Chapter 3

Inequality in Educational Development from 1900 to 2015

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Additional information is available at the end of the chapter

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Abstract

The industrial revolution marked a turning point in mankind as it not only initiated an economic turn from predominantly agricultural to industrialized societies but also shaped the need for an education revolution. This was the period when most industrialized societies implemented compulsory schooling systems and created the opportunity for universal access to basic education and later medium and higher education levels. However, this did not occur at the same speed everywhere, generating divergence between countries, and subsocieties within countries, whether it was at the level of residence, gender, generation, or class. Based on a dataset developed at the Wittgenstein Centre for Demography and Global Human Capital reconstructing levels of education in 5-year steps by age (5-year age groups) and sex for a large number of countries in the world, we look at the education transition from 1900 to 2015 to uncover different patterns and pathways of educational improvements that might explain the differences in the level of human capital today.

Keywords: education, demographic trends, human capital, population reconstruction, gender gap, JEL Code(s): I21, I24, I25, J11, J24, O10

1. Introduction and context

The twentieth century has witnessed many economic, technological, political, and societal changes. There is a large consensus that increased education played a role both in the initiation and diffusion of the many transformations that have occurred over the last 150 years. However, less is known about the structural effect of education in a comparative manner,

meaning what was the specific contribution of education globally at different levels, e.g., age, gender, and how did the pace of education diffusion differ between countries. In order to do this, one needs detailed data on educational attainment. The work that we are presenting here is part of an effort to create a globally consistent and comprehensive dataset on educational attainment by age and sex in the twentieth and twenty-first centuries. This shall be achieved by reconstructing the changing country-specific educational composition of 185 countries from 2015 back to 1950 (WIC 2018) and in the context of the *Education in the 20th Century* (EDU20C) project for selected countries back to 1900. This paper will focus on the second part by illustrating the theoretical framework, methodological challenges, and principles, as well as the results for selected countries.

Today, the availability and quality of global data on educational attainment are quite substantial as it is part of most data collection exercises, i.e., censuses, registers, and surveys. Data on educational attainment can be mapped according to the International Standard Classification of Education (ISCED) (see Section 2.1), which is a standardized categorization scheme that is widely recognized and used [1, 2]. However, the awareness about the importance of collecting internationally consistent and comparable data on educational attainment is relatively new. Most countries only started to collect these data according to their national education schemes not before the mid-twentieth century, and the implementation of the ISCED did not occur before the 1990s. Hence, most existing historical data on education suffer from several flaws that make them difficult to compare across countries and time: different measurements of educational attainment, different schooling cycles, different years at measurement, changing definitions, and changing political borders due to military conflicts and political upheavals [3–5]. For this reason, comparisons across countries over time and cohorts have been at least challenging, but often unfeasible.

As a result, a few researchers have looked at ways to reconstruct/estimate past levels of educational attainment. Those efforts follow two main methodological streams. The first that was primarily developed by Barro and Lee [6–9] was to use existing data points to inter- and extrapolate the missing data using a variety of methods such as linear interpolations or the perpetual inventory method. This approach was adopted and further used by other researchers like De la Fuente and Doménech, Cohen and Soto, and Morrisson and Murtin [10–12]. The second stream, which was introduced by Lutz et al., relied on back-projecting educational attainment using the multistate population projection methodology [13]. This approach takes advantage of the attribute of education that is primarily acquired at young ages and becomes a fixed attribute for most people in their remaining life. Hence, by using the cohort-component method, the educational distribution of a population at time t can be translated into the educational distribution at time t-n, when applying assumptions about education transitions as well as mortality and migration differentials by education. This method was later adopted by Barro and Lee, De la Fuente and Doménech, and Cohen and Leker [8, 9, 14, 15]. This methodological principle provides the basis for the reconstruction model used in this work, with substantial adaptations and further developments that will be described later in this text.

The project presented here aims to reconstruct past levels of educational attainment by age and sex of the population of selected countries from the beginning of the twentieth century up

to the present. The result of this effort is to create a complete, harmonized, and consistent time series in 5-year steps of the levels of educational attainment of the population by age and sex ranging from 1900 to 2015. It is the first step of a larger endeavor to reconstruct the past levels of education for most countries of the world in the twentieth century and to contribute to the wider understanding of the socio-economic developments in the last century.

1.1. Historical and theoretical framework

Research on educational expansion focuses on timing and pace of formal education formation and development in the context of historical and socio-political conditions. While lacking a *"grand theory"* that integrates multiple paradigms, the main theories addressing the potential causalities behind the education expansion from different, partially competing, perspectives are concerned with themes like industrialization, social privilege, and nationalism [16].

Since the early beginnings of education in cleric schools and temples in ancient civilizations, like in Egypt or China, it has been used as medium to pass on knowledge but also ruling structures, moral standards within societal hierarchies and class structures (i.e., from emperors via administrators and clerics to the regular people) and between generations. Shifts in societal (i.e., secularization or modernization) and political systems always came along with shifts in educational paradigms, like the provision of formal mass education, to provide the necessary skills for a productive workforce, create allocation rules for people to social classes and positions in the labor market, as well as to legitimize and reinforce the political ruling system by promoting nationalism to assure obedience [16–18].

The comprehensive implementation of formal and compulsory education systems started in the eighteenth and nineteenth centuries. The end of the nineteenth century and the beginning of the twentieth century was marked by the rise and fall of political systems, empires, and nations. While at the beginning of the century, most of Europe were ruled by monarchies, the political, and territorial landscape, which was deeply shattered as a consequence of the First World War (1914–1918). Multiple dynasties disappeared like the Austrian-Hungarian Empire (1804–1918), the German Empire (1871–1918) as well as other German Kingdoms (i.e., Bavaria, Saxony, Hanover, Württemberg), or the Russian Empire (1712–1917). These political collapses came along with a reshuffling of the European territorial landscape with the foundation of multiple new nations and an increasingly precarious economic situation in the interwar period. This period saw also the emergence of fascist and communist ideologies.

In those political reframing's, education played a major role for transferring and indoctrinating the population with the new ideologies. It was also used to legitimize the new political structures and the societal stratification in social classes [16, 18, 19]. Independently from their ideological orientations, the nation states, i.e., Italian Fascism, Austrofascism, Nazism, Communism in the Soviet Union, the Francoist Spain or the later German Democratic Republic, were unified in their intention to use literacy and education programs to grant access of all societal classes to primary and elementary education to create uniform and obedient adolescents, workers, soldiers, and peasants. Here, as well as in the former monarchies, individual autonomy and deviant societal and political ideologies of citizens were tackled

early on to avoid critical thinking and societal upheavals educating citizens with ideologically charged curricula, which was an instrument to maintain social stratification and equilibrium within the society. Apart from capitalist societies that promoted social stratification in a only seemingly pervious meritocratic system, even in self-stated classless ideologies, like socialism or communism, elitist structures were formed to separate the ruling class from the bureaucratic and legislative apparatus and the working class [18, 19].

These changing societal, economic, and political conditions are mirrored in the general theoretical discourse. For instance, the sociological **theories of education** study its role for national societies and economies in terms of educational structures, processes, and practices. This strand of sociological research focuses on the interactions of social, educational, economic and political systems and structures on different levels, reaching from a macroperspective down to inner classroom interactions between students and teachers. Émile Durkheim laid the foundation for this theoretical school with explicitly examining the role played by schools in educating students to participate in social systems and become productive members of society [20–24]. Sociology operates within the three main theoretical perspectives, namely consensus (or functionalist), action (or interactionist), and conflict perspective [23–26].

The **action perspective** originates from Weber's Interpretive Sociology, which focuses on subjective capacities of actors on an individual microlevel and their links to action and interaction, whereby along with phenomenology and ethnomethodology, the (symbolic) interactionism has shown to be the most prominent. The **consensus** and **conflict perspective** are system theories that focus on macrolevel processes from different perspectives. The conflict perspective, also denoted as **conflict theory**, has multiple strands, including Marxism, neo-Marxism, critical theory or feminism, whereby the consensus perspective is mainly represented in the **(structural) functionalism theory** [23–27]. Both, conflict theory and (structural) functionalism adopt a macroperspective [24, 26, 27], which is more relevant for this paper. **Structural functionalism** for instance claims that education's most crucial role is to educate students to become productive members of the socially and economically stratified society and to maintain, legitimate, transmit, and internalize a "collective conscience" rather than challenge the societal status quo [25, 27]. Representatives of this strand like Davis and Moore or Parsons state that schools are systems of social stratification in which all people get allocated to a role in society suiting their abilities and status. Schools serve in this system as bridges the gap between the particularistic values of the family and universalistic values of society [28, 29]. Schools pass on two major values, namely the value of achievement (meritocracy) and the value of equal opportunity [29]. According to Merton, schools serve, beside their manifest function of educating students, a latent function to pass on norms and values to ensure social stability and prevent societal upheavals. This is often referred to as *"hidden curriculum"* [30]. In this context, the improvements in educational systems, i.e., implementation of compulsory school, serve not only the conservative and integrative function to transmit the cultural heritage of older to younger generations and to maintain social order, but to guide pupils according to their abilities and social status from their joint family to their social and economically predefined status in the society. This creates and maintains social inequality, which is perceived as social necessity and not challenged, as schools shall solidify the social stratification, ensure stability, and social order in society at the expense of social change [24, 27].

The **conflict theory** [31–35] is in agreement with structural functionalism in the sense that both state that schools contribute to social, ideological, and labor force reproduction. Thereby, functionalism perceives this social inequality as a necessity while the conflict theory as a structure preventing equality, which has to be challenged from within the system. Education systems in both strands produce economically and politically obedient citizens that function according the economic requirements of a society. This also means that according to those strands educational progress in societies is determined by the economic needs of the labor market [23, 24, 26, 27].

At the macrolevel, education has been widely acknowledged to be a proxy for socio-economic development [5, 36, 37]. This thinking is in line with the basic premise of the **human capital theory** [38] that refers to the aggregate stock of competencies, knowledge, social, and personal attributes as abilities to create economic value [24, 37]. Human capital theory has been frequently cited, mainly by economists and demographers, to justify social and economic policies and reforms within and outside the education system. The theory as such emanates from the two neoclassical economic paradigms, *methodological individualism* and *rational choice theory*. Both highlight the individual as root of all social phenomena. Individuals in their human behavior are considered to act mainly in self-interest to maximize their economic benefits. Individuals acquire knowledge and skills to increase their productivity and in an ideal labor market their income and wealth. This stands in sharp contrast with the *methodological collectivism* that assumes that social phenomena cannot be reduced to individual actions, but are products of social, cultural, and environmental factors [37]. From this theoretical perspective, individuals are economic units, whereby investments in individuals serve economic interests to contribute to society as education is seen as an investment to stimulate productivity and economic growth not only for the individual, but also for the society. Education or the ability to perform labor is part of the economic capital, which shall ensure the acquisition of knowledge to generate higher income and serve the requirements of the national economy, which is a further elaboration of the structural functionalism perspective. Cunningham argues that education has a social aspect, which means that personal and social dimensions are mutually dependent. In this line of thinking, people construct and shape social structures, but are also influenced and framed by them. Therefore, individuals cannot be conceptualized outside of their societal and economic context [37, 39]. Both individualist and collectivist perspectives can be considered in the framework of the human capital theory.

In the field of demography, the most prominent theory is the **demographic transition** theory, which describes the different stages of demographic development in terms of changes in the mortality and fertility characteristics of societies and their potential implications on future population developments [40–44]. Education plays a crucial role in demographic development as it affects negatively the fertility of women and the mortality of children and adults. **Figure 1** illustrates demographic developments by means of the changing pattern of life expectancy at birth (y-axis), total fertility rate (x-axis), and population size (bubble size) by countries and regions for 1900 (gray) and 2018 (color). In the last 120 years, most countries showed remarkable increases in life expectancy, while the total fertility rate (TFR) has been rapidly declining, with Northern America and Europe as frontrunners, followed by Latin America, Oceania, and Asia, while most African countries are lagging behind. In the process of demographic transition, the population has substantially increased from 1.6 billion in 1900 to 7.6 billion in 2018 [45, 46].

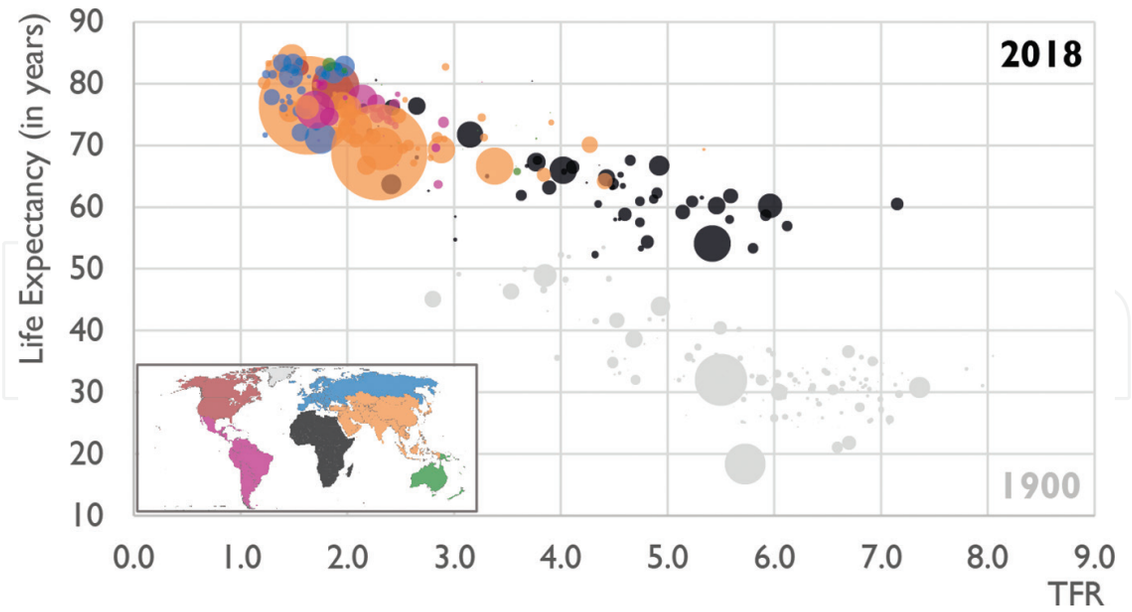

Figure 1. Life expectancy (y-axis), TFR (x-axis), and population size (bubble size) by country and continent in 1900 (gray) & 2018 (colored bubbles) ([45, 46], authors' illustration based on data from [47]).

Education is on the rise everywhere as many countries have essential part of their economies moving to knowledge activities. In this process, younger cohorts are increasingly gaining access to higher forms of education to suit the economic requirements. Over time, these steadily better educated younger cohorts started to replace the older and less educated cohorts in the workforce and general population. This has been causing a shift in the overall educational distribution of the society from lower to higher educational levels. Lutz (2013) describes this process of societal educational improvements due to cohort replacement in his **demographic metabolism theory** [36], which is based on concept of cohort replacement [48–50].

These shifts in educational progress are at the core of this work as described in the following sections.

1.2. Scientific impact

This work has a high potential scientific impact because it provides historical data on education to be used in models that both address and quantify the role of education in demographic [5, 51], econometric [9, 52], environmental [53, 54], technological, etc., developments, or need education as a as proxy for socio-economic development. Information gathered from the past can in turn inform the future in terms of policy and public investments.

The twentieth century was a century of change when it comes to the mutually reinforcing demographic, economic, social, political, and technological transformations during this time. The massive global gains in the educational attainment can be considered as contributing factors to those processes [5, 44, 55]. Available international datasets show lacks in consistency when it comes to comparability of used educational categories and data quality of model input data [9–12, 56], mostly because they rely largely on existing data points on education that have many flaws. This project also uses historical data but to a lesser extent and not without validating them first. As a result, this work is an important contribution to reconstructing the

historical educational composition and gain further scientific knowledge about the dynamics of educational development.

1.3. Geographical focus and data availability

The availability and reliability of global data on educational attainment has substantially improved in the last decades so that nowadays it is possible to retrieve education data from recent censuses, registers, and surveys and harmonize them according to the International Standard Classification of Education (ISCED) mappings [1, 2]. However, this does not go without any difficulties as documented by Bauer et al. [3], Speringer et al. [4], and Goujon et al. [5].

However, the further one goes back in time, the sparser availability of historical data on educational attainment, as most countries in the world did not start systematically collecting this information before the mid-twentieth century. The only data on education for the first half of the twentieth century were, if even available, on literacy or enrolment. This notable lack of consistent long-term data series and inconsistencies in historical census records make it necessary to reconstruct the educational composition over the course of the twentieth century.

The authors of this paper aim to model harmonized time series on education by reconstructing the levels of educational attainment by age and sex for selected countries for the period from 1900 to 2015. This work contains two strands of reconstruction. Firstly, the educational attainment was reconstructed for 185 countries in the world from 2015 to 1950, updating hereby the mid-term reconstruction iteration to 1970 published in Goujon et al. [5]. Secondly, the education in the twentieth century (EDU20C)[1] project aims to create harmonized time series for about 30 countries back to 1900 (see **Figure 2** and **Table 1**), whereby the list of countries will be steadily extended.

The 30 initial countries are located in Asia, the Americas, Europe, and Oceania (see **Table 1**). This paper focuses on 11 countries, namely Japan, Brazil, Costa Rica, Puerto Rico, Italy, Greece, Portugal, Spain, Hungary, Canada, and United States of America. Those selected countries have a long census history, whereby the majority of countries started to compile data on educational attainment after World War II. The listed countries represent different regions of the world as well as different paces and patterns of demographic transition (see **Figure 3**) and education transition from low to highly educated societies.

When it comes to the demographic transition from high- to low-mortality and fertility regimes, the majority of the 30 countries have achieved the last stage of the demographic transition and have attained low levels of fertility and mortality, while the rest of the countries are catching up fast. **Figure 3** illustrates the life expectancy (y-axis), TFR (x-axis), and population size (bubble size) by EDU20C countries and continent in 1900 (gray) & 2018 (colored bubbles). In 2018, the majority of the countries surpassed 70 years of average life expectancy at birth and are approaching or dropping beneath the replacement fertility level (TFR: 2.1), with countries like Guatemala (2.9), Philippines (2.9), Bolivia (2.8), Ecuador (2.4), Argentina (2.3), and Mexico (2.1) lagging behind. Nevertheless, there is a notable clustering in 2018 of the 11 countries according to the three visualized demographic characteristics compared to the scattered pattern in 1900 [45–47].

[1] For more information visit: www.edu20c.org

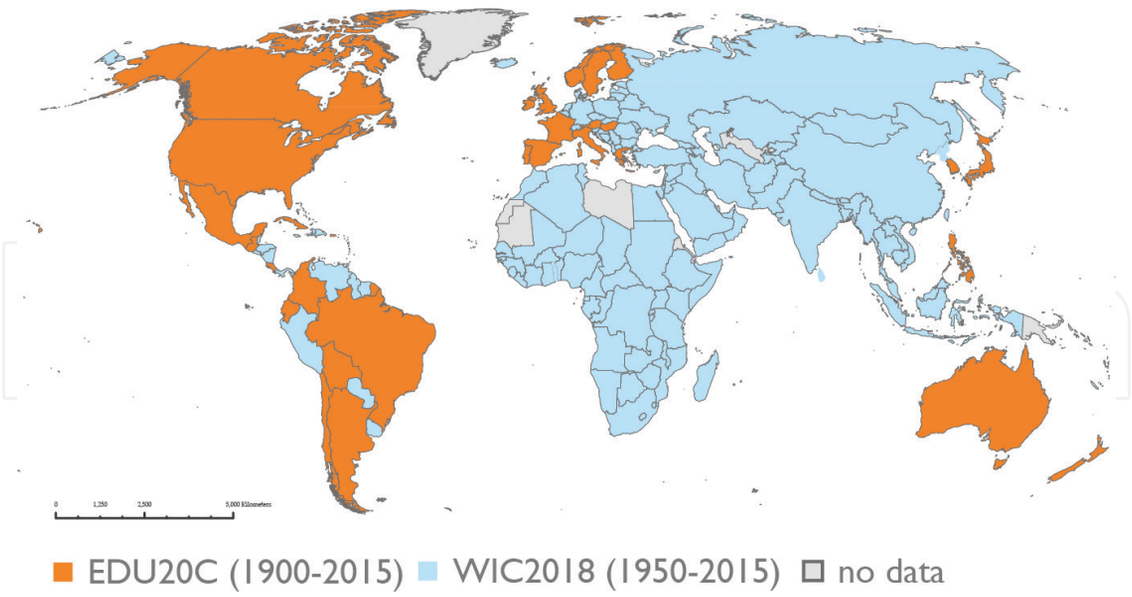

Figure 2. Geographical coverage of the WIC 2018 and EDU20C reconstructed data set.

Continent	Countries	LIT*	EDU**	Countries	LIT*	EDU**
Asia	Japan	NA	1960-2010	Rep. of Korea	NA	1966-2010
	Philippines	1903-1918	1990-2010			
Latin America	Argentina	1895-1960	1970-2011	Cuba	1899-1943	1953-2012
	Bolivia	NA	1950-2010	Ecuador	NA	1950-2010
	Brazil	NA	1940-2010	Guatemala	1921	1950-2012
	Chile	1907-1940	1952-2012	Mexico	1900-1940	1950-2010
	Costa Rica	1892-1927	1950-2010	Puerto Rico	1899-1940	1950-2010
	Colombia	1928-1938	1951-2005			
Europe	Austria	1900-1910	1951-2011	Ireland	1901-1911	1966-2011
	Finland	1900-1930	1940-2010	Italy	1901-1931	1951-2011
	France	1901-1954	1962-2011	Norway	NA	1950-2011
	Greece	1907-1928	1951-2011	Portugal	1900-1930	1940-2011
	Great Britain	1901	1971-2011	Spain	1900-1950	1960-2011
	Hungary	NA	1920-2011	Sweden	1930	1950-2011
North America	Canada	1901-1931	1941-2011	USA	1900-1930	1940-2010
Oceania	Australia	1911-1921	1966-2011	New Zealand	1901-1921	1961-2013

Table 1. Countries of study of EDU20C (colors referring to UN regions and 11 countries further elaborated upon in the study).

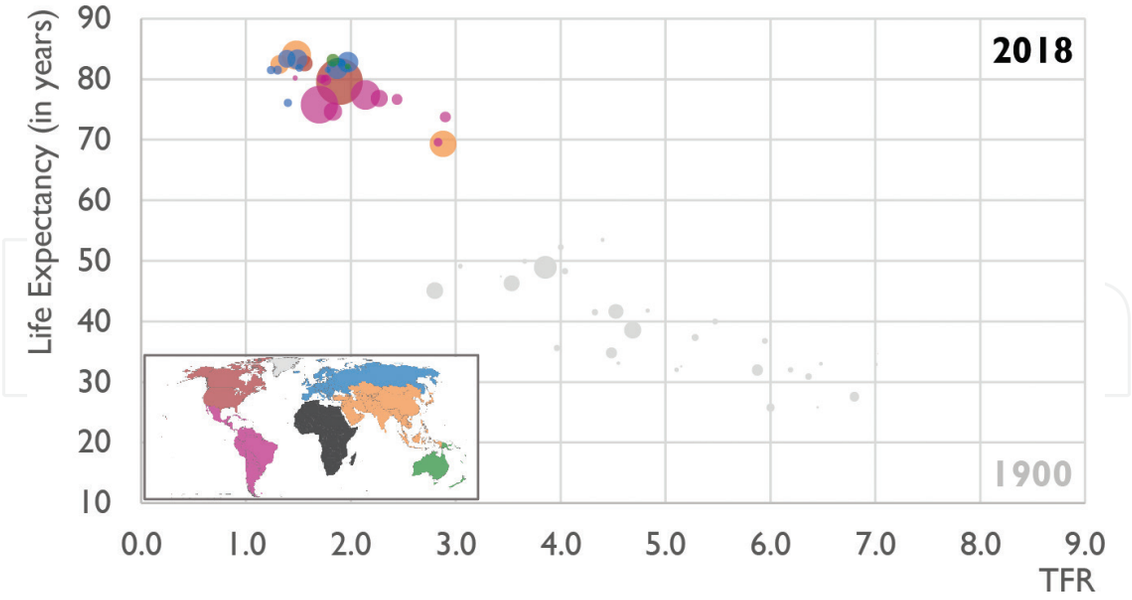

Figure 3. Life expectancy (y-axis), TFR (x-axis), and population size (bubble size) by EDU20C countries and continent in 1900 (gray) & 2018 (colored bubbles) ([45, 46], authors' illustration based on data from [47]).

Despite the availability of data and estimates on population size, fertility, and mortality in the twentieth century, the availability of data on education for the selected countries is limited. **Table 1** partially illustrates the gaps in the available data series. The preparation and processing of the collected data faces a number of challenges that revolve around the harmonization of educational categories, disaggregation and extensions of age structures (by education) and life tables as well as the filling of time series gaps, which are discussed in detail in Section 2.1.

2. Methodological approach

2.1. Challenges and estimation principles

The empirical data basis for the reconstruction is the collected, processed, and harmonized country-specific base-year data on educational attainment by age and sex from national educational classifications to the comparable ISCED categories (see **Table 2**). Furthermore, one major issue was concerning the availability of consistent age-sex-structures and life tables in 5-year steps for the entire reconstruction period, especially before 1950 as the United Nations (UN) provide this kind of data from 1950 onward [57, 58].

More than often, we had to decompose differently aggregated and varying open-ended age groups in the population age-sex-structures and life tables to retrieve consistent age groupings (5-year age groups from 0 to 100 years and higher) and to interpolate those for the entire reconstruction period. For instance, the basic information on the educational distribution by age and sex needed to be further processed to smoothen the educational distribution over age

ISCED 2011		ISCED 1997		[1900-1950] -		[1950-2015] WIC2012	
01	Early childhood development	-	-	x1	No Education	e1	No Education
02	Pre-primary	0	Pre-primary				
1	Primary	1	Primary	x2	Primary	e2	Incomplete Primary
						e3	Complete Primary
2	Lower Secondary	2	Lower Secondary	x3	Secondary	e4	Lower Secondary
3	Upper Secondary	3	Upper Secondary			e5	Upper Secondary
4	Post-secondary (non-tertiary)	4	Post-secondary (non-tertiary)	x4	Post-secondary	e6	Post-secondary
5	Short-cycle Tertiary	5B	First Stage Tertiary				
6	Bachelor's or equivalent	5A					
7	Master's or equivalent	5A					
8	Doctoral or equivalent	6	Second Stage Tertiary				

Table 2. The WIC educational attainment categories according to ISCED 1997 and 2011 classification (colors referring to education categories further used in the study).

groups, to convert irregular or aggregated age groups into 5-year age groups, to extend the highest open-ended age group with the usage of historical data-points to 100+ years, and/or to shift the input years to 0/5 round years (e.g., from 2011 to 2010).

While back to 1950, it was possible to use population age-sex-structures from the UN World Population Prospects (WPP 2017) and the data gaps before 1950 were increasing so that it became necessary to estimate intercensal population structures and life tables for many countries using an exponential interpolation by age groups to retrieve estimates for the missing years. **Table 3** illustrates the data preparation necessary to arrive at usable input for the reconstruction model.

2.2. Reconstruction principles

The reconstruction of past levels of educational attainment by age and sex relies on the basic principle that education is predominantly acquired at young ages, normally before the age of 25 years. Additionally, education is acquired unidirectional as an individual can only add skills and educational levels until it reaches the personal final or highest educational attainment level that becomes a fixed attribute for the remaining life. Therefore, the education of individuals can

Area	Estimations and adaptations
General	• Adaptation of available historical data to current border situations, with available estimates and historical regional records [3, 4] [EXCEL]
	• Harmonization of national education categories to ISCED [3, 4] [STATA]
Education	• Education distribution age smoothing and disaggregation using a smooth spline function [R]
	• Education distribution age extension using logarithmic extension of education distribution, historical cohort marker information, and smooth spline function [R]
	• Education distribution age shift to 0/5 round years following the age-specific education distribution pattern [R]
Life Table	• Life table age extension using a logistic extrapolation on the values for nqx, Lx, and ax for the last three age groups beneath the open-ended age group [R]
	• Life expectancy interpolation using a logistic function to at least two existing life expectancies at birth and sex, given the values of upper and lower asymptotes, based on E0LGST Spreadsheet [59] [R]
	• Life table interpolation using a function to interpolate the logarithms of the probabilities of dying (nqx) from two life tables using estimated life expectancies, based on INTPLTF/INTPLTM spreadsheet [59] [R]
Age-sex-structure	• Age disaggregation using the Karup-King formula [60–62] [R]
	• Age extension using the survivorship ratios (Sx) from the estimated life tables and using cohort splits [R]
	• Age interpolation using an exponential interpolation, which assumes a multiplicative relationship throughout the projection range, based on AGEINT spreadsheet [59] [R]

Table 3. Overview of used estimation procedures to create comprehensive and consistent input files.

be followed back in time along cohort lines, meaning that a 50-year old with a tertiary education in 2015, certainly had already acquired it in 2005 when he/she was 40 year old.

This reconstruction of educational level along cohort lines has limits, as some age groups are still undergoing major educational transitions. While most transitions happen before the age of 25 (age at which most people would have acquired a postsecondary education), still a substantial number of transitions are occurring at later ages. This is the reason why we developed educational matrices to model education transitions until the age of 34. We do not consider education categories below the age of 15 as this work concentrates on human capital measured by stocks of educational attainment in the population of working age.

Originally developed by Lutz et al. [13], the reconstruction methodology was extended to cover a longer timeline (back to 1900). The method, as in place today, can be described as **iterative multidimensional cohort component reconstruction model**. It relies on a given population by age, sex, and educational composition in a defined and available base year. As historical marker information, this method requires time-series data for the entire reconstruction period in 5-year steps on *population size* by age and sex, *mortality differentials* by education, and estimated *education transitions*, based on **educational attainment progression ratios (EAPR),** to reconstruct the historical changes in the educational distribution. Potential migration movements cannot be considered in the model itself, due to lack of comprehensive

Area	Reconstruction model elements
Model	• Iterative multidimensional cohort component reconstruction model [R]
Mortality	• Mortality differentials by education are expressed in terms of standard schedules in life expectancy at age 15 [5, 13, 51, 63], whereby the education-specific mortality differentials are converging along a logarithmic trend extrapolation to no differentials by 1950 [R]
Education	• Education transitions in the age groups 15–34 years based on the iterative back projection of EAPRs [R] • Collapse of the educational categories from 6 (1950 to base year) to 4 categories (before 1950)
Population	• Iterative adaptation of reconstructed education distributions by age and sex to the absolute population number by age and sex [R]
Projection	• As the reconstruction is based on the reconstruction from country-specific base years (i.e., 2015, 2010, or 2005), the population by age and sex has to be projected to 2015 to get consistent time series [5, 51] [R]

Table 4. Overview of required reconstruction model elements.

historical data of migration by education, but we adapt the model output according to the marker information, which implicitly handles the potential impacts of migration.

In total, the model requires three obligatory and one optional datasets for the base-year and/or the entire reconstruction period:

- Population by age (5-year age groups), sex and highest educational attainment for all 185 countries in the base year **(obligatory)**
- Population by age (5-year age groups) and sex for all 30 (185) countries from 1900 (1950) to 2010 in 5-year steps **(obligatory)**
- Life table by sex for all 30 (185) countries from 1900 (1950) to 2010 in 5-year steps **(obligatory)**
- Population by age (5-year age groups), sex, literacy, and/or highest educational attainment for all 30 (185) countries from 1900 (1950) to 2010 in 5-year steps **(optional)**

The reconstruction model itself consists of three major elements: mortality, education, and population. Furthermore, it is necessary to conduct a forward projection, based on the base year and reconstructed data, to retrieve with 2015 a consistent base year for all countries (see **Table 4**).

3. Results

The result of the described preworks and the reconstruction model itself is a dataset with the population by age, sex, and educational attainment for the selected countries from 1900 to 2015. This contributes to a better understanding of how countries shifted from relatively uneducated societies to higher educated societies in the course of the twentieth century due to comprehensive national education programs (i.e., compulsory schooling).

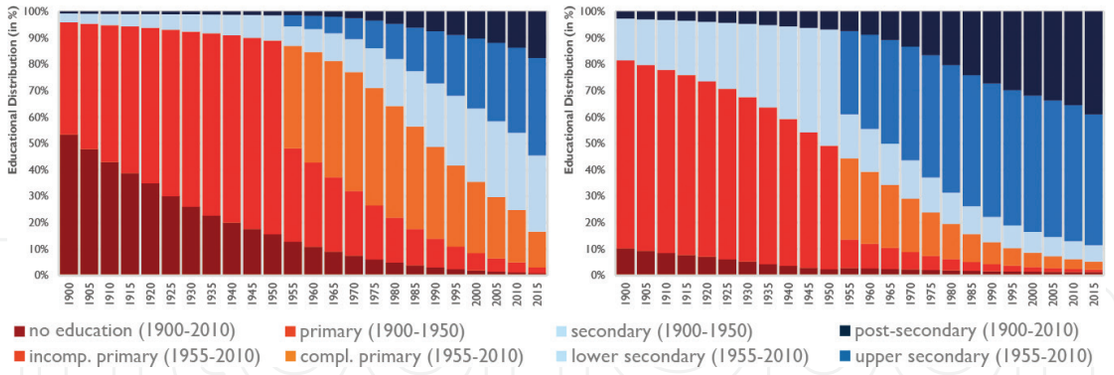

Figure 4. Share of total population aged 25 years and older by educational attainment in Italy (left panel) and United States (right panel), 1900–2015 (source: authors' calculations).

Figure 4 shows the example of how the educational composition of the total population aged 25 years and higher developed over time in Italy (left panel) and the United States (right panel). In Italy, the majority of population aged 25 years and higher in 1900 had either no education (53.4%) or primary education (42.5%). A law was passed in 1859 that made primary education compulsory with the general aim of increasing literacy. However, it was not enforced until 70 years later, particularly in rural areas. As a result, in 1955, there were still 48.2% with an incomplete primary education or less. From then onward, primary education has been decreasing again in favor of (lower and upper) secondary education as well as postsecondary education some years later. In the United States, laws to make education compulsory (most of the time up to age 16–18) were adopted by each federal states from 1852 onward. Implementation seems to have been more effective than in Italy although the share of the population who had neither incomplete nor complete primary education was above 50% until 1945, but it declined rapidly in favor of (lower and upper) secondary education. The share of the combined secondary education levels peaked with 60.2% in 1980 and 1985 before it started to slightly drop in favor of postsecondary education. The educational progress in both countries over time was driven by the gradual replacement of older less-educated cohorts with better-educated young population (see **Figure 4**).

The reconstructed data show when countries have reached certain benchmarks such as *universal primary education* [64, 65] or *universal lower secondary education* [5, 65–67]. **Universal primary education** is achieved when 95% of the population aged 30–34 years have at least primary education [64, 65]. This threshold has been reached by countries at different times. For instance, while countries like the United States (1965–1970) or Canada (1965–1970) reached this goal quite early, others like Brazil or Costa Rica still have relatively large segments of their population (mostly indigenous) who do not complete the full cycle of primary education.[2] In developed countries, the progress toward **universal lower secondary education**, which arguably can be considered as the compulsory level of education, is from relevance for policies aiming at labor force participation and economic development. Universal lower secondary is operationalized based on the literature as when more than 90% of the population in the age group 30–34 years has at least lower secondary education [5, 65–67].

[2] This is possibly the case in Japan and Hungary before 1950, although the primary education category, which aggregates incomplete and completed primary education, does not allow to state that firmly.

The timing of educational gains in at least lower secondary education is quite different among the selected EDU20C countries. While countries like the United States, Canada, and Japan showed already quite early in the twentieth century, a remarkable increase in the share of the population with at least a lower secondary education, others have been lagging behind, but catching up following different paces and trajectories. Countries like Hungary, Puerto Rico, Italy, or Spain showed a quite rapid increase between the 1950s and 1970s, while countries like Portugal, Brazil, or Costa Rica have been approaching slower. Among the selected countries, Hungary (1970), United States (1975), Japan (1975), and Canada (1980) have reached universal lower secondary first, while Portugal (2015: 88.9%), Brazil (2015: 75.1%), or Costa Rica (2015: 62.4%) are still below the threshold, but advancing fast (see **Figure 5**).

The improvement of the educational composition in the selected countries over time is also visible when looking at *mean years of schooling* (MYS), which is a widely used indicator to express the quantity of educational attainment in a single number [5, 68] (see **Figure 6**). The United States were kind of a frontrunner when it comes to educational progress, also in the mean years of schooling, as they showed a MYS of about 4.1 in 1900 and reached in 2015 about 12.1. Beside the United States, also Canada (12.5), Japan (12.1), Hungary (11.5), and Puerto Rico (11.0) from the selected EDU20C, countries surpassed 10 mean years of schooling. Others like Portugal (7.1), Costa Rica (7.4), or Brazil (7.4) are still lagging behind as the population still includes a very high share of less educated elderly. For instance, in 2015, about 67.2% of the Brazilian population aged 65 years and older had primary or less education. In those countries, it will need more time until the better-educated cohorts are finally replacing the less-educated ones.

An interesting feature is that the inertia of education was quite important for all countries, as lines do not cross very often, meaning that the pace of development in education seemed to be set quite early in educational history without abrupt changes.

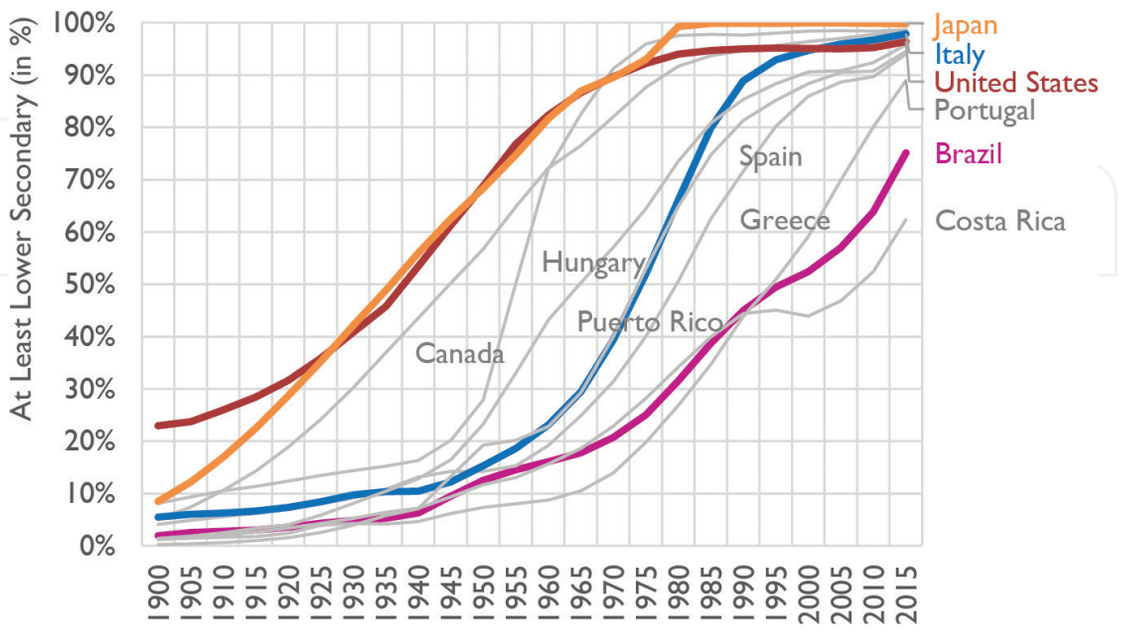

Figure 5. Share of population aged 30–34 years with at least lower secondary education by country, 1900–2015 (source: authors' calculations).

http://dx.doi.org/10.5772/intechopen.79165

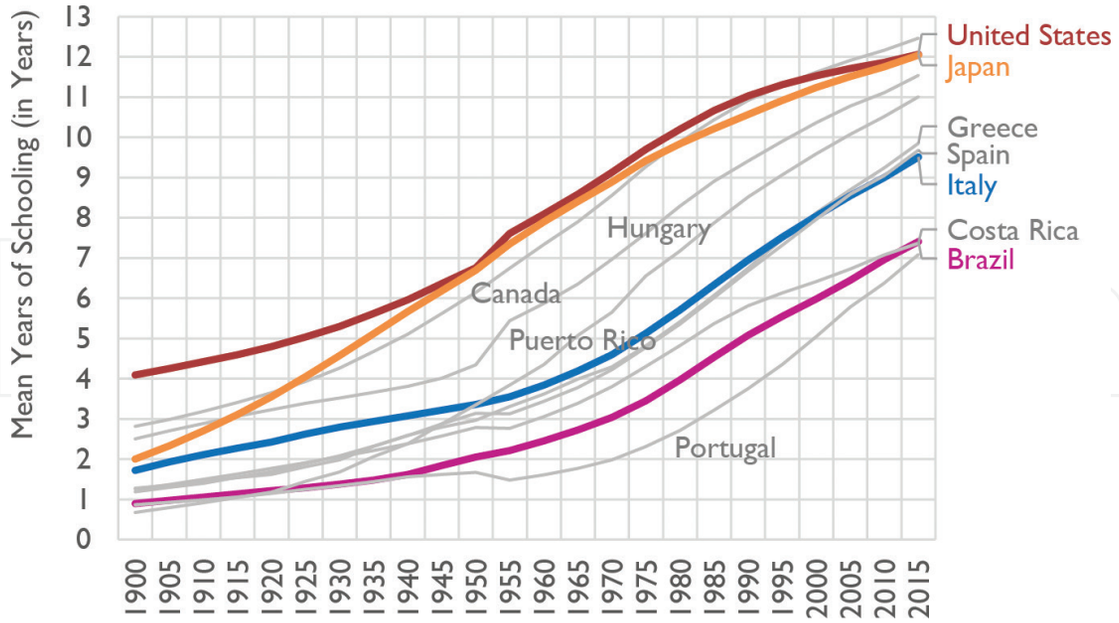

Figure 6. Mean years of schooling for total population aged 25 years and older by country, 1900–2015 (source: authors' calculations).

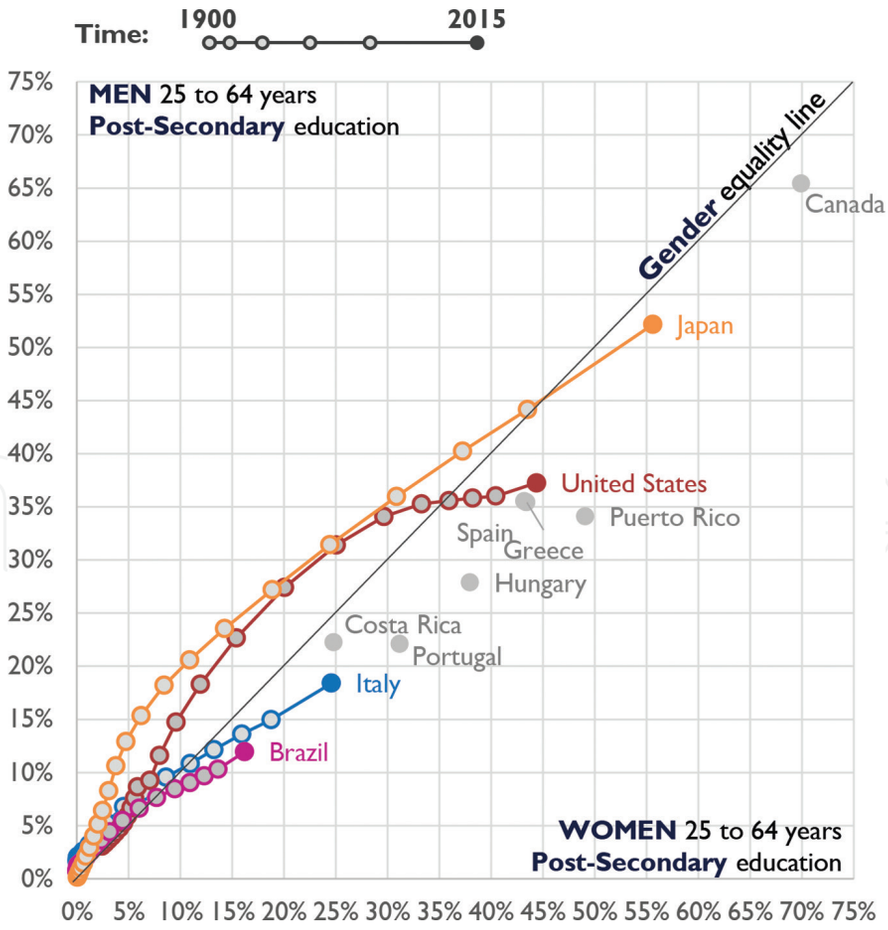

Figure 7. Share of population aged 25–64 years with postsecondary education by country and sex, 1900–2015 (source: authors' calculations).

If we concentrate on the educational progress of the population of working age (25–64 years) with postsecondary education, we see that the twentieth century witnessed a major shift in the participation of women in postsecondary education.

Figure 7 compares the changing shares of men (y-axis) and women (x-axis) with postsecondary education since 1900. Canada, Japan, and United States were frontrunners in increase in educational attainment. While men attained overall higher shares of postsecondary education compared to women (see **gender equality line**), whereby the gap has slowly diminished in many countries over the last decades. Most recently, this gender imbalance in postsecondary education has started to turn in favor of women. This phenomenon can be observed both at relatively low and high shares of postsecondary education in the population, i.e., in Brazil or Italy (low shares below 20% in 2015) vs. in Japan or USA (above 35% in 2015). The first of the selected countries to show a reverse in the gender imbalance of the population aged 25–64 years in favor of women was Puerto Rico (1980), followed by Portugal (1985) and Brazil (1990). The latest countries to experience this shift have been Japan (2015) and Canada (2010), the two countries showing the highest shares in postsecondary education for both sexes among all selected countries (see **Figure 7**).

The described process is driven by the cohort replacement of older less-educated cohorts with younger better-educated cohorts, which, when it comes to postsecondary education, are increasingly female. **Figure 8** shows the years in the reconstructed dataset when women surpassed men in their shares with postsecondary education at the age groups 25–34 years (gray) and 25–64 years (orange). Younger age cohorts that have gained wider access to postsecondary education mainly drive this reversal of the gender imbalance of the total population at working age 25–64 years. The frontrunners in the younger cohort (25–34 years) are Puerto Rico (1970), Portugal (1980), and Hungary (1980). From the selected EDU20C countries, Japan was in 2000 the last to show this shift in postsecondary education in the age group 25–34 years (see **Figure 8**).

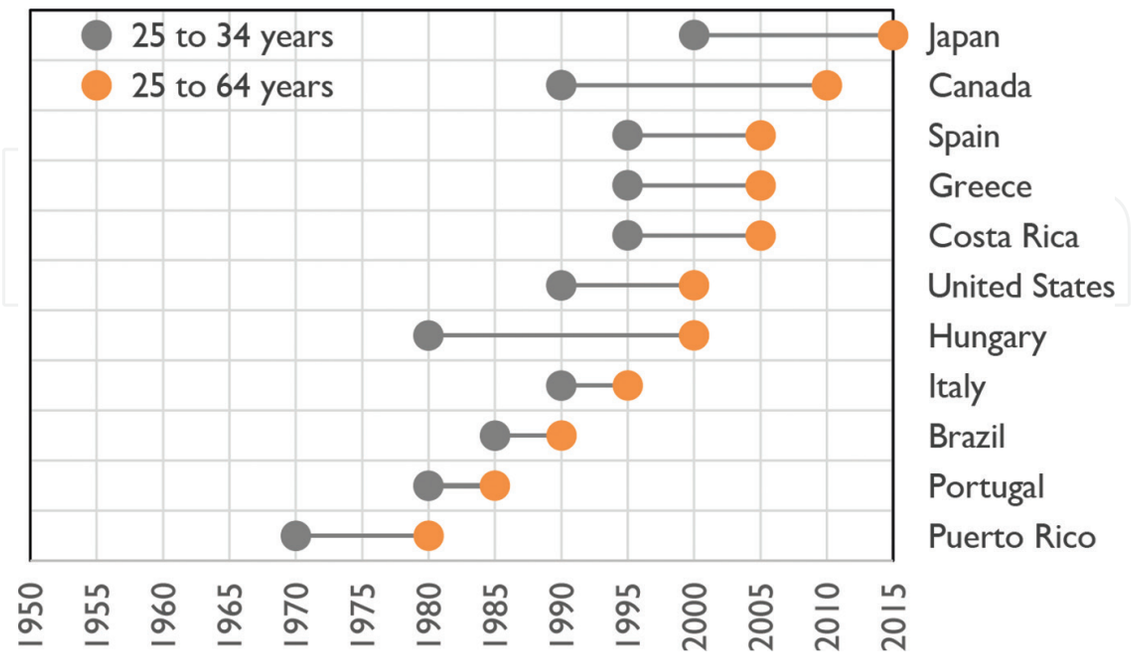

Figure 8. Years when gender imbalance in postsecondary education changed in favor of women for the age groups 25–34 years and 25–64 years, 1950–2015 (source: authors' calculations).

4. Conclusions

In the system theories of the sociology of education, investments in educational systems to increase attainment are determined by societal and economic agendas. The purpose of education systems is to evidently produce an eligible and productive workforce that has the potential to increase the national economic growth. The education system can be idealized as the medium that brings people from their primary embedment in a family system to an eligible position in the societal and economic structure of society, what inevitably creates a social stratification and societal classes. Depending on the theoretical framework, education either solidifies these class structures for the greater good to create a stable class equilibrium (i.e., structural functionalism) or enables the society to challenge those structures to initiate societal revolutions (i.e., conflict theory). The evolution of the role of education systems is connected with all kinds of political, societal, economic, technical, or industrial revolutions that challenged and redefined the roles of individuals in society. For instance, along with the third industrial revolution in the 1960s and 1970s, and the increased production and automatization due to the invention of computers and electronics, education had to redefine itself and had to create more specified education schemes in upper secondary and postsecondary education curricula. While facing the brink of the fourth industrial revolution in terms of Industry 4.0 due to Cyber-Physical Systems (CPS) and Internet of Things, the societies, labor markets and education systems all over the world will again face new challenges and transitions.

The model and dataset on population by age, sex, and education from 1900 to 2015 allows the decomposition of aspects and dynamic of education transition in terms of timing and pace. The dataset permits to follow countries through the diffusion of education along the continuum of education levels that happened with the implementation of compulsory schooling systems in the context of very diverse political regimes and in conjunction with the economic needs for a more educated and obedient labor force. While the connection between educational progress and socio-economic processes in societies are arguably linked, this dataset provides a profound basis to establish correlations among these and other processes, like demographic or technological revolutions.

Another finding of this research is the persistent existence of an education-specific gender imbalance with a changing direction of proliferation from a male- to a female-dominant educational structure, where women in higher shares than men attain postsecondary education. The question remains whether and how these increasingly higher shares of better-educated women will affect the socio-economic structure in those societies in terms of class stratification. The countries with the most progressive economic policies that integrate well-educated women in suitable labor market positions (e.g., Sweden) will increase their competitive advantage in the global economy.

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Appendices and nomenclature

a_x	**life table information:** average person-years lived in the interval by those dying in the interval [69]
EAPR	educational attainment progression ratio
EDU20C	education in the twentieth century project
IIASA	International Institute for Applied Systems Analysis
INED	Institut national d'études démographiques (engl.: Institute for Demography Studies)
INSEE	Institut national de la statistique et des études économiques (engl.: National Institute for Statistics and Economic Studies)
IPUMS	integrated public use microdata series
ISCED	International Standard Classification of Education
L_x	**life table information:** person-years lived between ages x and x + n [69]
ÖAW	Österreichische Akademie der Wissenschaften (engl.: Austrian Academy of Sciences)
${}_nq_x$	**life table information:** probability of dying between ages x and x + n [69]
S_x	**life table information:** survivorship ratio [69]
TFR	total fertility rate
UNESCO	United Nations Educational, Scientific and Cultural Organization
VID	Vienna Institute of Demography
WIC	Wittgenstein Centre for Demography and Global Human Capital
WPP	World Population Prospects
WU	Wirtschaftsuniversität Wien (engl.: Vienna University of Economics and Business)

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