development in the future with a special focus on cohort perspective of mortality patterns.

In that time, we decided to construct cohort life tables of the Czech Republic, as this kind of analysis was missed. In 2017, the project of the cohort life tables was finished and, in 2018, we published not only results from the analysis but also detailed review of historical data available for this case.

In my research, I combine many topics – pure mortality analysis, applied demography, social statistics, data analysis, and with my friends from different universities, we develop some models in paleontology or application of some demography models in estimates of stock of capital. I know that my work is not concentrated to one topic and it is sometime hard, but I love it. I love the opportunity to cooperate with lots of interesting colleagues from different areas. I really want to thank my wife and now also my two newborn kids for respecting this husband's and father's work, which has become his lifestyle.

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10.8 Jonas Schöley

Jonas Schöley is a quantitative social scientist interested in mortality, data visualization, scientific computing, and interdisciplinary meltdowns.[37]

Jonas is a recipient of the Audience award for best presentation/paper at 7th Demographic Conference of "Young Demographers" in 2016 and of the Cozzarelli Prize, which is given annually to six papers published in the Proceedings of the National Academy of Sciences and acknowledges papers that reflect scientific excellence and originality. The award was established in 2005 and named in 2007 to honor late PNAS Editor-in-Chief Nicholas R. Cozzarelli. [38]
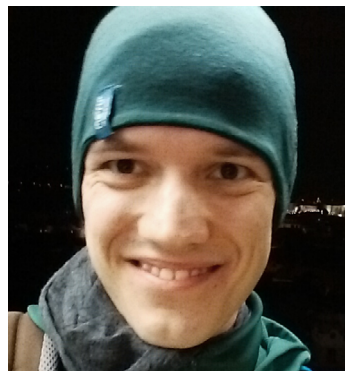
He is already a father enjoying also his parental leave (ignoring his inbox during that time)[39] ☺

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37 Source: https://jschoeley.github.io/about/
38 Source: http://findresearcher.sdu.dk/portal/en/prizes/cozzarelli-prize(9841befc-8223-44b3-88e8-5cae131aa5e5).html
39 Information based on our e-mail communication

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10.9 Martina Štípková

I was born in 1985 and grew up in a small town at the foothills of the Šumava Mountains in Southwest Bohemia. Since then, I became a sociologist and demographer interested in social inequality, family relationships, and health. I like to discover how individual experience that is often considered accidental (like having a happy marriage) is linked to social structures.

My academic career is interdisciplinary. I did my Bachelor's and Master's degrees in social anthropology at the University of West Bohemia. I had an opportunity to take courses in sociology and demography during these studies and realised that these disciplines are much closer to my interests. During my Master's studies, a new Department of Sociology was established at the faculty and I started to work as a research assistant at a project of the founder of the department, Martin Kreidl. This collaboration transformed into my doctoral research that focused on the rising trend in non-marital childbearing and its consequences on health of infants. I enrolled in a Ph.D. programme in Sociology at the Faculty of Social Sciences at the Charles University but also needed more education in demography to address such an interdisciplinary theme. I first took some courses at the Max Planck Institute for Demographic Research in Rostock and then joined the European Doctoral School of Demography, an 11-month study programme that was hosted by the Autonomous University of Barcelona.

Although I enjoyed travelling and gaining international experience, home is home. I finally settled in Pilsen and work at the Department of Sociology at the Faculty of Philosophy and Arts of the University of West Bohemia, where my career started.

Since the beginning of my Ph.D. study in 2009, I have taught hundreds of students, got a grant from the Czech Science Foundation, and published about 20 papers or chapters, including articles in Demographic Research, European Journal of Population, and European Journal of Public Health. After years of such intensive work, I have slowed down and had a son who is now 2 years old. Reaching a balance between work and family is not always easy but I am happier than ever and experience first hand the positive effects of supportive family relationships that I have been studying.

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10.10 Francisco Villavicencio

Originally from Barcelona, I am currently an Assistant Scientist at the Johns Hopkins Bloomberg School of Public Health in Baltimore. I hold Bachelor degrees in both Mathematics and Geography, and a Master in Population Studies from the Autonomous University of Barcelona. I discovered demography on my undergrad studies, when attending a basic course in population studies. I was fascinated by the concept of life table and how we build them to estimate the life expectancy. For a few years I was undecided about my future, until 2012, when I enrolled the European Doctoral School of Demography. I completed my PhD in Statistics/Demography in June 2017 at the University of Southern Denmark.
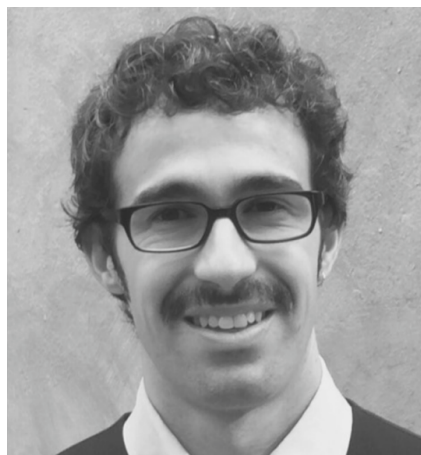
My main research interests are the development of methods for the analysis of incomplete demographic data using Bayesian inference and agent-based modelling. I am also very interested in formal demography. In fact, what I like the most of demography is its ability to tackle with different methods and borrow from other disciplines – from mathematics to history and biology – to study population dynamics.

Working at academia requires travelling and living in different countries. This is usually challenging and rewarding, although it can be hard to combine with family life. But so far, so good! Moreover, it gives me time to devote to my hobbies: chess, literature, classical music and football.

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