

Yidan Prize
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Education: The key to global sustainable development

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Foreword

Most of us can recall conversations with our grandparents: “How the world has changed! In my day...”. They are right. The world has changed. Over time, education has helped us to live more prosperous, more secure, and longer lives than ever. It’s enabled the vibrant societies and civic spaces we enjoy today. It’s helped us to build institutions and technologies that have reshaped the way we live.

We have changed too. New advances in neuroscience are showing how our physical and emotional selves develop, and how education shapes those processes.

The Yidan Prize Foundation is pleased to present this report by Wolfgang Lutz and Claudia Reiter of Wittgenstein Centre for Demography and Global Human Capital. It neatly summarizes decades of research on the benefits of education, adding force to the arguments through analysis of rich and unique databases created by the Centre.

Moreover, the paper is forward looking. It discusses the biggest challenges facing us today — sustainability, growth, and institutions — and argues that education needs to be a global priority.

Education will be the foundation of progress in the future, as it was in the past — but with an important caveat: in a globalized world, we are all in this together. The majority of the world’s young people are growing up in the most resource constrained countries, and their education needs to be everyone’s concern. This generation will profoundly shape issues of climate change, jobs and technology, health and well-being, and governance. Unlocking their potential is our best hope for a better future.

Advances in the science of education, technology, understanding development in the early years of life, economics, and neuroscience provide the fuel for education systems to rise to the challenge. If we invest in better education for all, we will be able to say to our grandchildren “How the world has changed — for the better!”

Dr Christopher Thomas

Director of Partnerships, Yidan Prize Foundation

At the Yidan Prize Foundation, we bring together people and ideas that are already changing the world for the better. We’re building networks of the world’s brightest thinkers — including educators, economists, statisticians, and neuroscientists. With this increasing wealth of information showing us that education is the fundamental force for change, we inform and influence policymakers to invest in all our tomorrows.



Introduction

As long as scholars have reflected about the determinants of long-term human well-being and the priorities to be set in terms of policies to move towards this goal, education has figured very prominently among them.

The longest documented intellectual traditions both in the East (Confucius, Laozi, and Buddha) as well as in the West (Socrates and Plato) have placed priority emphasis on learning and education as a necessary prerequisite for empowered participation in society. 500 years ago, the Reformation of Martin Luther first demanded universal literacy for everybody (including the “lowest maid”) to be able to read the bible directly. As a secular side effect of this focus on universal reading skills, the Protestant territories were the first in the world to show high literacy rates, which subsequently resulted in better health, economic growth, and good governance (Lutz, 2017). After WWII, the right to education has been elevated to the level of universal human rights and in the Millennium Development Goals (MDGs) universal primary education was listed as one of the key goals. The Sustainable Development Goals (2015-2030) then included the even more ambitious goal of high-quality primary and secondary education for all girls and boys in all countries. While there seems to be broad theoretical agreement on these goals, in reality they are far from being achieved and education is rarely given the top priority it deserves to have.

In this paper we will attempt to give a very concise summary of the extensive research that shows that education is an essential prerequisite for humanity’s most important aspirations, including health and avoidance of premature death, ending poverty and hunger, improving institutions and participation in society, technological innovation and economic growth, voluntary choice of family size and even enhancing adaptive capacity to already unavoidable climate change. Much has been written on these topics before with respect to specific countries, specific indicators and specific mechanisms of influence. However, only recently a comprehensive global data set on full educational attainment distributions by age and gender has become available for all countries from 1950 onwards with scenarios until the end of the 21st century. Only such a harmonized data set on long-term educational attainment of adults of all ages allows for the systematic analysis of the benefits of human capital and how they gradually evolve as better educated young cohorts move up into the prime working ages and bring their additional skills to fruition. It has long been known that education is a longer-term investment which in the short run brings mostly costs (having children in school serves a social function but matters for productivity only when they leave school) and only such consistent data on long-term trends can quantitatively illustrate the multiple mid- to long term benefits of such investments. This is why in the following section of this paper we begin with describing this newly available long-term global data base on educational attainment.

“Education is an essential prerequisite for humanity’s most important aspirations.”



Measuring and modelling human capital formation by age and gender since 1950

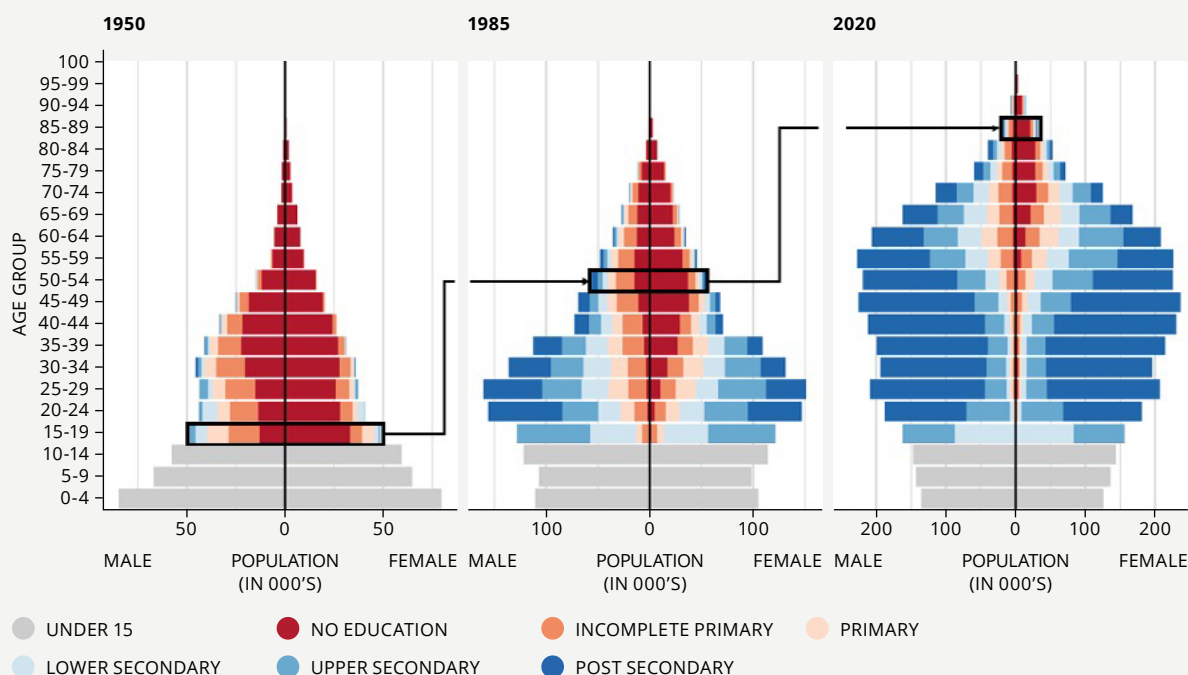
Data on educational attainment distributions by age and gender have been collected for many years in censuses and surveys around the world, but internationally comparable consistent time series data are still difficult to obtain. Several research attempts have been made to reconstruct and harmonize time series on levels of educational attainment which are consistent over time and between countries. One of the first approaches, which was primarily developed by Barro and Lee (1993, 2001) and later on adopted by other researchers such as Cohen and Soto (2007) or De la Fuente and Doménech (2000), was to estimate missing data points from the very fragmentary available information by interpolation and using the more easily available information on school enrolment rates. Enrolment data, however, tend to suffer from many flaws — in particular over-reporting — especially in countries with poor statistical systems (Chapman & Boothroyd, 1988; Jansen, 2005; Samoff, 1991), rendering its translation into educational attainment highly problematic. An attractive alternative is the application of demographic back-projections methods which assure age-specific trajectories that are by definition consistent along cohort lines (Lutz et al., 2007). This approach which applies the powerful tool of multi-dimensional population modelling to age, gender and level of highest educational attainment makes use of the fact that formal education is mostly completed by young adulthood and typically remains invariant over the rest of the life cycle thereafter. In other words,

when we know how many 60-year-old women in a given year have at least completed secondary education, we have a good basis for estimating how many 30-year-old women 30 years ago had this level of education after some adjustments for mortality and migration.

The basic logic of the multi-dimensional cohort-component model is illustrated in Figure 1, depicting the education-specific population pyramids of Singapore, a country with one of the fastest and most remarkable educational expansions in human history. In 1950, Singapore was still a poor developing country with a very young population structure and virtually all women above the age of 40 had never attended any school. For the pyramid in 1985, we clearly see that the entire education pattern has essentially moved up the age pyramid by 35 years. By then, the better-educated younger cohorts had reached the main working ages which also was a factor driving the rapid economic growth of that time. By 2020, the education structure had moved up another 35 years and as a consequence of improved female education, birth rates strongly declined. In seven decades, Singapore's population has transformed step by step in a regular and mostly predictable way from being a least developed society to one of the most highly developed and richest in the world. This model of population change along cohort lines has also been generalized to a model of social change with predictive power called demographic metabolism (Lutz, 2013).

“In seven decades, Singapore's population has transformed step by step in a regular and mostly predictable way from being a least developed society to one of the most highly developed and richest in the world.”

FIGURE 1. POPULATION PYRAMIDS BY EDUCATIONAL ATTAINMENT, SINGAPORE, 1950, 1985, 2020



SOURCE: WIC DATA EXPLORER

This multi-dimensional demographic model has been used to reconstruct educational attainment distributions for decades back and equally to project for decades into the future. Researchers from the Wittgenstein Centre for Demography and Global Human Capital (WIC) have produced several rounds of reconstructions and projections gradually expanding the time horizon, the number of countries covered, and the number of educational attainment categories included (Goujon et al., 2016; Lutz, Butz, et al., 2014; Lutz et al., 2007, 2018; Lutz & KC, 2011; Springer et al., 2019). The reconstructed data set now covers the period

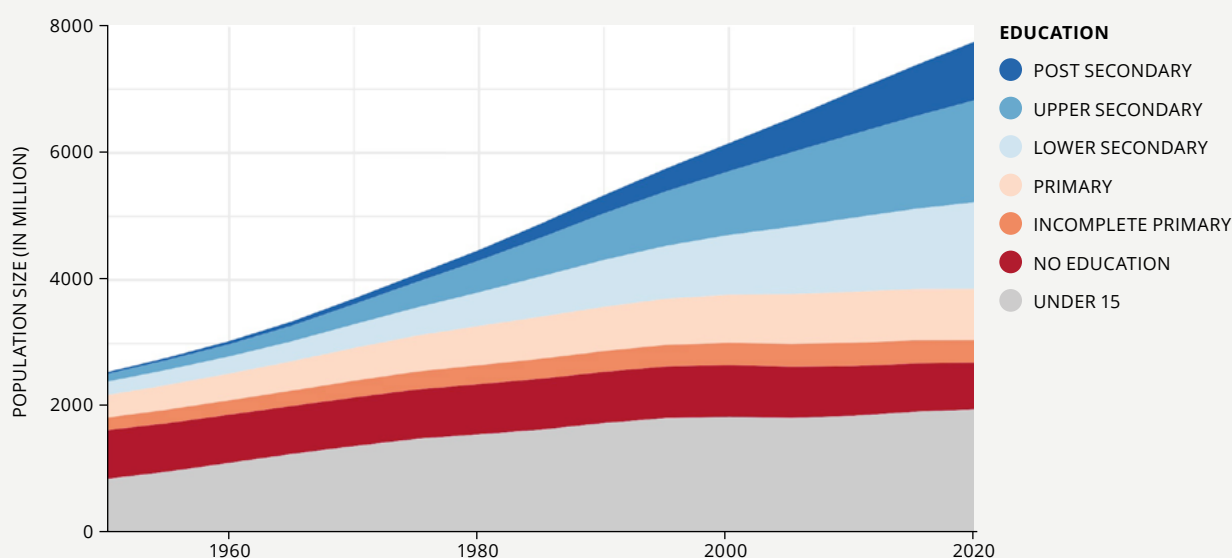
1950-2015 for 185 countries and six education categories. For the period 2015-2100 a number of alternative scenarios have been calculated as will be discussed in the sections below. This WIC data set thus offers the world's most comprehensive harmonized dataset on national populations by age, sex, and educational attainment with data being consistent across time, cohorts and countries. The data are available and presented in graphical form at the WIC Human Capital Data Explorer: <http://dataexplorer.wittgensteincentre.org/wcde-v2/>.

It is worth noting that compared to other education datasets that only give the mean years of schooling as the educational attainment indicator (Cohen & Leker, 2014; Cohen & Soto, 2007; Morrisson & Murtin, 2009), there is much to be gained from breaking down this aggregate measure into both the full distribution of educational attainment categories (capturing the inequality in education) and into different age groups, hence revealing inter-cohort changes that drive many of the socio-economic consequences that come from improving human capital (Lutz et al., 2018). As shown in the example of Singapore (Figure 1), this disaggregation is particularly relevant for countries that have recently gone through rapid educational expansions, with younger cohorts being much better educated than older ones. It can be shown that e.g. economic growth was most rapid during the time when the better educated young cohorts entered the prime working ages. As will be discussed below, this more detailed age-specific account of educational attainment also allows for a more accurate assessment of the returns to education.

Educational attainment since 1950 around the world

Figure 2 depicts the total world population by six levels of educational attainment from 1950 to 2020. The increase in educational attainment is impressive: while in 1950, only roughly one fifth of the world's population aged 15 years or older had completed lower secondary education or higher, this proportion has more than tripled to 67 percent in 2020, or, in absolute terms, increased by more than 3.5 billion people. During the same period, the share of people aged 15+ who never went to school diminished from almost half of the world's population (45.6%) to only 12.6% in 2020. In absolute terms, however, the population without any education has stayed roughly unwavering, from 763 million in 1950 to 729 million in 2020. Nevertheless, the gains in human capital are remarkable, particularly considering that the world population increased from 2.5 billion to 7.8 billion during this period, making school expansion an uphill battle.

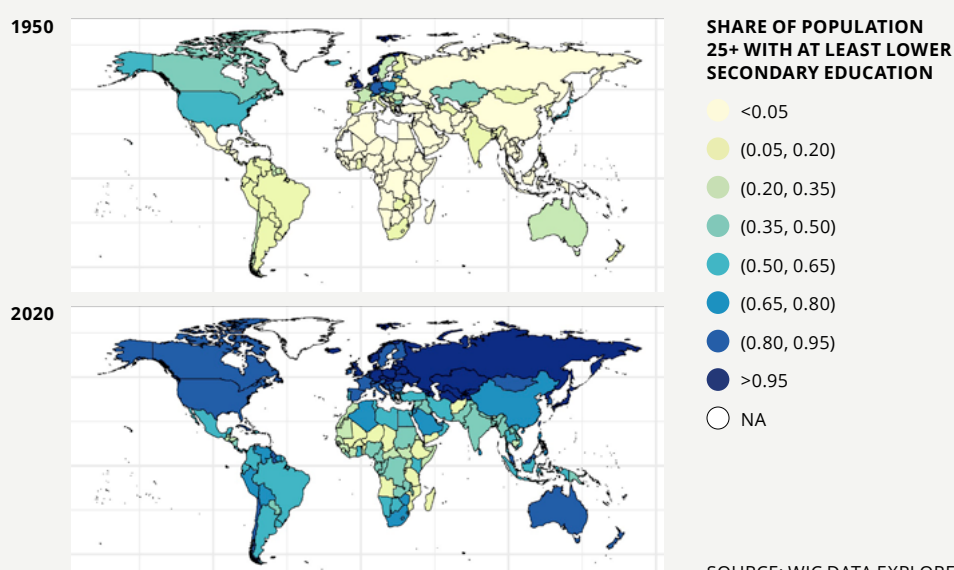
FIGURE 2. WORLD POPULATION BY EDUCATIONAL ATTAINMENT, 1950-2020



Albeit expansion in formal education has recently happened also in the poorest parts of the world, inequality in educational attainment between countries and regions remains relatively high. Figure 3 shows two maps comparing the educational attainment by country — summarized by the share of population aged 25 years or older with at least lower secondary education — for the years 1950 and 2020. While in 1950, in more than two thirds of the countries less than ten percent of adults had attained junior secondary education — with the few positive exceptions being located mostly in Europe and North America — the situation is much more heterogeneous in 2020. Significant improvements in terms of educational attainment have happened almost everywhere; however, the extent and pace of these improvements differ substantially between countries and regions. Some of the most impressive examples of acceleration in terms of educational attainment can be found in Asia: China, South Korea, Singapore, or Russia, for example, have all increased by about 80 percentage points or more. On the other end of the spectrum, in many

Sub-Saharan African countries, only small parts of today's adult population have attained at least lower secondary education, with a record low of only 6.8 percent in Niger. For these countries, meeting SDG 4, “to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all” by 2030 will be an immense challenge if past trends of educational attainment and demographic developments continue in the future. On top of that, the widespread closure of schools due to COVID-19 puts additional pressure on the countries' human capital formation: Sub-Saharan African classrooms have been fully or partly closed for longer than the global average, with remote learning being hardly possible considering that half of all Africans live without electricity. Many children, particularly girls, are likely to never go back to school, potentially resulting in a lost generation of young people who may lack any prospects and opportunities (The Economist, 2021).

FIGURE 3. SHARE OF POPULATION 25+ WITH AT LEAST LOWER SECONDARY EDUCATION, 1950 AND 2020

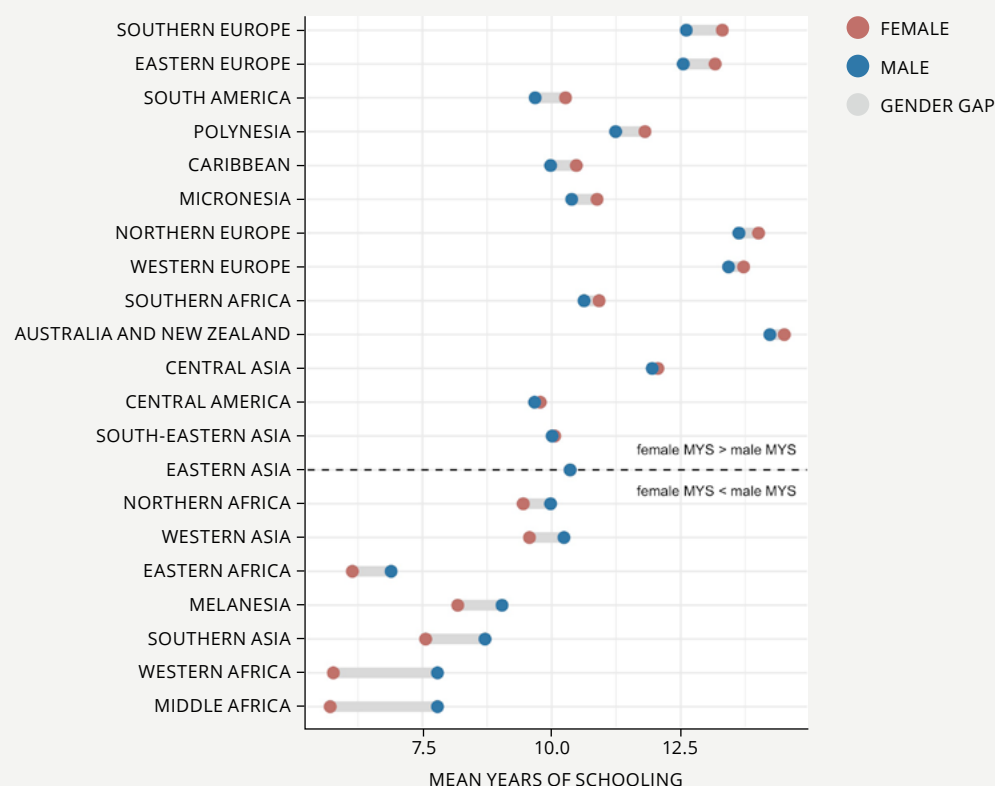


Differences in educational attainment can not only be identified between countries, but also between men and women. The gender gap has been declining over the last decades in most countries, but women have still not caught up with men. On a global scale, women still considerably outnumber men in terms of the population 15+ without any education (451 million women vs. 278 million men in 2020), and — contrary to men — the absolute number of uneducated women has hardly changed over time (446 million women vs. 318 million men in 1950).

Paradoxically, at the upper end of the education spectrum, the gender gap has been reversed with women having more education than men in many rich countries. In fact, this has already happened in most of the world regions, as can be seen on Figure 4 that depicts the gender gap in mean years of schooling (MYS) for the age group 30-34 (the age when education is usually completed). In wealthier regions, gender differences in terms of mean years of schooling are low, with women having a minor advantage compared to men. South Europe shows the largest positive gender gap: on average, Southern European women aged 30-34 have spent 0.7 years longer in school than their male counterparts. On the other end of the spectrum are African regions, Southern and Western Asia as well as Melanesia. In these regions, women are still considerably disadvantaged in terms of access to school, with the largest gaps in Western and Middle Africa, where 30-34-year-old males, on average, had more than two schooling years more than women. Given that, almost universally, better educated women consistently want fewer children, have greater autonomy in reproductive decision-making, and more knowledge about and access to contraception (Bongaarts, 2010; Cleland & Rodriguez, 1988), female education needs to be a policy priority not only to improve the life of individual women, but also considering the demographic development of a country.



FIGURE 4. GENDER GAP IN MEAN YEARS OF SCHOOLING (FEMALE MYS MINUS MALE MYS) OF THE POPULATION AGED 30-34 BY WORLD REGION, 2020; REGIONS ARE SORTED BY THEIR GENDER GAP



SOURCE: WIC DATA EXPLORER

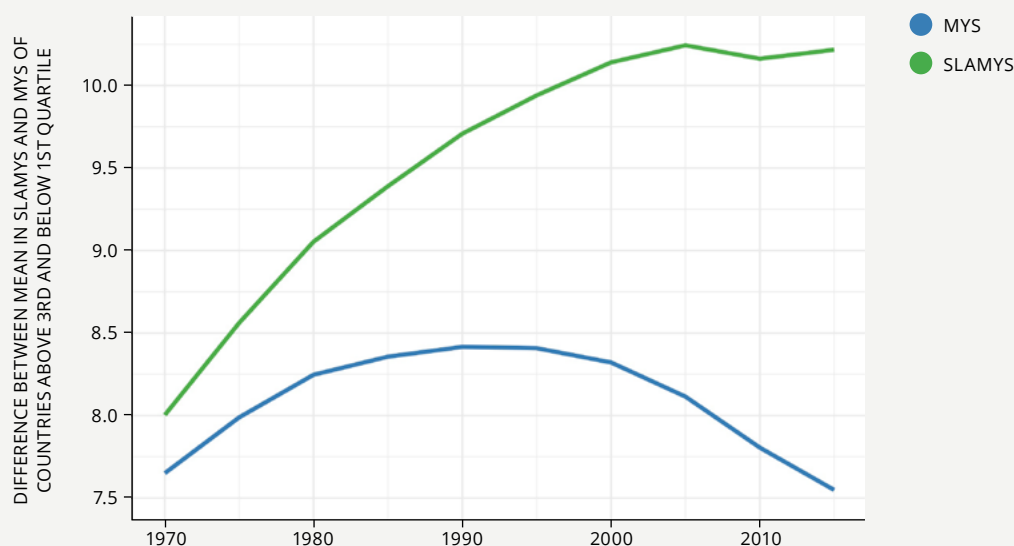
Actual skills also matter

Finally, albeit this paper has a clear focus on formal educational attainment, the quality dimension, i.e. the skills people actually have, as well as content and direction of education are likewise important. Education quality in terms of measurable skills has recently been shown to also matter greatly for many of the benefits of education, whether it is about earnings (Mateos Romero et al., 2017) or health (Kakarmath et al., 2018) on the individual level, or about economic growth (Hanushek & Woessmann, 2008, 2012) and employment rates (Li et al., 2016) on the aggregate level.

Recent research suggests, however, that despite the massive educational expansions that happened around the globe, learning outcomes, i.e. the cognitive skills people have, are still relatively poor in many countries, with the negative implications of the current COVID-19 pandemic on schooling possibly exacerbating the situation. In Lutz et al.

(2021) the authors estimated that the gap between mean years of schooling (MYS) and skills in literacy adjusted mean years of schooling (SLAMYS) — a new measure of human capital that considers not only the quantity but also the quality of education — has increased. In other words, the impressive recent gains in the expansion of schooling did not lead to a corresponding increase in literacy skills of the working-age population — particularly in poorer countries. When school inputs and government spending in education are low, many education systems struggle to cope with the increase in the number of students due to massive educational expansions. This quantity-quality tradeoff is, however, not inevitable: some countries, notably Japan, Finland and South Korea, have managed to display a remarkable increase in skills over time, with growth rates of SLAMYS being partly even higher than those of MYS.

FIGURE 5. DIFFERENCE BETWEEN THE MEAN OF COUNTRIES ABOVE THE 3RD QUARTILE AND THE MEAN OF COUNTRIES BELOW THE 1ST QUARTILE IN MYS AND SLAMYS, 1970-2015



SOURCE: LUTZ, REITER, ET AL., 2021

To illustrate these findings, Figure 5 depicts the differences between quartiles of the distribution of MYS and SLAMYS for 185 countries ranked by their average level over 1970 to 2015 and grouped into quartiles accordingly. The picture shows the change over time in the difference between the mean of the countries above the highest quartile and the mean of the countries below the lowest quartile. For MYS, this difference peaked around 1990 to 1995 and has since declined because some of the countries with very low education levels have made progress in terms of expanding formal education. However, the trend over time in SLAMYS shows no such reversal. The gap between highly skilled and low skilled populations is widening and has increased to the equivalent of over 10 years of schooling.

This widening global gap in the literacy skills of the working-age population will have significant implications for disparities among countries in their economic development, health, and well-being, particularly in the current transition to knowledge societies and the digital transformation. Given the great relevance of these findings, better and more internationally comparable data on adult skills are required to help policy makers achieving not only universal access to education but also ensuring that students actually learn skills and competencies essential for success in daily life.

“The gap between highly skilled and low skilled populations is widening and has increased to the equivalent of over 10 years of schooling.”



How education has served development and human well-being

Human capital is widely recognized as a fundamental prerequisite for economic development and the building and maintenance of good and effective institutions. What is less well known is the decisive role that empowerment through education plays for human health and survival, including the avoidance of premature death of ourselves and the people we care about. Female education is also a key determinant of the conscious choice of family size and thus the decline of very high birth rates in many countries with negative implications for the well-being of future generations (smaller families allow more investment in the health and education of children, particularly in countries where much of the burden for social expenditures falls to the household). Because these important demographic impacts of education are literally questions of life and death, we will first discuss them before coming to the more conventional analysis of economic implications.

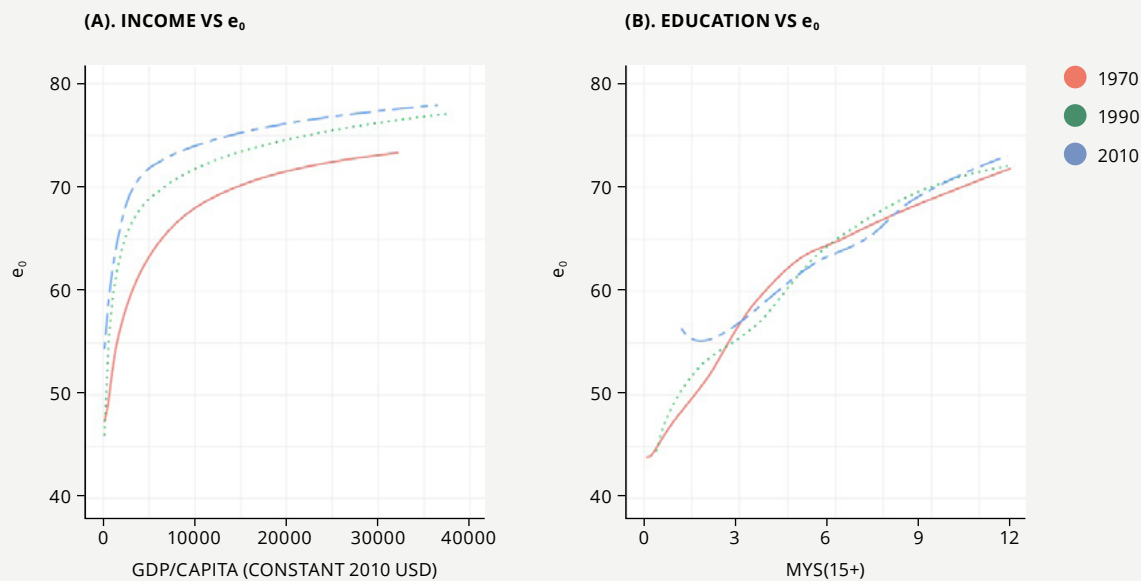
Education and cognition as determinants of health and demographic transition

In much of contemporary social science, education is primarily seen as a marker for socioeconomic status or social class. Typically, not much attention is given to the question how education directly affects our minds, our cognition and the way we think and perceive the world. As we will discuss in the following section on the causal mechanism, there actually is a lot of scientific evidence that education directly affects our abstraction skills and the degree of rationality in our choices as well as the length of the planning horizon for conscious behavior. In other words, education is a factor that greatly contributes to strengthening cognitive capacity. Most people use this enhanced cognitive capacity to try to improve their lives — and the most important prerequisite of having a good life is to continue to stay alive, i.e. avoiding premature death (Lutz, Striessnig, et al., 2021).

The secular mortality decline first started in 19th century Sweden with a decline in child mortality followed by adult mortality toward the end of the century. It then spread all across Europe and the Americas and after WWII reached most of the developing countries, with life expectancy at birth at the global level increasing from around 45 years in 1950 to currently above 70 years. What does the literature say about advances in knowledge and education as causes of mortality decline? Cutler, Deaton, and Lleras-Muney (2006) highlight this connection in their comprehensive look at the determinants of mortality. In particular with respect to the differences among social groups within countries, the authors conclude that education is the primary determinant of mortality differences — also when contrasted to the role of income. This conclusion acknowledges a long trajectory of research that has shown a stronger and more consistent effect of education than of income (Mechanic, 2007; Mirowsky & Ross, 2003; Smith, 2007). Recent evidence on inequality of health in Europe also confirms the dominant role of education, which Mackenbach (2019) attributes to a large extent to real causal effects of education rather than possible selection or third factors.

In terms of drivers of the impressive global improvements in life expectancy of the past century, the Preston Curve (Preston, 1975) has become a major point of reference. It illustrates the global relationship between GDP per capita on the horizontal axis and life expectancy at birth on the vertical axis up to the 1960s. This work reveals a strong but diminishing effect of increasingly higher incomes on life expectancy, as well as an upward shift of the curves over time, which has been interpreted as the effect of medical progress and health care on top of the effect of income. A recent update of this curve is given in Figure 6. It shows this global level relationship for three curves with data for around 1970, 1990 and 2010 and compares it to the relationship between educational attainment and life expectancy.

FIGURE 6. RELATIONSHIP BETWEEN GDP/CAPITA (LEFT – A) AND THE MEAN YEARS OF SCHOOLING OF THE ADULT POPULATION (RIGHT – B) TO LIFE EXPECTANCY AT BIRTH (VERTICAL AXIS) FOR ALL COUNTRIES IN THE WORLD IN 1970, 1990 AND 2010 (CURVES FITTED THROUGH DATA POINTS)



SOURCE: LUTZ & KEBEDE, 2018

This comparison suggests already visually that increasing educational attainment explains the observed life expectancy improvements much better than increasing income. The relationship is more linear, implying that even at an already high level of education further increases are associated with additional gains in life expectancy and there is no unexplained shift of the curve over time. Lutz and Kebede (2018) also conduct multi-variate statistical analyses confirming this better explanatory power of education. They conclude that the widely assumed direct association between income and health is likely of a spurious nature, since better education has positive consequences on both higher income and higher life expectancy thus resulting in a positive association between the two. For sorting out the complex issue of causality

in this interacting triangle of education, income/ economic growth and health/life expectancy it is very helpful to focus on the above-described time lag between the time schooling happens and the time in which the educational attainment of adults matters for their income and health. While income and health has also been shown to affect schooling, they cannot directly affect adult educational attainment several decades after the schooling has happened. Hence, there is no simultaneity of effects but a clearly identifiable time structure. In this respect, the cohort-specific analysis of education described in this paper is a key to sort out the vexing chicken and egg problem in socioeconomic development.

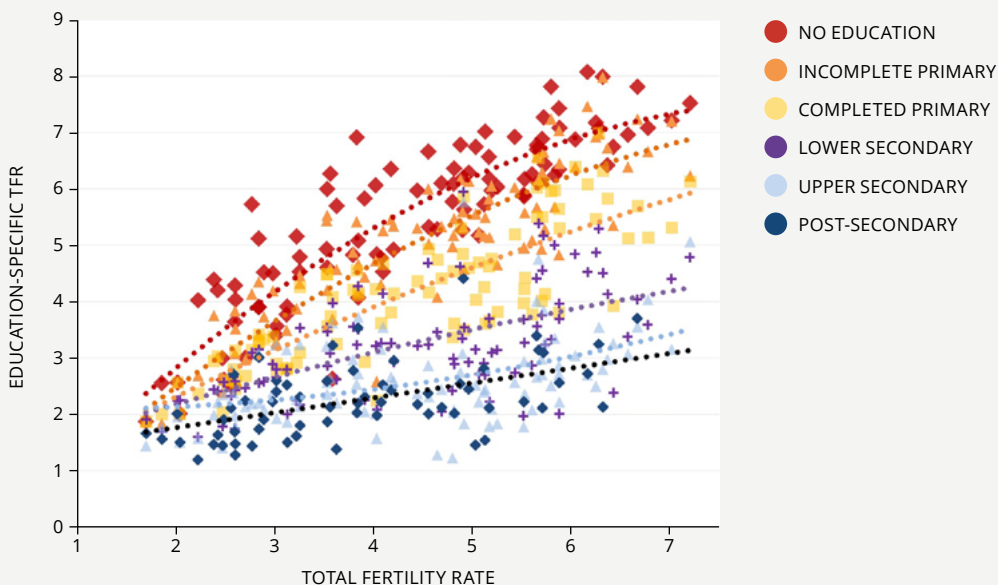
Education and the end of world population growth

Birth rates have started to decline from traditional high and uncontrolled levels in the 19th century in France, during the first half of the 20th century in the rest of Europe, and thereafter in an increasing number of countries. This global fertility transition — both historical as well as ongoing in Africa — from having as many children as God gives to having as many as parents want is closely linked to the spread of literacy among broad segments of the population. Today, the overwhelming proportion of the world population has already become literate and entered into or passed through this major cognitive and cultural transition that has led to conscious planning of family size. It is important to stress that this is not just a transition linked to Western culture but rather a universal development linked with abstraction skills that are associated with literacy and formal education also of a non-Western type.

This cognitive transition is a necessary precondition for a lasting fertility decline, but not the only precondition. As clearly specified by Ansley Coale (1973), there are three such necessary preconditions: (1) fertility must be within the calculus of conscious choice; (2) lower fertility must be advantageous; (3) there must be acceptable means for preventing births. While the first precondition reflects the transition from fatalism to planned behavior in family formation, the second one refers to the costs and benefits of having children (not only economic but also in terms of mothers' health), and the last one refers to the means and availability of contraception.

Consistent patterns of fertility differentials by mothers' education have been found from medieval times to the present in virtually all countries and at very different stages of economic developments (Skirbekk, 2008). The differentials are particularly pronounced in countries during the process of demographic transition when death rates have already fallen and birth rates start to fall after a certain time lag (Fuchs & Goujon, 2014). The empirical evidence for a strong fertility-reducing effect of education in today's high- and medium-fertility countries is overwhelming, although there are some country-specific peculiarities. Figure 7 shows comparable data based on recent Demographic and Health Surveys (DHS) for 58 lower income countries, with fertility levels (TFR) given for six different groups of women according to their highest educational attainment, ranging from no formal schooling at all to post-secondary education. It shows that within the same countries there is a wide spectrum: in some cases, uneducated women have, on average, six or more children, while highly educated women have less than two children, i.e. levels similar to Europe today. Averaged across all countries (dotted lines), there is a consistent ordering of fertility levels according to the level of education. The highest fertility levels today are in Africa, where studies on the causes of educational fertility differentials consistently show that better educated women want fewer children, have greater autonomy in reproductive decision-making, more knowledge about and access to contraception, and are more motivated to practice family planning (Bongaarts, 2010). It has been shown that different future scenarios of female education alone (assuming otherwise identical patterns of education-specific fertility rates) can cause difference in world population size of more than one billion already by mid-century (Lutz & KC, 2011).

FIGURE 7. FERTILITY BY LEVEL OF FEMALE EDUCATION IN HIGH-FERTILITY COUNTRIES, 58 DHS COUNTRIES (MULTIPLE TIME POINTS), SORTED BY AGGREGATE TFR IN COUNTRY



SOURCE: DHS

Fertility declines to levels at or around replacement level (i.e. two surviving children per women) are the only benign way of stabilizing world population growth, which is widely assumed to be a major impediment to global sustainable development. There is abundant literature on the benefits of limiting family size both at the individual level (from improving household income and health to liberating women) as well as at the aggregate level as detailed in the following section. The macro-level benefits have been described under the notion of a demographic dividend resulting from the combination of improving education and a changing age-structure as a consequence of more moderate fertility levels (Lutz et al., 2019). This combined force has been shown to explain a significant part of the economic growth of some of the most successful countries including the Asian tigers.

Visit the Wittgenstein
Centre Human Capital
Data Explorer

Explore, select and download
population data and figures by level of
education for all countries since 1950
and scenarios for the 21st century:

<http://dataexplorer.wittgensteincentre.org/wcde-v2/>

Human capital fosters economic growth and better institutions

Human capital is a fundamental prerequisite for economic progress and good institutions as has been shown by the literature over and over. At the level of individuals, empirical evidence shows beyond any reasonable doubt that more years of schooling, on average, lead to higher income. This pattern can be found in virtually all countries and discussions only concern the specific patterns of benefits from different kinds of education. At the macro-economic level, however, the empirical evidence relating changes in education measures to economic growth has been more ambiguous until recently. Many authors suggested that this may be due to problems with the global empirical data on human capital (Cohen & Soto, 2007; de la Fuente & Doménech, 2006; Pritchett, 2001). Indeed, the usually used education indicator in the form of mean years of schooling of the entire adult population above age 15 does not reflect the often marked changes between the educational attainment of older cohorts and younger, typically better educated cohorts. As illustrated in Figure 1 for the case of Singapore, under conditions of very rapid education expansion, the young adult cohorts who are decisive for economic growth can already be highly educated while the education indicator across all ages can still be depressed due to the largely still uneducated older cohorts. In analyses that explicitly consider the age structure of human capital growth, regressions unambiguously confirm the key role of human capital in economic growth (Lutz et al., 2008). In addition, when utilizing the full range of age-specific educational attainment distributions (i.e. the colored population pyramids as shown in Figure 1) in economic growth regressions, findings reveal great policy relevance: for poor countries with very low levels of education, only the combination of universal primary education together with secondary education for broad segments of the population

results in the kind of rapid economic growth that has the potential to push countries out of poverty (Lutz et al., 2008). This important new insight is also reflected in the SDGs: while the earlier MDGs only called for universal primary education, SDG4 calls for universal high-quality primary and secondary education.

Another series of recent studies highlights the importance of improving education for the quality of institutions. Some development economists see institutions as the key factor for development (Acemoglu et al., 2005) but good institutions do not fall from heaven nor can they be imposed from outside. Rather, they are gradually built up by informed and empowered people. The same is true for the spread of liberal societies. Following Lipset (1959), an increasing level of education helps individuals to develop a stronger sense of civic duty and greater interest in good governance and institutions, thus leading to more political participation. Series of comprehensive econometric studies based on age-specific educational attainment distributions of men and women in 120 countries since 1970 show that improvements in education not only lead to generally more effective institutions, but also turn out to be a significant determinant of civic participation, investment rates, life expectancy and other socioeconomic indicators (Lutz et al., 2010). With respect to gender differentials, these findings also show that an increase in female relative to male education actually enhances these positive effects of education. Most of these empirical findings depend on a proper specification of changing human capital by age-cohort and gender.

Education and resilience to environmental change

In the analysis of climate change, the attention has recently shifted from an earlier almost exclusive focus on mitigation, i.e. reducing greenhouse gas emissions, to adaptation, i.e. coping with the consequences of already unavoidable changes of the climate. Much of the ongoing research in the field of adaptation analysis, however, is based on the very problematic assumption that the projected climate conditions for the second half of the century somehow encounter societies in the same conditions we see them today. However, we know for sure that not only the climate will be changing but also societies will be different in the future (Lutz & Muttarak, 2017) — as shown above for their age and education compositions which are likely associated with very different economic, scientific and public health capabilities. In addition, migration and differential growth will lead to different settlement patterns. Disregarding such future social change in the analysis of resilience is misleading. It has been clearly demonstrated that education is a key determinant of differential vulnerability both at the individual and the

societal level (Butz et al., 2014; Lutz, Muttarak, et al., 2014). At the individual level, it is the better access to information, the better abstraction skills and longer planning time horizons as well as the typically better income and health resulting from education. Box 1 describes one finding clearly demonstrating this effect. At the aggregate level, the effect happens through the above described importance of education for improving institutions and governance that also include warning systems and general protective policies. The Shared Socioeconomic Pathways (SSP) scenarios to be described in the following section operationalize these important insights in terms of specifying alternative degrees of socioeconomic challenges to climate change adaptation through different future trajectories in human capital formation (KC & Lutz, 2017; Riahi et al., 2017). These findings on the key role of education in managing adaptation also have consequences for the allocation of resources, such as the pledged \$100 billion per year of the Green Climate Fund to help developing countries, which tends to focus on environmental engineering. The subtitle of a Policy Forum in *Science* on this issue succinctly summarizes our point saying “Fund more educators rather than just engineers”.

“...Good institutions do not fall from heaven nor can they be imposed from outside. Rather, they are gradually built up by informed and empowered people.”

Case study:

Lifesaving abstraction skills in Indian Ocean tsunami

When on 26 December 2004 an earthquake measuring 9.1 on the Richter scale occurred off the coast of Sumatra (Indonesia) a series of massive tsunami waves of up to 30 m hit extended sections of coastline in Indonesia, Thailand, India and other countries, essentially without any previous warning.

There were an estimated 330,000 direct fatalities with many times those numbers wounded and displaced. The worst affected region was the Aceh province of Indonesia. While almost everybody was taken by surprise by this event, several studies have shown that not all population groups were equally affected and that in particular differentials by education were significant. By coincidence the base line survey for a major Indonesian household panel was taken shortly before the tsunami and the subsequent rounds of the survey allowed for a rather detailed follow-up (Frankenberg et al., 2013). With a focus on Aceh, the study showed that more educated people were less exposed to the risk, were less vulnerable when affected by the risk and in particular were significantly faster in recovering mentally and economically from damage.

A few years later, a natural experiment in the region helped to identify the mechanisms by which education reduces disaster vulnerability even more clearly. On 11 April 2012 another strong earthquake (magnitude 8.6) happened in the same regions and the meanwhile installed tsunami warning systems were activated. Fortunately, the tsunami didn't occur because it was a slip-strike earthquake with lateral movement of tectonic plates that did not lead to a vertical displacement of water. Another empirical study soon after this event focused on the Thai province of Phang Nga, which was the hardest hit Thai province in 2004 and a major destination for tourists as well as internal labor migrants.

This study focused on disaster preparedness and assessed how people reacted to the tsunami warning in 2012. Here very interesting differentials by education showed up. Of the people who were already in the region in 2004 and had experienced the tsunami then, virtually all — irrespective of their education — knew what to do after the warning and took the right protective measures. Among those who had moved to the region after 2004, however, a clear divide appeared between those with better education who also knew how to react to the warning and those with low education who tended to react helplessly without knowing what to do (Hoffmann & Muttarak, 2017; Muttarak & Pothisiri, 2013). The most plausible explanation for this pattern is that the better educated people could better think of the abstract and not yet experienced possible tsunami and draw the right conclusions, whereas the less educated were not in the same way able to imagine the counterfactual they had not yet seen. But other factors, such as better access to information, can also have played a role in this.

At the global level, this important role of education in enhancing societies' adaptive capacity to climate change has also been confirmed. In particular, the demographic metabolism model that underlies the modelling of educational attainment changes presented in this paper can also be used to forecast adaptive capacity according to different scenarios (Lutz and Muttarak 2017). Rapid social development driven by rapid improvements in the educational attainment of populations will make future societies thus more resilient to environmental change.



The causal mechanism: how education changes our brains, our way of thinking and our behavior

While there is abundant literature on the association — and in many cases the causal nature of influence — between improvements in education and the progress in many desirable development outcomes as described above, much less has been written about the mechanisms of causation itself. Many studies refer rather vaguely to “changing socioeconomic status” without saying what aspects of this status make the difference. In fact, there is a direct effect in the way that education changes our brains, enhances our abstraction skills and risk perception, and thus ultimately alters our behaviour.

Modern brain research has made it possible for several decades now to track and physiologically explain most acts of information recording down to the level of molecular processes. The brain is constantly bombarded with a wealth of information received through the five senses. The brain tries to filter out and order key information and store those pieces that might be relevant for the future. This is particularly true for information that generates the associations we have encountered in one way or another before. In a crowd, we recognise those who we have already met at some point and remember this encounter, but we forget strangers from that crowd. Evolution has made our brains so complex that we can improve our future by learning from experience. And every experience leaves traces in the nervous system by connecting activated neurons through synapses. The more often certain experiences are made, the more stimulated are previously used synapses and the more easily these connections can be stimulated in the future. The resulting neural networks are reflecting our learning experiences over time. The more and the larger networks we have, the faster and more easily we learn and the better we can retrieve and combine stored information.

Eric Kandel, a native of Vienna who worked as a neuroscientist at Columbia University in the USA and was awarded the Nobel Prize in Physiology or Medicine in 2000 for his pioneering research in the field of memory, sometimes concluded his lectures with the following remark: “Let us repeat this thought for a third time. In the third repetition, new synapses will have formed in your brain permanently. And if you now exit through this door, you are physically a different person than when you entered.”¹

This learning, which changes the neural structure of our brains, starts before birth and continues until the end of life, but the very first years of life are particularly formative when the foundations for future learning are being built. The work by James Heckman and others (Heckman, 2006; Heckman & Masterov, 2007; Heckman & Raut, 2016) has made it very clear how important early childhood experiences and education is for later success. In addition, formal education in primary and secondary schools also makes essential contributions to further developing our neural networks and has the social function of providing joint learning opportunities for children with different parental backgrounds. It has been argued that a particularly critical threshold for personal as well as societal development is the acquisition of numeracy and literacy with the associated abstraction skills — assigning a meaning to the combination of symbolic signs (Lutz, 2017, 2018).

¹ Wolfgang Lutz, personal communication.

This focus on the neural processes in our brains that result from learning makes it very clear that education does not simply elevate us to a higher social class or has a so-called signalling effect (you get a higher salary because you went to a good school), but most importantly it does change the way we think, perceive the world around us, and choose our actions. It also shows that cognitive skills are not a given that we inherit from our parents. Even identical twins, who grew up with the same genetic blueprint, have physically different brains as a result of their different experiences. Consequently, learning literally turns us into different people.

“Education does not simply elevate us to a higher social class or have a so-called signalling effect (you get a higher salary because you went to a good school)... it changes the way we think, perceive the world around us, and choose our actions.”

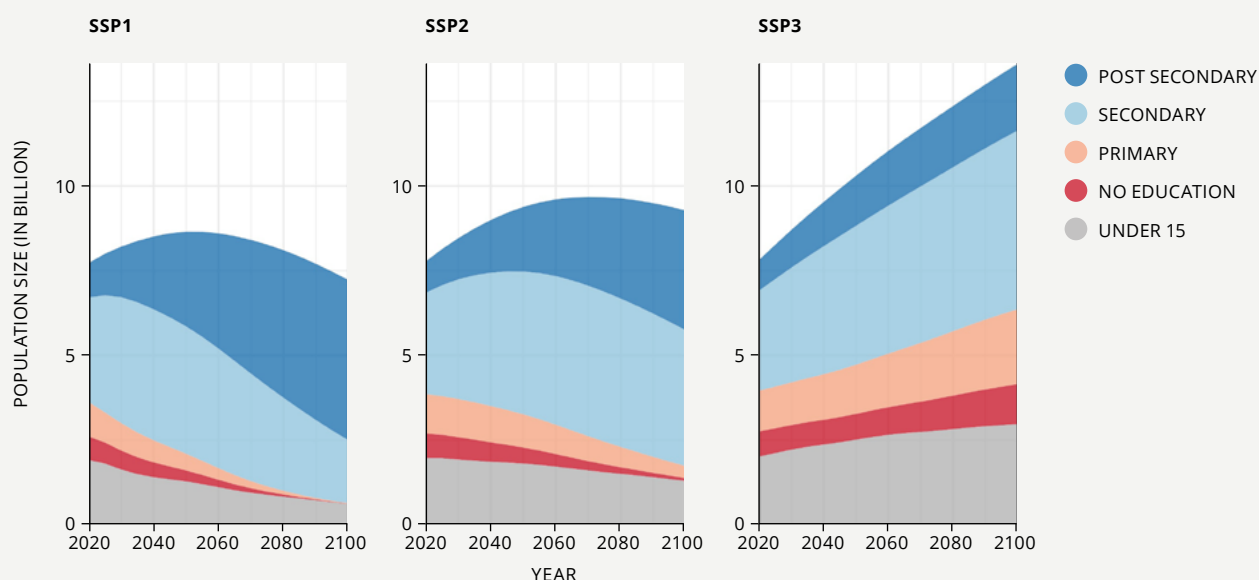


Human capital scenarios for all countries for the rest of this century

The multi-dimensional approach of modelling population dynamics by level of educational attainment in addition to age and sex also forms the “human core” of the Shared Socioeconomic Pathways (SSPs), a set of global scenarios developed by the international climate change research community and widely used in the context of the IPCC (Intergovernmental Panel on Climate Change). These SSPs comprehensively address the socioeconomic determinants of climate change mitigation and adaptation. They are based on five different storylines about future developments in all countries of the world in terms of different demographic, social, economic and technological dimensions (Riahi et al., 2017). In addition to the

middle of the road scenario SSP2, which can also be interpreted as the most likely trend as assumed today, here we also discuss two extremes, namely the “stalled development scenario” SSP3 and the “rapid development scenario” SSP1. In terms of education assumptions, SSP1 is highly optimistic in terms of assuming that all countries would follow the unusual experience of Singapore and South Korea in expanding their education systems, whereas SSP3 assumes the very pessimistic case of no further improvements in school enrollment (KC & Lutz, 2017). Figure 8 shows the global level results in terms of total population size for these three scenarios, spanning the wide range of possible future developments assumed under the SSP approach.

FIGURE 8: WORLD POPULATION TRENDS BY LEVEL OF EDUCATION ACCORDING TO THE THREE SCENARIOS SSP1 (RAPID SOCIAL DEVELOPMENT), SSP2 (MIDDLE OF THE ROAD) AND SSP3 (STALLED DEVELOPMENT)



SOURCE: WIC DATA EXPLORER

In particular, the two opposing scenarios SSP1 and SSP3 show very different futures for humanity. They all start at the same level with today's pattern. Since today in most countries the younger cohorts are better educated than the older ones, some further progress in educational attainment over the coming years is already pre-programmed. But as the figures show, in the longer run, the different assumptions about future trends in school enrolment clearly dominate the picture. Under SSP1, in the second half of the century, the education structure of the whole world will look similar to that of the most developed countries today, which will likely be associated with many of the positive effects of education discussed above. With the stalled development scenario SSP3, however, the world will be even more divided than today, with poorly educated countries being likely to have difficulties to come out of the vicious cycle of poverty and rapid population growth. On top of this, more people with lower resilience will be exposed to climate change related hazards, resulting in much more human suffering.

Nevertheless, the global patterns as shown in Figure 8 hide major regional and national differences. For this reason, in Boxes 2 and 3 we will focus on the results for two big countries, Nigeria and Pakistan, and contrast the SSP1 and SSP3 scenarios. Nigeria currently has a population of around 200 million, which is still growing at a rate of over 2.5 percent per year due to an average fertility rate of around six children per woman and a very young age distribution. Pakistan currently has about the same population size of 200 million, but its population growth rate is lower as fertility has already declined to just above three children per woman. Both countries still have high proportions of women without any formal schooling (30-40 percent). And both Nigeria and Pakistan have fundamentalist groups that directly attack any efforts to educate girls. The name of the Nigerian insurgent group Boko Haram means in translation "education is sin" or "books are sin". In Pakistan, Malala Yousafzei was shot in the head at the age of 14 by a group related to the Taliban simply because she wanted more girls to go to school. Resisting modern education, which is regarded as the source of all unbelief, is often at the heart of the rejection of the West by such groups. The future of education in these two countries is thus still highly uncertain. As illustrated in Box 2 and 3, both countries are currently at the cross-roads and the two scenarios show strongly contrasting choices for the future. If the spread of education stalls, the population will continue to grow rapidly and political insecurity is likely to hinder investments and the creation of jobs. This can lead into a bleak future that will not leave the rest of the increasingly globalized world unaffected.

Case study:

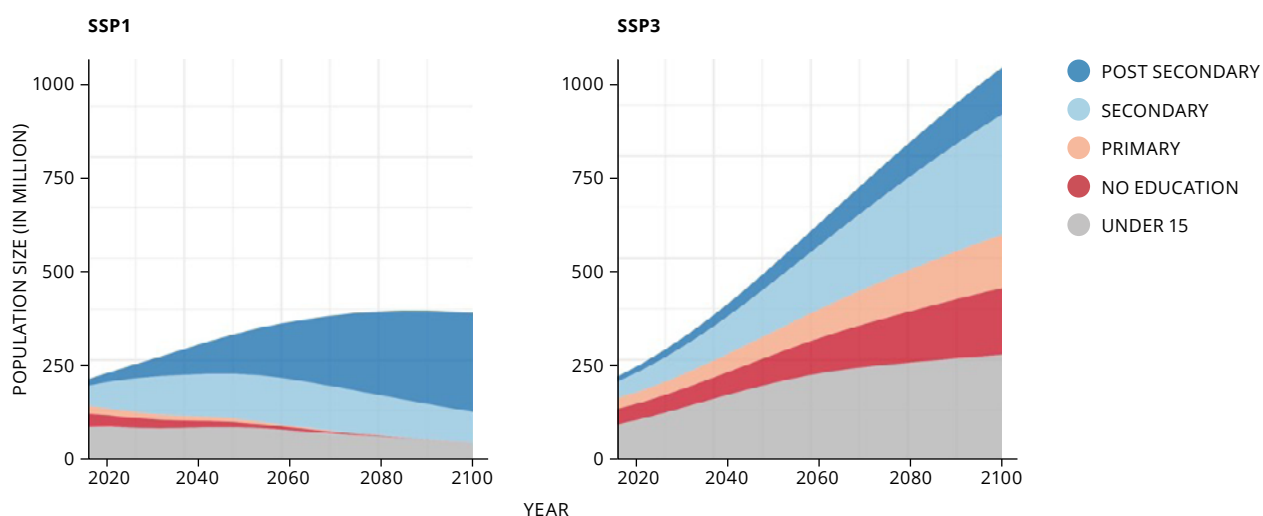
Nigeria at the cross-roads

Nigeria could be a rich country, if it had higher human capital and better institutions.

Although the nation has more than 700,000 square kilometres of usable farmland and two thirds of Nigerians work in agriculture, productivity is so low that Nigeria has to import 4 million tonnes of wheat per year (Food and Agriculture Organisation of the United Nations, 2019) and is one of the largest rice importers in the world (IndexMundi, 2020). Nigeria is also the tenth largest oil producer in the world. Income from oil sales accounts for over 90 percent of its export business and more than 70 percent of government revenues.

Today, women with no education have on average 6.7 children, making it difficult for their households to invest sufficiently in their children's health and education, while women who are better educated have fewer than three children. The high population growth will certainly continue for some time, because 43 percent of adult women have still never attended school. Among young women aged 20 to 24 years, this proportion has declined, but it still stands at 21 percent. This shows a divided society, since 38 percent of women in this age group now have a higher secondary education and 8 percent a tertiary education.

	2020	2050-SSP1	2050-SSP3	2100-SSP1	2100-SSP3
POPULATION IN MILLION	205	313	459	367	973



The figure above shows on the left the rapid development SSP1 scenario which assumes very rapid future education expansion and declining fertility and mortality. If the government actually manages to put the country on this very ambitious path, Nigeria could rise to an important global power by mid-century, owing to a much better educated population and a growing economy. However, the future looks very different under the stalled development scenario SSP3. Due to stalled expansion of schools, the number of people without schooling would rise significantly as a result of continued rapid population growth. Social and economic development might collapse, and the population would reach 459 million in 2050 (Nigeria would then have the third largest population in the world after China and India) and increase to 973 million by the end of the century. These scenarios, however, do not yet incorporate possible feed-backs from very rapid population growth to possibly increasing mortality as a consequence of food shortages, diseases or political instability and conflict. In addition, the country would face greater difficulties in coping with the likely serious consequences of already unavoidable climate change. This will not be a pleasant future for one of the biggest countries in the world.



Case study: Pakistan at the cross-roads

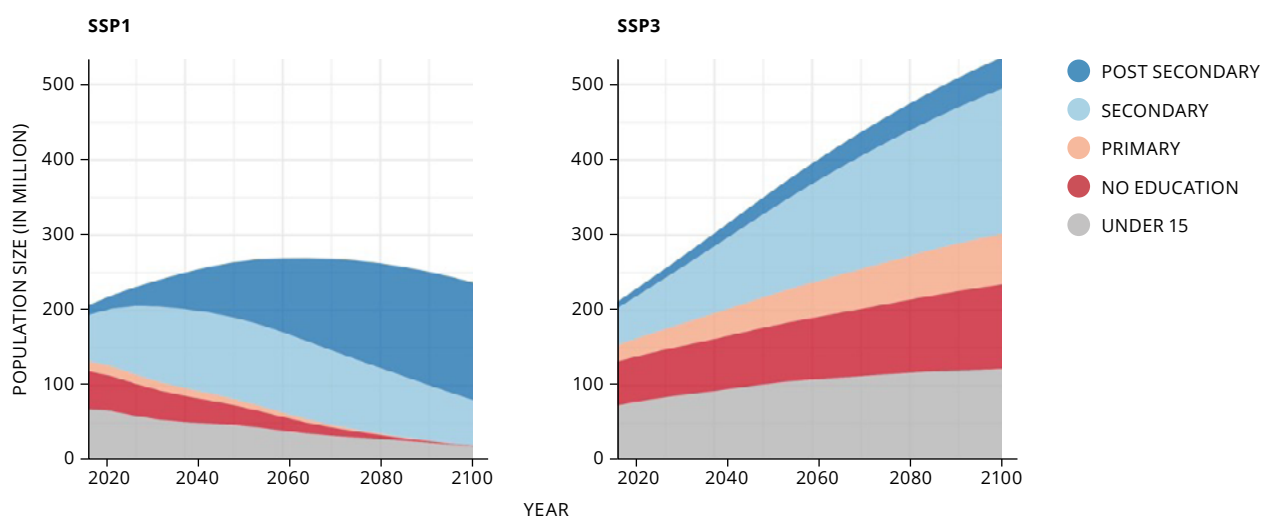
According to an UNESCO assessment, Pakistan has some of the worst education indicators globally and the second highest number of children who do not attend school, two thirds of them being girls (UNESCO, 2012).

Particularly alarming, according to UNESCO, is the situation in rural areas, especially in the northern and western provinces, where girls face substantial social and economic barriers. As a consequence, 92-97 percent of rural adult women are illiterate. Pakistan has almost the highest population growth in Asia. Since its independence in 1947, the number of people has increased from 38 to 209 million.

At the same time, birth rates in Pakistan are still quite high by Asian standards with an average of 3.3 children per woman. Uneducated women have 3.8 children, women with a university

degree on average only half as many. Therefore, the future of Pakistan depends, as with most developing countries, to a large extent on the further expansion of education. It also is a divided country in terms of education. But if education stalls, the high-fertility and low-educated parts of the country will grow very rapidly and gain an increasing proportion of the total population. This interaction between high fertility and low education results in the fact that under the SSP3 scenario the population with no formal education at all would actually increase in size. But this is no inevitable predicament. The SSP1 scenario shows that with strong efforts in education and social development the education structure in Pakistan could look like that in industrialized countries over the second half of the century.

	2020	2050-SSP1	2050-SSP3	2100-SSP1	2100-SSP3
POPULATION IN MILLION	209	264	350	235	540





“The future of Pakistan depends, as with most developing countries, to a large extent on the further expansion of education.”

Policy priorities resulting from this analysis

Humanity — currently numbering 7.9 billion, but soon to reach 9 or 10 billion — faces titanic challenges for the rest of this century. It must overcome poverty and hunger, tackle climate change and loss of biodiversity and win the fight against conflict and insecurity — with the battle against global pandemics recently added to the list.

Only informed and empowered people will be able to contribute productively to this task. We will not succeed as long as 58 million children of primary school-going age are out of school, more than 200 million people are unemployed and over 770 million illiterate adults remain excluded from any participation in the global information society.

Universal primary education has been a key element of the Millennium Development Goals (MDGs) set in 2000 and this has been expanded to universal high-quality primary and secondary education for all girls and boys in the Sustainable Development Goals (SDGs) defined in 2015. In spite of these goals, broadly shared global aspiration towards the funding base for education has been eroding — at least on paper. Spending on education has been declining as a proportion of total development assistance over recent years: the share of education in clearly allocable total aid fell from 14.8 percent in 2003 to 9.7 percent in 2013. It has since recovered a little to 10.8 percent in 2018, but it is still considerably below 2010 levels (UNESCO, 2020). In addition, the current COVID-19 pandemic is putting additional stress on education systems around the world.

While this is likely to contribute to education inequality in most countries, in the least developed countries the risk of discontinued basic empowerment through education is particularly high. Unless strong education efforts pick up very quickly in these countries this may produce a “lost generation” with severe negative consequences for themselves, their families and their societies.

There are many policy fields related to education that need urgent attention and innovation. In the following we will only highlight five specific policy priorities.

(i) Education begins before schooling

All countries in the world should take note of the scientific findings of neurobiology, psychology, linguistics, sociology and economics, which state that the learning experiences of early childhood have a sustained impact on the further development of a human being. The first years of life, during which the brain of a child matures, are crucial for the future benefits that this organ may bestow on its owner. Problems in early childhood development can hardly be remedied in later stages of life, not even with intensive training.

What can governments do in a context where care and education in the first years of life is often considered a private family matter? In this respect, the Finnish *Neuvola* (meaning “advisory”) system is a pioneering achievement. From the beginning of pregnancy up to primary school age, children are provided with free medical care, educational counselling and regular check-ups of their mental development, carried out by qualified personnel in local health centres. *Neuvola* fosters equal opportunities and ultimately economic success. In 1944, Finland introduced the system nationwide. These early childhood efforts may well be related to the fact that Finland has been doing particularly well in scholastic tests such as PISA and has been ranked for several years in a row the happiest country in the world.

(ii) At least 10-12 years of schooling for all

While universal primary and secondary education are now enshrined in the SDGs, many countries, particularly in Africa, are still so far away from this goal that the question has arisen whether an achievement by 2030 is indeed a meaningful goal to set. On the other hand, studies have shown that universal primary education is not enough to bring a poor country out of poverty (Lutz et al., 2008). In the context of rapid globalisation and technological progress, basic literacy is not enough for a person or country to be globally competitive. With respect to health and reducing child mortality it has been shown that at least completed junior secondary education of women is some sort of threshold for significant improvement. For good reasons, schooling and education are obligatory in virtually all higher income countries for at least ten years. Why should a measure that has been recognised as good and important in rich countries not also be put into practice in all other countries in the world? While a minimum of 10 years is a priority goal to aim at, clearly 12 years or more would still be better for the future of the students and their countries alike.

(iii) More and better trained teachers

Likely no other factor increases the learning success of children more than good, motivated and motivating teachers. However, in poor countries, the teaching staff has to cope with classes of 43 children on average. Payment and control of teachers is usually so poor that they often do not even appear for duty. Many teachers do not even have higher education qualifications, let alone a teaching degree. In 48 countries of the world, teachers for the lower secondary level also only need a lower secondary education as training. This means that they are as well qualified, at best, as their students will be.

In the first section of this paper, we have described new data showing that even at a given level of educational attainment the literacy skills differ dramatically between countries and the gap has been widening over recent years. Given that it is the actual cognitive skills that matter for generating the multiple benefits of education and not just the formal level of education, this is a very worrying trend. It is not primarily the teachers that are to be blamed for this, but the whole educational systems in which teachers and students are embedded. School reforms including better paid, better qualified, and better motivated teachers need to be an urgent priority in many countries that are falling back on skills.

(iv) Make use of innovations

Today, the Internet can provide knowledge almost for free in every remote corner of the earth, opening up access to education. This digitalisation, which transformed the entire industry culture, offers enormous, hitherto largely untapped potential for the spread of education. Why should people in remote and economically stalled parts of Africa wait for their governments to build schools and train the teachers who are needed for the teaching of many children, when a mobile network can do the same much faster and more cheaply?

This technical solution does not make good teachers obsolete, but it would mean that teachers without adequate professional skills can use online educational services in the classroom. Once children have received a basic education, they could participate in any online training course available in their own language. But the use of these promising new options requires a certain level of basic education and some critical thinking. To use the Internet, children must be able to read. To distinguish valuable from nonsensical information, they need to apply judgment. Finally, learning has a strong relationship component, especially in children. This can only be offered by a teacher, not a computer.

(v) Lifelong learning

In wealthier countries, it is slowly being recognised that education does not only happen during school and job training, but that it is a lifelong necessity. The rigid life phases of education-work-retirement are dissolving. What a person has learned in her younger life years nowadays rarely suffices for an entire career. Knowledge and techniques quickly become obsolete and need to be refreshed in ongoing training. This is the only way to ensure that workers remain productive for a longer period of time, which becomes more and more necessary in the face of steadily rising life expectancy. Lifelong learning is also the best basis for a healthy and active life up into old age.

As discussed above, education also is a key driver of longer lives and is the main reason behind population ageing. But it is also the most important lever to alleviate the consequences of ageing, as people who are better educated not only live longer, but remain, on average, physically, mentally and economically active for a longer period of time. Again, one leads to the other: people with a better initial education can more easily engage in lifelong learning.

Postscript: “Homo Sapiens Literata”

It has been argued that the rise of human civilization over the millennia was driven by the proportion of the population that is able to read and write (Lutz, 2017). In fact, the decisive changes in development happened around 500 years ago when, as part of the Reformation, Martin Luther demanded that all men and women, even of the lowest classes, should become literate in order to be able to read the bible themselves. And this resulted — first in the protestant countries of Northern Europe and subsequently in the rest of Europe and the world — in social and economic development as a consequence of increasing proportions of the population, in particular women, becoming literate. In this context, Lutz coined the notion of “*human sapiens literata*” which he presented in the opening lecture to the 2018 general assembly of the Pontifical Academy of Sciences in the Vatican (Lutz, 2018). There he tried to summarize recent findings in demographic and interdisciplinary research showing the central role of education of not just elites but the general public including all women. This was a rather courageous step, not only in terms of proclaiming a new human sub-species — which is legitimate in the context of cultural evolution as long as it marks a significant qualitative change that is essentially irreversible — but also because of the intentional use of the female gender of the adjective “literata” to homo, which in conventional Latin grammar has a male gender although it refers to both men and women.

The female gender was chosen to underline the decisive role of female literacy and education in the transformation of human societies.

The empowered *homo sapiens literata* has shaped the world, involving not only an improvement in living conditions but also a visible footprint on the natural environment which threatens to undermine our own life support systems in the future. But knowledge and education may offer opportunities for insight and foresight which can bring about a transformation towards sustainable development as well as the potential to strengthen our adaptive capacity to already unavoidable environmental changes. This has also been stressed in a statement of the German National Academy of Sciences Leopoldina on “Brainpower for sustainable development” in the context of the Global Sustainable Development Report 2019 (Leopoldina, 2019).

Endnote:

Minor parts of the text of this paper draw on Lutz (2017), Lutz (2018), and Lutz & Klingholz (2017).

“Humanity faces titanic challenges for the rest of this century. It must overcome poverty and hunger, tackle climate change and loss of biodiversity and win the fight against conflict and insecurity... Only informed and empowered people will be able to contribute productively to this task.”

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