Working Paper

The Importance of Education in Future Population. Global Trends and Case Studies on Cape Verde, Sudan, and Tunisia

Anne Goujon and Annababette Wils

WP-96-138
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IIASA International Institute for Applied Systems Analysis • A-2361 Laxenburg • Austria
Telephone: +43 2236 807 • Telefax: +43 2236 71313 • E-Mail: info@iiasa.ac.at

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Contents

Abstract

Education is a central issue in the complex process of development, for it has been found to be related to fertility and hence population growth, to the status of women, to labor force skills, as well as to cultural and infrastructural development in general. This paper consists of two main parts. The first examines the role of education and reviews school enrollment patterns in the world during the last 30 years. We deduce from this review some general patterns of enrollment increase and gender differential. The second part presents multi-state population projections by educational level and the resulting adult educational attainment, fertility levels and population growth. This is done through three case studies on the countries of Cape Verde, Sudan and Tunisia. The projection exercise shows some important dynamics of education and fertility change. The benefits to countries who have taken great strides to increase enrollment with superficially disappointing results to date will become obvious in the future. This may lead to some unexpected fertility declines and other changes associated with higher education. Adult levels of education have a long momentum and education increases in the adult population are non-linear. This is an important aspect when defining scenarios for future population growth.

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> [d]evelopment does not start with goods; it starts with people and their education, organization and discipline. Without these three, all resources remain latent, untapped, potential. Here lies the reason why development cannot be an act of creation, why it cannot be ordered, bought, comprehensively planned: why it requires a process of evolution. Education does not 'jump'.
>
> Schumacher (1973)

1. Introduction

Population growth, the status of women, and labor force skills are three of the many issues which are involved in the complex process of development, that we, along with many others, find central, even if there is some disagreement on the nature of their influence. Education has been found to be related to fertility and hence population growth, to the status of women, and to the labor force skills. Therefore, education is a central issue for development. In this paper, we make future scenarios of the educational level of the adult population using multi-state population projections. These scenarios show that adult educational levels have a long momentum and that education increases in the adult population are non-linear. The momentum and non-linearity, we argue, have significant implications for the way we think about the future of population growth, status of women and labor force skills. In particular, the practically linear declines of fertility such as those assumed in most of the UN and World Bank population projections are shown to be unlikely because of the non-linear changes in the level of education. It is more likely that there will be corresponding non-linear declines in fertility. Also, once the momentum of education increases begins to catch hold, this may cause unexpected, rapid fertility declines on a global level, as well as substantially slower rates of population growth than shown in present projected populations, for example the United Nations medium population projection (UN 1994).

The paper begins with a brief discussion of the role of education, followed, in Section 3, by a review of school enrollment patterns from 1960-1990 using United Nations data (UNESCO 1993). Some general patterns of increase and gender differential emerge. Section 4 presents multi-state population projections by educational level and the resulting adult educational attainment, fertility levels and population growth. For the population scenarios the method used is multi-state population projections. Multi-state population projection was originally developed by Rogers (1975) and used in recent years at the International Institute for Applied Systems Analysis (IIASA) in Austria for projects on Mauritius (Lutz 1994; Wils and Prinz 1996), Cape Verde (Wils 1996), and Algeria, Egypt, Libya, Morocco, Sudan, Tunisia (Yousif et al. 1996). Section 5 summarizes some of the main conclusions.

2. On the Role of Education

The International Conference on Population and Development (ICPD) held in Cairo in 1994, underlined education as one of the most important keys to social and economic development, improved status of women, and smaller family size. The ICPD Programme of Action sustains that "it is at the same time a component of well-being and a factor in the development of well-being through its links with demographic as well as economic and social factors" (United Nations 1995, p. 57). It further recommends the achievement of "...universal access to quality education, with particular priority given to primary and technical education and job training, to combat illiteracy and to eliminate gender disparities in access to, retention in, and support for, education" (p. 57).

Education is an end in itself, but it is also a means to address sustainable development, women's well-being, and demographic issues. Given the many-faceted importance of education, it is imperative to know and to understand the patterns of education diffusion. That entails knowledge of the patterns in school enrollment increases, and their translation into levels of educational attainment among the adult population. Increases in education levels among the adult population are non-linear, lagged effects of education policies.

The historical data on enrollment demonstrate that there are general patterns of enrollment increases with respect to the level of education and to the differential rates of enrollment of boys and girls. Most countries have not been able to avoid a gender gap in school enrollment in favor of boys. In most countries where there is no full primary school intake, more boys go to school than girls. Global data show that over time, as the general level of enrollment increases, the enrollment of girls tends to catch up with the enrollment of boys.

How do these enrollment patterns translate into adult population educational attainment? Like many demographic processes, education diffusion is a process with very long lags and long momentum. This means for example that an increase in primary school intake, even if it is to 100 percent as the ICPD recommends, does not result in a young adult population with universal primary education until two decades later, and requires almost six decades to move entirely through the adult population. These lags may test the patience of leaders in countries which have made great strides to educate their young in the past few decades--as many countries have--and who have yet seen so little results in terms of a highly skilled adult population or changes in women's status and fertility or rate of population growth. On the other hand, these countries will see the fruits of their past efforts in the decades to come.

It is hoped by the authors of the ICPD Programme for Action, that increases in adult education will translate into social and economic development, greater empowerment of women, smaller family size, better health and the promotion of genuine democracy.

Many studies and authors (for example, the World Fertility Surveys; Federici et al. 1993; Freedman 1987; Jejeebhoy 1995; Mcgrath 1976; Noor 1981; Oppong 1987) have noted the inverse relationship between fertility and the education of women. This link operates independently of other factors such as economic status, husbands' education or the types of egalitarian or non-egalitarian settings in the society. Among the reasons which are mentioned by these authors for a causal relation between education and fertility are:

- education delays the entrance of women into their reproductive life by delaying the age at marriage;
- schooling improves the information of girl children about the outside world; it expands these future women's horizon beyond motherhood and the household level, giving them more confidence in their capacities and potentials;
- the opinions of women with more education are more respected; they have a greater say in household decisions, concerning expenses, family planning and the education of children;
- educated women have lower expectations of help from their children because they have themselves been educated; they would rather see their children in school than at home;
- in almost every country, educated women have healthier children than those who are uneducated; the survival rate of children born from an educated woman is very high which results in a lower desired birth rate.

The future scenarios which are presented in this paper highlight one of these aspects: the link between education and smaller family size, or lower fertility levels. Combining both education and fertility scenarios such as those in the sections below, shows the education momentum and the non-linear development in adult educational levels, plus the demographic momentum of population growth.

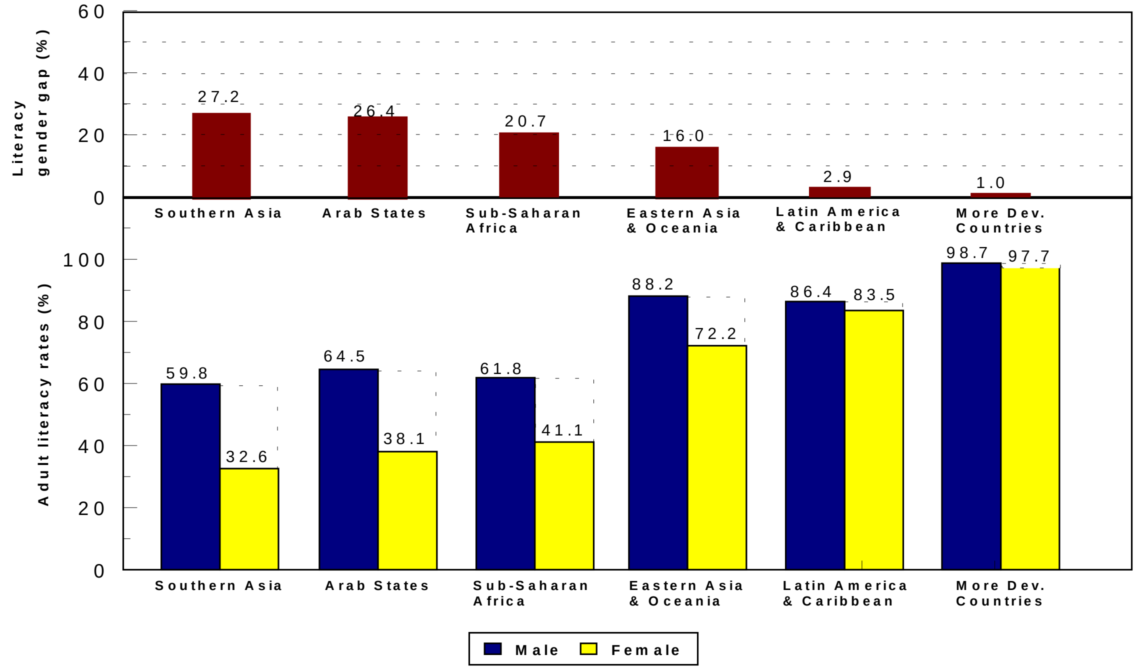
For future scenarios, the paper uses the example of three countries: Cape Verde, Sudan and Tunisia, each with a characteristic education profile, illustrative of three common education profile types in developing countries. Cape Verde has mediocre levels of education among adults, but has had very high rates of enrollment in primary and secondary schools among girls and boys for the past two decades. Cape Verde will experience an increase in educational level among adults even if enrollment rates stagnate at the present level. Sudan has a history and present of very low schooling and rapid growth of the school-age population. Consequently, both young and adult populations are poorly educated; even if the country begins an education campaign today, it will take many decades for this effort to influence the educational attainment of the adult population. Tunisia is a country with slightly higher educational levels than Cape Verde and a longer history of high primary school intake. These efforts have "matured" as it were, and a continuation of enrollment at present rates will not result in great education changes in the near future.

3. Education Increase from 1960-1990 in Six World Regions

3.1. Illiteracy

Governments in all countries have invested in the education of their nation's youth, and sometimes in adult education. In industrialized countries, this has resulted in nearly universal literacy, 10-13 average school years among adults, and equal education for men and women at all levels of the schooling scale. On the other extreme, some countries in Africa (i.e. Burkina Faso, Niger) still had illiteracy rates up to 85 percent in 1990 among the adult population (UNESCO 1994), with a large gender gap, sometimes despite continually increasing outlays for schooling. Sub-Saharan Africa, the Arab States and Southern Asia all have similar literacy rates around 60 percent for men. Literacy rates for women in these regions are only 30-40 percent (UNESCO 1993). In Latin America and the Caribbean, there were almost universal adult literacy rates in 1990 with only a very small adult education gender gap. Eastern Asia had almost universal literacy for men, but only 72 percent for women. UNESCO data show that 20 percent of the world's population aged 15 and over were illiterate in 1995. It is particularly disturbing that almost two-thirds of the illiterate adults--64 percent--are women, which translates into approximately 565 million illiterate women worldwide (Figure 1).

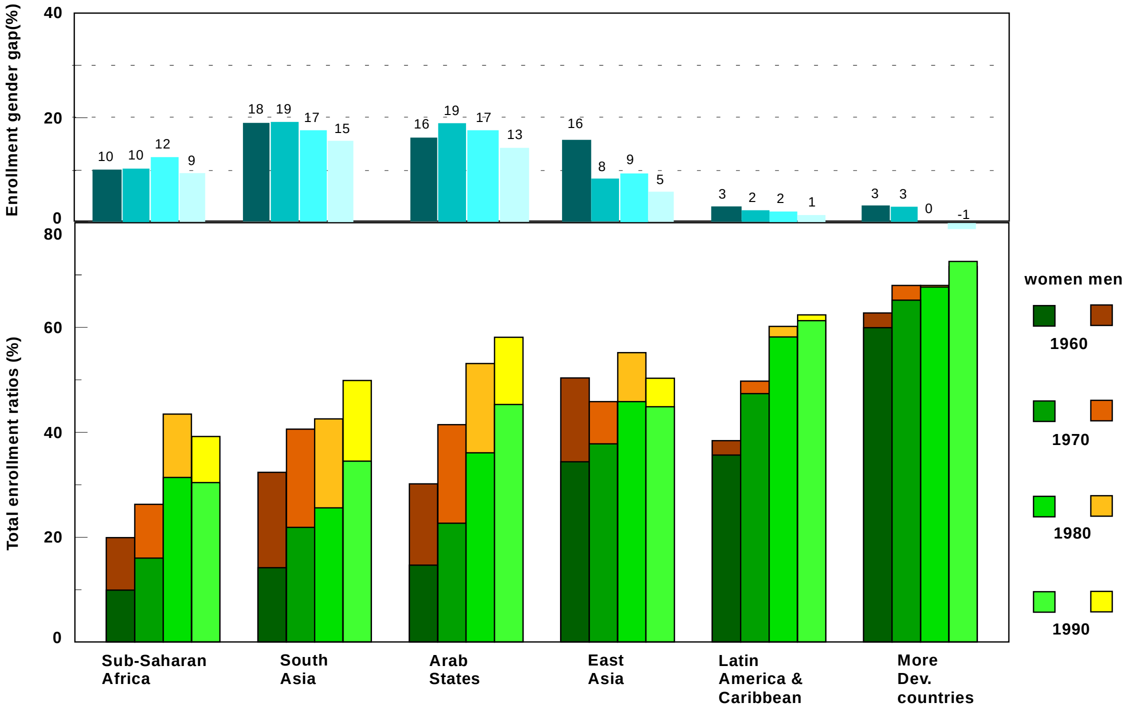
Figure 1. Adult literacy rates by sex and literacy gender gap in six major world regions, 1990. Source: UNESCO (1994).



3.2. Global enrollment ratios

This section looks at the enrollment ratios of the three decades from 1960-1990. Enrollment rates are indicators of education policies at one point in time and represent the percentage of children in school. Figure 2 shows some very clear patterns of enrollment increase in the last 30 years in the major world regions for ages 6-23 years for both sexes. The past enrollment rates are indicators for future adult educational levels. To some extent, the average enrollment rates of 6-23 year olds are a reflection of age structure, however, this effect is not large enough to significantly alter the results shown here.

Figure 2. Total enrollment ratios by sex and enrollment gender gap in six major world regions, 1960-1990. Source: UNESCO (1993).



The enrollment ratios in developed countries started at 63 percent for men and 60 percent for women in 1960, and increased slowly to 72 percent for men and 73 percent for women aged 6 to 23 years in 1990. There is virtually universal education in the developed countries and the fact that enrollment ratios are less than complete means that not all people study until the age of 23. It should be noted that in 1990, there was on average a one percentage point school enrollment gender gap between males and females in developed countries, but in favor of female pupils.

The increase in enrollment has been fairly general in all regions of the developing world. In Sub-Saharan Africa, although enrollment rates almost doubled between 1970 and 1980--from 26 percent for men and 16 percent for women enrolled in 1970 to respectively 44 and 31 percent in 1980--still less than 50 percent of the population aged 6-23 are enrolled. The gender gap in school enrollment has practically remained the same, around 10 percentage points difference in favor of male enrollment.

In South Asia, the increase in total enrollment has been steady since the 1960s for both sexes: from 32 percent for men and 14 percent for women in 1960, to respectively 50 and 35 percent in 1990. The gender gap has been closing slowly, but was still 15 percent in 1990.

Arab States also showed a very clear trend of increase in enrollment for both sexes: for males and females respectively 30 to 58 percent, and 15 to 45 percent. The 1970s was a period of high educational improvements, especially for male children. The gender gap increased from 1970 to 1980 when it went as high as 19 percent. The trend in the last decade is toward a slow decline in the gender gap as female total school enrollment increases.

East Asia had a more confusing trend. This may be due to the fact that this region contains a mix of countries with very different rates of population growth and enrollment patterns which, taken together, make a chaotic pattern. Male enrollment levels in 1990 are as they were in 1960, although going through several phases of increase and decline. Female enrollment has constantly improved over time. This means the existing gap between male and female school enrollment rates declined from 16 percent in 1960 to 5 percent in 1990.

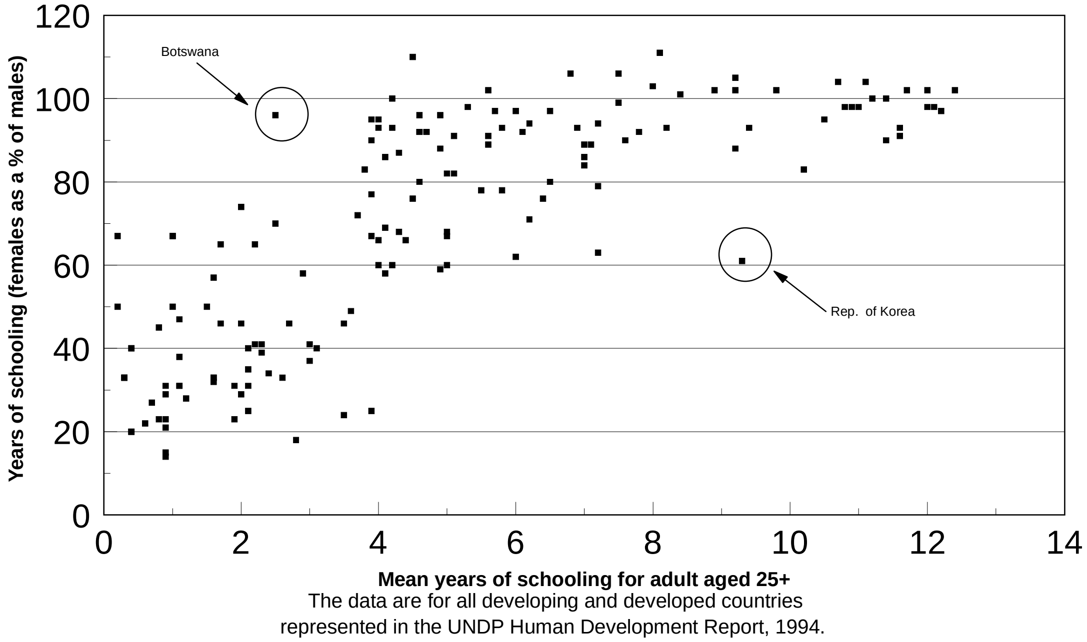
The highest enrollment rates in developing countries were found in Latin America and the Caribbean with more than 70 percent of both men and women in the age group 6-23 enrolled in school. Latin America is special in that throughout the period there has also been almost no gender gap (below 3 percent).

These empirical observations show that during the past 30 years, in all regions of the developing world, men had higher enrollment rates than women. The data also show, however, that the male to female ratios in enrollment rates decreased in all the world regions throughout the observation period without exception. We return to this in Section 3.3 below. In general, the male to female ratios in enrollment were higher in countries with a generally lower enrollment rate.

This enrollment ratio pattern is translated into a typical relationship between average years of adult education and the adult education gender gap. The scattergram in Figure 3 represents the average number of years of education by country in 1990 for the adult population as a whole on the x-axis, and the ratio of female to male years of education on the y-axis by country. It clearly shows that where the average level of schooling of the adult population is low, the gender gap for education between men and women is largest. At the lowest average levels of schooling of 1-3 years, in 85 percent of the countries women have less than half of the average schooling of men, except for Botswana, which is one outlier. At medium levels of schooling 3-7 years, women have more than 50 percent of the male level. At high levels of schooling of over 8 years, males and females tend to have received the same number of years of schooling, except in Korea, which is the second outlier. This means that the education increase curve for women rises at a later time than the curve for men.

There is a rough geographical distribution. Most of the countries in the low education/high gender gap area are in Africa; most of the countries in the medium education/medium gender gap are in Asia and Latin America; and most of the high education/no gender gap countries are in Europe and North America. This itself may be related to the level of development.

Figure 3. Average number of years of schooling for all adults by the ratio of female to male education by country in 1990. Source: UNDP (1994).



3.3. Enrollment ratios by schooling level

Figure 4 (a-f) shows the enrollment of children in age groups 6-11, 12-17 and 18-23 by sex and by regions between 1960 and 1990 for five developing regions and developed countries; the tables under the graph show the ratio of male to female enrollment by age group and by years. In our analysis, we will consider that the three age groups correspond approximately to the three consecutive schooling levels: primary, secondary and tertiary.

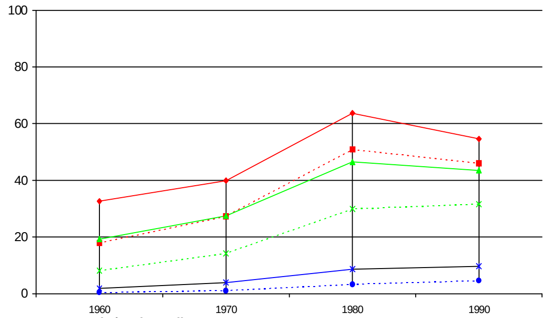
Several general patterns can be noted. At consecutively higher levels of education in each region, the enrollment ratios are consecutively lower. In each region and throughout the whole observation period 1960-1990, the male to female enrollment ratio is significantly higher for each higher level of education. However, at all three educational levels in all regions shown here, the male to female enrollment ratios declined significantly. The largest declines in the ratio are in tertiary education: for example, from a ratio of 4.92 men to one woman in tertiary education in the Arab States in 1960, to 1.62 in 1990.

In 1990, most developing regions had high intake rates for male children in primary schools; in 1990 over 80 percent of the male children between 6-11 years old in Arab States, Latin America, East Asia and Southern Asia were enrolled in school. Only Sub-Saharan Africa still had very low primary enrollment rates even for males, 55 percent. In Latin America and East Asia as many girls are enrolled in school at this age as boys (respectively 87 and 84 percent). In Arab States and South Asia, the enrollment rate of girls 6-11 years old is only 69 and 62 percent respectively. In Sub-Saharan Africa female enrollment rates lag furthest behind; only 46 percent of the age group 6-11 years is enrolled. However in relative terms the male to female enrollment ratio in Sub-Saharan Africa is the same as in the Arab States and much smaller than in Southern Asia.

Figure 4. Enrollment rates by sex and age group and male to female enrollment ratios by age group in six world regions, 1960-2000. Source: UNESCO (1993).

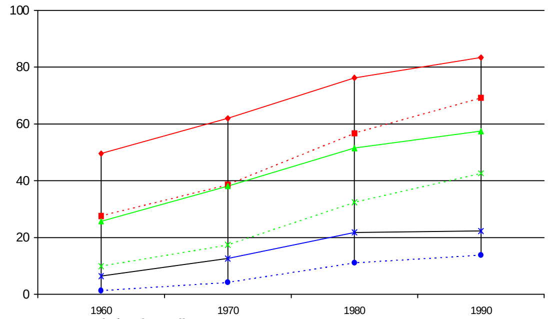
a) Sub-Saharan Africa

b) Arab States



male:female enrollment ratio

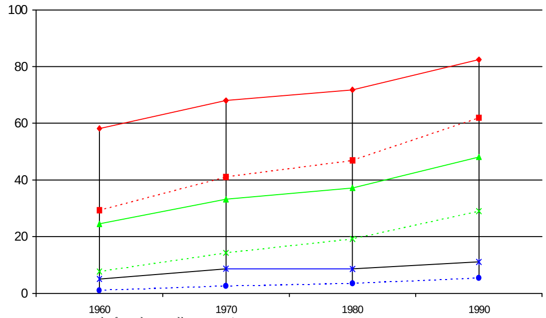
age	1960	1970	1980	1990
6-11	1.82	1.46	1.25	1.19
12-17	2.38	1.94	1.56	1.38
18-23	4.75	3.55	2.64	2.11



male:female enrollment ratio

age	1960	1970	1980	1990
6-11	1.80	1.61	1.34	1.21
12-17	2.60	2.19	1.59	1.35
18-23	4.92	3.00	1.96	1.62

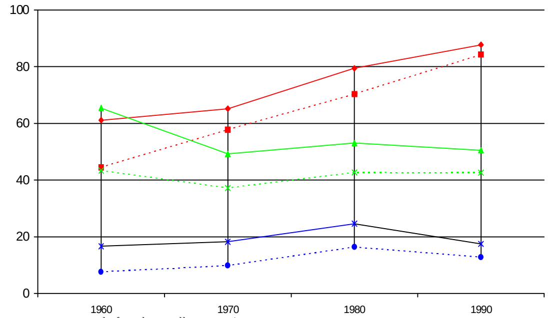
c) South Asia



male:female enrollment ratio

age	1960	1970	1980	1990
6-11	1,99	1,65	1,53	1,33
12-17	3,18	2,32	1,94	1,66
18-23	4,64	3,35	2,46	2,06

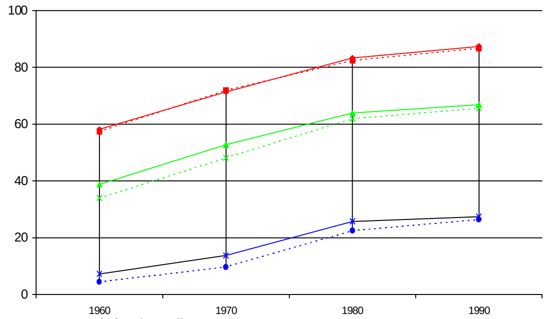
d) East Asia



male:female enrollment ratio

age	1960	1970	1980	1990
6-11	1.37	1.13	1.13	1.04
12-17	1.51	1.32	1.24	1.19
18-23	2.18	1.86	1.50	1.37

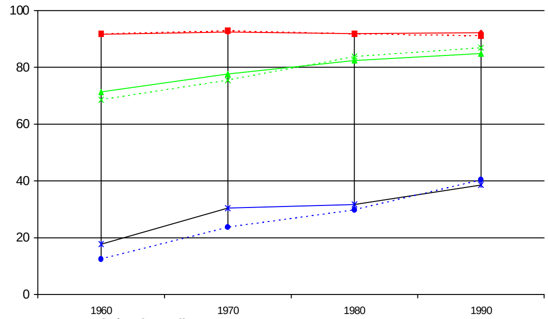
e) Latin America and Caribbean



male:female enrollment ratio

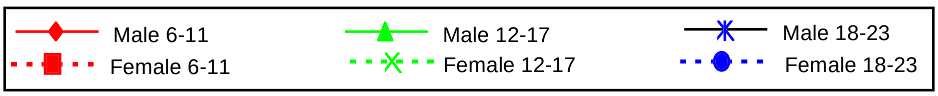
age	1960	1970	1980	1990
6-11	1.01	0.99	1.01	1.01
12-17	1.14	1.10	1.03	1.02
18-23	1.64	1.41	1.14	1.04

f) Developed Regions



male:female enrollment ratio

age	1960	1970	1980	1990
6-11	1.00	0.99	1.00	1.01
12-17	1.04	1.03	0.98	0.98
18-23	1.42	1.28	1.06	0.96



In all regions, enrollment rates for secondary education are considerably lower than for primary, and the education gender gap is wider, with the exception of Latin America where no gender differences are reported at any age. In South Asia, only 29 percent of the girls in the age group 12-17 remain in school and 48 percent of the boys. These figures are respectively 32 and 44 percent in Sub-Saharan Africa, 43 and 58 percent in the Arab States, and 43 and 51 percent in East Asia. There are two boys enrolled for each girl in secondary schools; the male to female secondary enrollment ratio is 1.4 in Sub-Saharan Africa and in the Arab States, and 1.2 in East Asia.

Enrollment rates for tertiary education at ages 18-23 are lower still. Whereas 40 percent of the population in the age group 18 to 23 years are still enrolled in developed countries, it is less than 15 percent for developing countries. Here again the gender gap is higher than for lower levels of schooling. In 1990, the male to female enrollment ratio between 18 and 23 years of age was 2.1 in Southern Asia (1.3 for age group 6-11 and 1.7

for age group 12-17), 2.1 in Sub-Saharan Africa (respectively as above 1.2 and 1.4), in the Arab States 1.6 (1.2 and 1.4), and in Eastern Asia 1.4 (1.0 and 1.2). In the Latin American and Caribbean region, the male and female enrollment rates were almost equal at all educational levels.

The closing of the gender gap is general to all regions and all age groups between 1960 and 1990. The progression of enrollment rates at all levels is almost as general. The exceptions are that in Sub-Saharan Africa between 1980 and 1990, enrollment decreased at the primary level for both males and females, and at the secondary level for males only. Also during this period in East Asia, male and female enrollment in primary and secondary education decreased. The trend in Africa, where education is already low, population growth high, and economic output per capita stagnating, is particularly worrisome.

4. Population Projection with Multiple Educational States

4.1. Methodology

4.1.1. The extended Leslie matrix

The scenarios for education are made using a population projection method that is a combination of the discrete time cohort component projection used for single-state populations (Leslie 1945), and an adapted form of the multi-state population projection method first compiled in complete form by Rogers (1975) and Rogers and Wilson (1980). In the population projection method formalized by Leslie, the population is subject only to births, deaths and external (net) migration. An age- and sex-specific population vector is pre-multiplied by the so-called Leslie matrix which has scalars for the birth, death, and net migration rates. In the multi-state projection method the age- and sex-specific population is further divided into states--such as marital status, educational achievement, place of residence--and the *transitions* between these states are included in the projection. These transitions are specific to each age and gender group, and are represented by age- and sex-specific transition matrices. These transition matrices can replace the age- and sex-specific birth, death, and net migration scalars in the Leslie matrix. The multi-state population projection is then represented as an *extended Leslie matrix*. The population vector is also extended to include the population by states. The matrix is arranged as the original one-state Leslie matrix, but now, each scalar in the matrix has been replaced by a small transition matrix and each scalar in the population vector is a small vector of the population states. The mathematics for this method and a simplified annotation which shows clearly the relationship between the original Leslie matrix and the extended multi-state Leslie matrix are described in Technical Note 1.

4.1.2. Estimation of the transition rates between levels of education

The multi-state projection in this paper requires data on the transition of children from one level of school to another. Data on these rates are seldom available, and have to be estimated.

Some basic observations on education are taken into account. Educational levels are hierarchical, that is, an individual must go through and complete the lower level of school (such as primary school) before being allowed to move to the next, higher level. Transition rates tend to be less than complete. Also, school levels tend to be divided into age groups of "normal" or usual transition ages that do not correspond to the age groups used in cohort-component population projection; for example many children enter school at age six, in the middle of the age group 5-9; they may make the transition to secondary school at age 13, in the middle of the age group 10-14; and the "normal" transition to college or university can range from age 17 to 19.

Two different methods were applied to calculate the transition rates. Method 1 was used for Sudan and Tunisia. Method 2 was used for Cape Verde. Both of these are described in Technical Note 2. These two methods make little difference in the patterns observed in the results. They were used because of different data sets. For Cape Verde, we were able to obtain historical census data back to 1970; for Tunisia and Sudan we used the 1990 UNESCO data.

Briefly, in Method 1 the population is distinguished by four levels of schooling: no schooling, primary, secondary, and tertiary.[1] People move from one educational category to the next from the moment they change

[1] The four educational states are defined as:
No schooling: those who have never attended school plus those who have completed less than one year of primary schooling;

school level. All children are born into a category with no schooling. A portion of these children (the primary school intake) makes a transition to "primary school." Those who do not enter school are classified as "no schooling" for the rest of their life in the population. At higher ages, a portion of those with primary education makes a transition to secondary school; the rest remains in the "primary" state. It is similar for tertiary education.[2]

In Method 2 the population is distinguished by those who are "pre- or in school"; and two non-school groups: those who have left school with "primary or less," or "secondary or more" education. Within the "pre- or in school" state, no distinction is made between levels of schooling. People are born into the "pre- or in school" state and remain there until they leave school, with "primary or less" or with "secondary or more" education.[3]

In both methods, the fertility rates specific for age and education were deduced from information on age-specific fertility rates for the country and patterns of fertility differentials according to the education of the mother.

Mortality was considered to affect people equally in each educational category. Only a gender distinction was made. The assumption of no differential in mortality depending on the education is of course unrealistic if one considers that the maternal mortality rate is already highly correlated with the education of the mother. As well, population with no or little education mostly live in remote areas with little access to any health facilities, increasing the chances of death when medical attention would be immediately needed. However, data on age-specific death rates by educational level are scarce and were not available for the countries studied.

4.2. Scenarios

Three countries were selected for population projection by educational level: Cape Verde, Sudan and Tunisia. Sudan is the prototype of a country with a very wide base population age pyramid; very low levels of education for both sexes, high gender gap; and high fertility. Tunisia has high levels of school enrollment in primary and a relatively well-educated adult population with still large male/female discrepancies in the educational attainment of the population, and 70 percent higher TFR for women with low education than with high. Cape Verde has high school enrollment with substantially lower adult educational levels and 105 percent fertility differential in the starting year. The data used in these scenarios are the most recent national census data.

The scenarios are made primarily to assess the effects, lags, and momentum of past and hypothetical future educational policies on the educational level of adults, fertility, and population size. They also show that multi-state projections have different results than the more conventionally used one-state population projection, *even if the assumed rates of change are the same*.

In the scenarios shown here, the differences between the multi-state and the aggregate scenarios are greater, the larger the difference between the initial adult educational level and the educational level implied by

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Primary: those who have completed the final grade plus those who have completed more than one year of primary, even without completing the full course;
Secondary: those who have attended some secondary school whether or not they have completed the full course;
Tertiary: those who have undertook third level studies, no matter for how long.

[2] In Method 1, one of the characteristics of increasing school enrollment and education is that the transition rates of any level increase. As well, no distinction is made between persons who have attained a given level of education and are still in school, and those with the same level of education who have left school. It has the No schooling: those who have never attended school plus those who have completed less than advantage that the proportions of individuals in each education level during the schooling years are considered, which may be particularly useful for fertility studies, since fertility may be connected to education level even during enrollment in the age group 15-24.

[3] This method is useful to calculate education costs--with rising costs at higher age levels--or in cases when there is a noticeable fertility difference between women in school and women with a similar level of education but already out of school (for example young women in high school have a different fertility than young women in the same age group but no longer in school). One of the characteristics of more education is that the transitions out of school occur at progressively later ages. School exit transition rates are similar to fertility or mortality rates: they result in "births" in the non-school population, or conversely, "deaths" in the "pre- or in-school" population. In a population where most children leave the "pre- or in-school" population without ever having gone to school, the transitions into the non-school population groups are high in the age group 5-9. In a population which enforces mandatory school attendance until age 15 or higher, the school exit transition rates are low in the age groups below 15 and high in the age groups that follow, mostly into the "secondary or more" group.

the school enrollment rates, and the larger the fertility differentials between female adult educational levels. Although this paper does not give a mathematical proof that these tendencies are general, we believe that they can also be shown formally.

Section 4.2.1 compares aggregated population projections to multi-state for Cape Verde, Sudan and Tunisia. In Section 4.2.2., three multi-state scenarios for each country are made: a “Conservative” constant rates scenario; a “Gradual” fertility decline but no educational change; and a transition to “Modern” levels of education and fertility.

4.2.1. Multi-state educational and aggregate population scenarios

The populations of Sudan, Tunisia and Cape Verde were projected with a 35-year time horizon as a whole (aggregate case), and as multi-state versions (multi-state case) from starting year 1990 for Cape Verde, 1988 for Sudan, and 1989 for Tunisia to respectively 2025, 2023 and 2024. In both the aggregate case and multi-state case, age-specific mortality rates were equal and constant for the aggregate population and for the educational categories throughout the projection period. Constant fertility rates were applied to the aggregate case and multi-state case. In the multi-state case, there is a fertility differential between women with various levels of education. The starting level of overall TFR is the same in the aggregate case as in the multi-state case. In the multi-state case with different education states, constant school transition rates were applied throughout the whole period.[4] The assumptions and the results are summarized in Table 1.

[4] Our results are not particular to constant rates scenarios. We could also have compared an aggregate case and multi-state case scenario in which fertility rates decreased, for example at the annual rates assumed by the UN medium projection. In that case, the TFR of all women would have decreased at the given annual rate of decrease in the aggregate case, and the TFR of each education state at the same annual rate of decrease in the multi-state case. Of course, this would result in different population sizes and fertility levels than with a constant rates scenario. However, the extent of the differences between aggregate case and multi-state case results would be the same as with a constant rates scenario.

Table 1. Assumptions and results of multi-state and aggregate population scenarios for Sudan, Tunisia and Cape Verde.

	Sudan		Tunisia		Cape Verde	
	Aggregate	Multi-state	Aggregate	Multi-state	Aggregate	Multi-state
Total population, starting year						
	24 million in 1988		8 million in 1989		369,000 in 1990	
Total fertility scenario rates, starting year, constant rates through projection period						
Total TFR	4.95	4.95	3.42	3.42	5.12	5.12
No school	--	5.16	--	3.89	5.23	5.23
Primary	--	4.47	--	3.17		
Secondary	--	3.95	--	2.80		2.55
Tertiary	--	3.16	--	2.24		
School enrollment transitions, starting year, constant rates through projection period (in percent)						
To primary	--	male: 42 female: 33	--	male: 99 female: 90	--	
To secondary	--	male: 31 female: 24	--	male: 69 female: 53	--	rural: 48 urban: 62
To tertiary	--	male: 13 female: 7	--	male: 20 female: 14	--	
Percent of adult population with each educational level in starting year						
No schooling	--	male: 69 female: 82	--	male: 31 female: 58	--	female: 97
Primary	--	male: 19 female: 12	--	male: 35 female: 26	--	
Secondary	--	male: 11 female: 6	--	male: 29 female: 15	--	female: 3
Tertiary	--	male: 1 female: 0	--	male: 5 female: 2	--	
Total population, ending year						
	51.5 million in 2023	51.1 million in 2023	14.9 million in 2024	14.1 million in 2024	975,000 in 2025	717,000 in 2025
Percent of adult population with each educational level in ending year						
No schooling		male: 60 female: 68		male: 5 female: 14		75 percent
Primary		male: 29 female: 25		male: 36 female: 44		
Secondary		male: 10 female: 7		male: 48 female: 36		25 percent
Tertiary		male: 2 female: 0		male: 11 female: 5		

Table 1 shows that for Sudan, the population size by the end of the projection period is almost the same for the population as a whole as when it is divided by educational categories; in the case of Tunisia, aggregate case population is 6 percent larger than multi-state case; for Cape Verde, aggregate case is 36 percent larger than multi-state case. In terms of average annual growth rates, the Sudan annual growth rates are 2.2 percent for both cases; the Tunisian growth rates are 1.9 percent annually in the aggregate case and 1.7 percent in the multi-state case; and the Cape Verde rates are 2.8 and 1.9 percent, respectively. This shows that with this scenario, the disaggregation clearly makes a difference in some countries but not in others. This can be explained.

Let us begin with the country that least proves the point of significant differences between aggregate and multi-state population projection, namely Sudan. Although in Sudan there are fertility differentials by educational level--women with no schooling had a TFR of 5.16 in 1988 and those with tertiary education had a TFR of 3.16--consideration of education makes almost no difference to the aggregate case or multi-state case results. The answer is that during the projection period for Sudan, the education distribution remains virtually constant. Therefore, the relative weights of the educational groups remain constant and the overall fertility changes at the same rate with or without consideration of education.

One can see this education stagnation by comparing the starting year transition rates to the starting year education distribution among adults. The constant transition rates from no schooling to primary are 42 percent for boys and 33 percent for girls, meaning that of the present school generation, 58 percent of the males and 67 percent of the females will never go to school. This is only a slightly better educational level than that which already exists in the Sudan adult population: in 1988, 69 percent of the adult men and 81 percent of the women had never attended school. With present enrollment rates, the literacy rate in Sudan will remain close to its present low level.

A similar case of potential stagnation portends for secondary education. With the present transition rates, (42 percent x 31 percent) 13 percent of the males and (33 percent x 24 percent) 8 percent of the females will reach secondary school. This is almost identical with the existing secondary education level among adults: 11 percent for men and 6 percent for women in the base year.

Transition rates are translated into an adult education distribution with a time lag. If the adult education distribution that will result from present transition rates is similar to the existing adult education distribution, there will be little or no change in the future. In the case of Sudan, with constant rates, there will be no change in the educational level. Hence, the aggregate and the multi-state population projections are almost identical.

Tunisia shows a significant difference between the transition rates and the adult education distribution. Of the girls who were at the school entrance age in 1989, only 10 percent would not go to school--compared to 58 percent of the older cohorts of women aged 20-60 who had not gone to school in 1989--and 42 percent (90 percent x (100-53) percent) would have primary education only. At 1989 transition rates, (90 percent x 53 percent) 48 percent of those girls would go to secondary school. The 1989 girl transition rates imply that ultimately (14 x 53 x 14 percent) 7 percent of the girls then in school will go to the university.

By the end of the 35-year projection period these transition rates have been partially translated into educational levels of the adult female population. The percentage of women with no schooling is 14 percent, with primary 44 percent, secondary 36 percent and tertiary 5 percent. These are substantially higher women's educational levels than in 1989. Concomitant to the higher adult educational levels distribution, with larger weights on the low fertility levels of the better-educated women, the aggregate total fertility rate is lower than in the starting year, even though the fertility rates *within* the educational groups were constant. Lower total fertility in the Tunisian multi-state population projection leads to a 6 percent smaller population in the multi-state case compared to the aggregate case projection.

This indicates a simple rule as to the direction of future changes. We observe that *the future education distribution of the adult population will be between the present education distribution and the "steady state education distribution" implied by the transition rates.* We believe that a formal proof would show the above to be a general rule, and would also show that the longer the time horizon, the closer adult educational rates will be to the "steady state education distribution."

Much of the same applies to Cape Verde, but with an even bigger difference between the aggregate case and the multi-state case population in the end year than with Tunisia. This is due to two factors. First, the difference between the starting year adult education distribution and the transition rates is considerably larger for Cape Verde than for Tunisia: on Cape Verde only 3 percent of the women had secondary education in 1990, compared to a roughly 50 percent transition to secondary school. Second, the fertility differential by educational group in Cape Verde in 1990 was larger than in Tunisia in 1989. A comparison of these scenarios shows that *the bigger the difference between the education distribution of adult women compared to school transition rates, and the larger the fertility differential by educational group, the bigger the difference between the aggregate and the multi-state population projections at the end of the period.* Again, we believe this to be a general rule that can be established formally.

4.2.2. Multi-state scenarios with different trajectories of fertility and education

The previous sub-section implements a scenario of constant rates for the three countries. However, a policy maker may want to explore the effect of improving the educational intake, for example along the lines of the ICPD recommendations. One may also want to consider that TFR within educational groups will fall in the future as it has in the past. To accommodate such exploration, three similar scenarios were produced for each of the three countries.

The first group is called Conservative. It assumes there is no change in the education system over the projection period, that is, transitions, school exit patterns, and fertility within each educational group remain constant at the level they had in the projection base year. This is identical to the multi-state case scenario discussed in the previous section.

The second scenario group is called Gradual. Like the Conservative, it assumes no change in the education system over the projection period. However, a Gradual decline in fertility is assumed. The annual rate of fertility decline in all educational groups is equal. It is equal to the rate which is necessary to achieve a total fertility rate equal to that assumed in the UN medium population projection for each country: 1.5 percent annually within each educational group for Cape Verde, 1.3 percent annually for Sudan and 0.9 percent annually for Tunisia.[5]

The third scenario, called Modern, assumes school enrollment increases plus the above fertility decline. In Cape Verde it is assumed that a mandatory school attendance until the age of 15 is implemented gradually until 2025, in effect assuming secondary education for all by that period--a policy the government presently wants to implement. In Tunisia and Sudan, the Modern scenario assumes an implementation of the ICPD Programme of Action whose goal is universal access to primary education before the year 2015; the eradication of female illiteracy; and closing the gender gap in primary and secondary school education by the year 2005. It is clear from the previous section that implementation of universal primary education will entail much less change in Tunisia than it will in Sudan.

It is important to bear in mind throughout this section that the variation between the different scenario results are due to (i) a fertility decline between the Conservative and the Gradual scenario; (ii) improvements in educational achievement between the Gradual and the Modern scenario; and, (iii) the combination of fertility decline and educational improvements between the Conservative and the Modern scenarios.

Cape Verde

Population scenarios for Cape Verde distinguish four groups of women: those with secondary or higher education in urban and rural areas separately, and those with primary education or less in urban and rural areas separately. These distinctions were made based on the observation in Cape Verde that 1) fertility levels differed considerably by only these two groups of education, and 2) that educational attainment was very different in urban from rural areas. For comparison, historical background data is given for the period 1970-1990. Assumptions and results for males are not shown. There was some migration from rural to urban areas between 1970 and 1990 on Cape Verde. For the enrollment rates, this means that the rates of enrollment increases for the country as a whole were larger than for urban and rural separately. There were almost no rural/urban fertility differentials by educational group in 1990. No further migration is assumed in the projection period.

Table 2 shows that in 1970, fertility was high at 6.15 per woman (no separate data by education was available); secondary education in rural areas was practically nil, but in urban areas nearly one-third of the children were leaving school with at least some secondary education; and, that the overall proportion of adults with secondary education was only one percent.

Between 1970 and 1990, the government of Cape Verde put much energy into increasing school attendance and school availability. The result of this effort is seen in the much higher rates of children leaving school with secondary education in 1990 than in 1970. In 1990, almost half of the children in rural areas were receiving some secondary education before leaving school, and in urban areas, 60 percent of the girls were receiving secondary education.

Table 2. Assumptions and results of the multi-state population scenarios for Cape Verde.

[5] The 1.5 percent assumed for Cape Verde is slower than the 1.8 percent annual average overall fertility decline from 1980-1990. Until 1984, there was no family planning program on Cape Verde. The rates assumed for Tunisia and Sudan are also much slower than the fertility decline which has happened in the last decade: -1.8 percent in Sudan from 1979 to 1990 and -5.4 percent from 1978 to 1988 in Tunisia. All of the assumed rates lead to the UN medium scenario level of fertility in the end year of the projection.

	1970	1990	2025 Conservative	2025 Gradual	2025 Modern
TFR primary (percent annual change)	N.A.	5.23	5.23 (0.0)	3.15 (-1.5)	3.15 (-1.5)
TFR secondary (percent annual change)	N.A.	2.55	2.55 (0.0)	1.53 (-1.5)	1.53 (-1.5)
TFR total *(percent annual change)*	*6.15*	*5.12 (-1.8)*	*3.59*	*2.13*	*1.62*
School exit with secondary education (in percent)	rural: 1 urban: 29	rural: 48 urban: 62	rural: 48 urban: 62	rural: 48 urban: 62	rural: 89 urban: 92
Percent adults with secondary education	*1*	*3*	*25*	*28*	*44*
Total population size *(x1000)*	*272*	*369*	*717*	*595*	*545*

Yet, in terms of the “percentage of adults with secondary education” the twenty years of educational effort from 1970-1990 made almost no impact: the percentage of adults with secondary education in 1990 was a mere 3 percent. Here we see the long gestation period necessary for an educational change to come to fruition, and the long momentum in the education of the adult population which influences future educational achievement levels in the adult population. In actual fact, the efforts of Cape Verde are on the verge of bearing fruit. In the next decades, the secondary education levels of Cape Verde will begin a steep rise.

In the Conservative scenario, identical with multi-state case above, with no changes in the enrollment rates and constant fertility by educational group, the proportion of adults with secondary education increases by a large amount between 1990-2025 to a quarter of the adult population. Average educational levels among the young, childbearing adults are even higher. This result is reflected in the large fertility decreases between 1990-2025. Total fertility declines from 5.12 in 1990 to 3.59 in 2025 even though the fertility levels per educational group remain unchanged. The total population increases from 395,000 in 1990 to 717,000 in 2025.

In the Gradual scenario, the fertility levels within the educational groups are allowed to decline, although more slowly than observed from 1980-1990 (even considering education). This leads to replacement fertility by 2025. The women with primary education or less still have fertility levels above three children, but the women with secondary education or more have very low fertility levels comparable to those in industrialized countries today. The lower fertility results in a much lower population than in the Conservative scenario, namely 595,000 people in 2025.

Adding higher education efforts to the Gradual scenario produces the Modern scenario. In this scenario, the school exit rates for secondary education in Cape Verde are on a par with industrialized nations by 2025. With the same fertility assumptions as above, the fertility within each educational group is the same as in the Gradual scenario. However, because of the larger proportion of women with secondary education than in the Gradual scenario, the total fertility level is much lower, closer to the level of women with secondary education. The lower fertility results, of course, in an even smaller population, namely 545,000. More important for the economy of the country however, may be the higher proportion of people with secondary education in the labor force.

Sudan and Tunisia

The scenarios for Sudan and Tunisia divide the population into four educational sub-groups: people with no schooling; with primary education; with secondary education; and with tertiary education. The education scenarios differ for men and women, and fertility differentials are assumed between women at each educational level. Table 3 shows some selected figures for the base year and the results of the three scenarios for both countries in the end year. Shown in the table are population size, total fertility rate, and the proportion of male and female adults in the age group 20-60 with each of the four educational levels.

Table 3. Results of the Conservative, Gradual and Modern scenarios for Sudan and Tunisia.

	Sudan		**Tunisia**	
	1988	**2023**	**1989**	**2024**

	Base Year	Conser-vative	Gradual	Modern	Base Year	Conser-vative	Gradual	Modern
Total Population in million Percent annual change	23.9	51.1 (2.19)	43.2 (1.71)	42.9 (1.69)	7.8	14.1 (1.71)	12.8 (1.43)	12.8 (1.43)
TFR Percent annual change	4.95	4.89 (-.03)	3.21 (-1.23)	3.13 (-1.30)	3.42	3.00 (-0.29)	2.25 (-1.19)	2.21 (-1.24)
Percent No Schooling in adult population								
Male	69.0	59.7	59.7	48.9	31.4	4.6	4.7	4.6
Female	81.6	67.9	68.0	55.2	57.7	14.1	14.2	12.5
Percent Primary education in adult population	18.7	28.6	28.5	36.0	35.2	35.9	36.0	36.1
Male	12.1	24.6	24.6	32.3	25.8	44.2	44.2	38.7
Female								
Percent Secondary education in adult population	11.2	10.2	10.4	13.3	28.7	48.4	48.2	48.3
Male	5.9	7.1	7.1	11.7	14.9	36.4	36.2	42.4
Female								
Percent Tertiary education in adult population	1.1	1.5	1.3	1.7	4.8	11.1	11.1	11.1
Male	0.4	0.4	0.4	0.7	1.6	5.4	5.4	6.3
Female								

The Conservative scenario for Sudan and Tunisia is identical to the multi-state case of the previous section. Due to very slow educational increases in Sudan, the overall TFR declines only marginally. In Tunisia, with a greater educational momentum built into the present structure, overall TFR declines from 3.42 in 1989 to 3.00 in 2024. In 2023 the population of Sudan would be 51 million (compared to 24 million in 1988). The population of Tunisia would grow from 8 million in 1989 to 14 million in 2024.

In the Gradual scenario, the same annual declines of fertility levels within all four educational categories are assumed. The decline rates are set so as to approximate the TFR projected by the United Nations medium variant fertility in 2020-25: 3.56 for Sudan and 2.1 for Tunisia (United Nations 1994).

In Sudan, the TFR for the whole population diminishes at the same rate as the TFR for women by educational categories. The 1.25 percent annual fertility decline between 1988 and 2023 in each educational category leads to a 1.23 percent annual decline of the total fertility rate. This is because the adult education distribution hardly changes, in which case, as pointed out in Section 4.2.1, the scenario results are the similar for the aggregate and the multi-state populations. In Tunisia, overall TFR decreases at a yearly rate of -1.4 percent although the decrease in each educational category was only -0.9 percent annually. The overall decrease is larger than within categories because low fertility, high educational groups gain more weight as time passes.

With the lower fertility rates, the resulting Gradual scenario population is smaller than in the Conservative scenario: 43 million instead of 51 million for Sudan, and 13 million instead of 14 million for Tunisia.

The Modern scenario for Sudan and Tunisia simulates the implementation of the ICPD recommendations that there is universal access to primary education by the year 2015 and the removal of any gender gap at primary and secondary level by 2005.

This policy would mean a major effort on the part of the Sudanese. In Sudan, the goal of 100 percent intake in primary for boys and girls by the year 2015 would imply large investments which seem unattainable at the moment considering the state of the country (civil war, famine). This scenario is actually optimistic in that it is assumes that there are no financial constraints and no major cultural impediments to attain the ICPD goal.

In Tunisia, which already had 90 percent school entry rate for girls in 1989, it is comparatively a trifle to increase primary intake for girls to 100 percent. To reduce the gender gap between boys and girls would mean that 69 percent of the girls would go to secondary school; this is up from 53 percent with constant education transitions.

The populations in the Modern scenario are 43 million in Sudan and 13 million in Tunisia, hardly less than those in the Gradual scenario with no enrollment rate increases. The reason the Modern populations are so similar to the Gradual is because the educational efforts occur after 1988 or 1989. Most efforts are not completed before 2015 in the Modern scenario, at least in terms of universal access to primary schools. This leaves too little time for these changes to affect the population size. There is a time lag between the education of girls and their arrival in fertility ages, at least ten to fifteen years; therefore, although some changes are reflected into the educational composition of the population, at least in the young age groups, and in the TFR of the whole population, most women who have benefited from the educational improvement have not yet finished their fertile years by the end of the projection period and have therefore not yet affected fully the rate of population growth.

Is it true that the educational investments would make so little difference? We argue that on two grounds (at least) such a conclusion would be false. First, enrollment increases translate into significantly higher educational levels among young adults by 2023/4. Second, the enrollment increase effect on fertility and population growth simply needs more time to mature, which can be shown by extending the projection horizon. The Modern scenario shows clearly how long new educational policies need to take effect. Both arguments are discussed in order.

The largest differences between the Modern and the Gradual scenario up to 2023/4 are in the population educational composition, which can be seen in a comparison of the educational make-up of the end-year population pyramids for both the Modern and the Gradual scenarios, shown in Figures 5a and 5b for Sudan and Figures 6a and 6b for Tunisia.

Figure 5a. Age pyramid of Sudan in 2023 - Gradual scenario

Figure 5b. Age pyramid of Sudan in 2023 Modern scenario

Figure 6a. Age pyramid of Tunisia in 2024 - Gradual scenario

Figure 6b. Age pyramid of Tunisia in 2024 - Modern scenario

The educational difference between the Gradual and Modern scenarios is large in Sudan, especially at the lower educational levels, and with regards to the gender gap in adult level of schooling. The gender gap is considerably lower in the Modern than in the Gradual scenario. For Sudan, in the Gradual scenario, 60 percent of the male adult population and 68 percent of the female were without any education in 2023. In the Modern scenario, the percentage of no schooling in the adult population is 49 percent for males and 55 percent for females. This means a moderate decline in illiteracy. The no-schooling group is absorbed mainly by the primary level group. Whereas only 29 and 25 percent of male and female adults had some primary education in 2023 according to the Gradual scenario, they are 36 and 32 percent in the Modern scenario. The proportion of adults with some secondary education is higher in the Modern as well, more noticeably for women. Only 7 percent of the adult population has secondary education in 2023 in the Gradual scenario, compared to 12 percent in the Modern scenario (Figures 5a and 5b).

The ICPD goal is almost already attained in the base year in Tunisia, so the difference between the Gradual and the Modern scenario is small. In Tunisia, the implementation would imply that female children catch up with their male counterparts at primary and secondary levels. The proportion of male adults at each educational level is almost equal in the Gradual and in the Modern scenario. Women are better educated in the Modern Tunisia scenario than in the Gradual one. The gender gap is never more than 7 percentage points whatever educational level is considered. The proportion of adult women without any schooling is 12.5 percent under the Modern scenario, whereas it was 14.2 percent under the Gradual scenario. The percentage with primary education is substantially lower in the Modern scenario, 39 percent instead of 44 percent under the Gradual scenario. This corresponds to more people with secondary education in the Modern scenario. Under the Gradual scenario, 36 percent have some secondary education; they are 42 percent under the Modern scenario (Figures 6a and 6b).

By 2023, most projected enrollment changes in Sudan and Tunisia have affected the young age groups of the population and have not yet reached the whole adult population group. In 2023 the eradication of illiteracy in the population is on its way but is not fully accomplished. As shown in the age pyramids of the two countries, the no-schooling group has been eliminated up to the age of 14 years for both sexes; above this age there are still some people, and more noticeably women, who have never received any schooling. The gender gap still remains at some schooling levels.

It is clear from the age pyramids that although the educational level of the population would improve in both countries from 1988/9 to 2023/4, the implementation of the policy has still some fruit to bear. The educational policy needs more time to mature. To show how much more time, the scenario horizon is extended to 2103 for Sudan and 2104 for Tunisia. Fertility, mortality, educational transition remain constant after the end of the initial projection period.

In Sudan, in the absence of any adult education, it would take until 2068 before all the adult population has had some schooling; not until 2098 would the whole population have minimum primary schooling--85 years after the implementation of the policy. This figure calls for a redefinition of long-term vision in policy management!

Even in Tunisia, which has much higher educational levels than Sudan today, and where the implementation of the ICPD Programme would not imply tremendous effort--girls achieve full primary intake by 2004, and boys achieved it in 1988--illiteracy does not disappear from the adult male population until 2039; it takes until 2069 to eliminate illiteracy among women!

By 2103, the difference between the population sizes in the Gradual and Modern scenarios becomes evident. Following the Gradual scenario, the Sudanese population would reach 52 million in 2103, whereas the Modern scenario would lead to a much smaller population of 41 million; the Gradual population is 27 percent larger than the Modern population in 2103.

For Tunisia, the main long term difference between the Gradual and the Modern scenario is in the proportions of women with secondary schooling. With the implementation of the Modern scenario educational policy, Tunisian women would reach the same educational levels as men by 2104: 31 percent with primary education and 55 percent with secondary education compared to 42 percent of women and 55 percent of men with secondary education under the Gradual scenario. The Tunisian population size in the Gradual is 11 percent larger than in the Modern scenario in the extension to 2104: 13 million with the Gradual scenario in 2104 and 11 million with the Modern scenario. This difference is not as large as it is in the Sudanese case; the Modern scenario for Tunisia reflects the relatively small improvements over the enrollment levels which already existed in Tunisia in 1989.

5. Conclusions

The role of education in socio-economic development, women's status, health, and desired family size was emphasized as early as 1795 by Condorcet, recently at the 1994 ICPD in Cairo, and in between by countless others. Given the pivotal role of education for human welfare, it is important to understand the patterns with which education increases, past and future. This is the purpose of this paper.

Data for school enrollment rates by major global region from 1960-1990 show that school enrollment at all school levels increased. The highest school enrollment rates were observed in the Developed Countries, Latin America and the Caribbean, and East Asia; lower rates were observed in the Arab States, Sub-Saharan Africa, and South Asia. The data show that when there is an educational increase, enrollment rates of boys tend to increase before the enrollment rates of girls. As school enrollment rates close to unity, both boys and girls have similar enrollment rates. In the interim, there is a gender gap. The exception to this observation is Latin America and the Caribbean, where male and female enrollment ratios have been equal since 1960. Enrollment ratios are highest for primary school and lowest for tertiary education, as expected. The gender gap pattern described above tends to be repeated for each educational level, although the gender gap observed in each region is higher and has declined more quickly at higher levels of schooling.

Future scenarios were made for three countries, Sudan, Tunisia, and Cape Verde, with multiple levels of education in the population. Three groups of scenarios were made: Conservative, with no fertility changes within the educational groups and constant school enrollment rates; Gradual with some fertility declines; and Modern with fertility declines and enrollment rate increases.

The multi-state population projections are compared with an aggregate single-state projection for each country. Even with identical rates of change in fertility, mortality and migration for each state (multi- or single) the total population size and TFR trajectories over the projection period differ for the multi-state and the aggregate population.

The present school enrollment or school transition rates, if projected without change, transform into stable population educational proportions. For example, if 20 percent of the children leave school with primary education today, and this rate is projected forward, eventually the whole adult population will have 20 percent "stable" primary education. In the scenarios we saw that, in cases where the present enrollment rates are higher than the present proportions educated in the adult population--as they are in Tunisia and Cape Verde and are not in Sudan--the constant transition rates tend to improve the educational level of the adult population in the direction of "stable" proportions. When the present enrollment rates are higher than in the past, with larger portions of the population, specifically women, achieving higher educational levels, and there are fertility differentials by education, the total average fertility falls more quickly in the multi-state scenarios than in the aggregate scenarios, even if the rate of fertility change is the same in each sub-population as in the aggregate population. This is because the shifting weight of the female population to the high education, low-fertility groups is added to whatever fertility changes occur independently.

We believe that, as a general rule, the bigger the difference in the starting year between the enrollment rates and the proportion of the adult population educated (i.e. the educational effort is recent), and, the bigger the fertility differentials by educational level, the larger the difference between the aggregate and the multi-state population projections.

It may be argued that in single-states population projections, the effects of increasing educational levels on fertility are implicitly accounted for in assumptions about decreasing fertility levels. However, doing so has the same disadvantage as projecting the future population size based on assumed changes in the population growth rate alone: non-linearity by changing group weights in a heterogeneous population cannot be accounted for. There is a time lag between the time an educational policy is implemented, and the time the beneficiaries complete their schooling and enter their fertility years, causing lower fertility on the aggregate level due to educational fertility differentials. An increase in female enrollment will result in larger cohorts of women with higher levels of education. As these "higher educated" cohorts are assumed to have lower fertility levels, aggregate fertility may show a stepwise decline rather than a smooth linear one. The two phenomena above show the importance of simultaneously considering age-specific levels of education and fertility. Furthermore, the age pattern of fertility of women in each educational category is different and will influence the pattern of fertility decline. The usual linear interpolation between present aggregate fertility and that assumed for a certain point in the future does not capture these relevant effects.

The diffusion of education has a long momentum. Thus, there is a long time lag between beginning an effort to educate the youth and the effect of having an adult population which is well educated. In the scenarios presented in this paper, the time lag is considerably longer than a generation, rather more the length of an adult working lifetime (i.e. 40-50 years rather than 15-20). An implementation of the ICPD recommendation to aim for full primary school intake by 2015 would take 85 years to eliminate illiteracy from Sudan because of this long lag.

Once the momentum begins to take hold, the educational level of the adult population can change quickly, particularly when young generations are very large in relation to the present adult population. In the countries used as examples, the change from an "uneducated adult population" to an "educated adult population" is non-linear and can happen quite suddenly when the large young cohorts become adults. Where there have been recent increases in education, the aging of the better-educated cohorts in the adult category, and the gradual death of the older, less-educated cohorts lead to future increases in education, even if the education system stagnates. On Cape Verde in 1990, only 3 percent of the adults had secondary education. In the Conservative scenario and the Gradual scenario, each with constant school enrollment rates, the percentage of adults with secondary education increases to 25 percent by 2025 simply because of this momentum.

The non-linear increase of average educational levels also means that the associated fertility levels decrease in a non-linear fashion. In fact, fertility can drop at a rate that is faster than expected once a large cohort of relatively well-educated young women enters the childbearing age. This dynamic could, in part, explain some of the sudden fertility changes observed in some countries (Mauritius, Thailand, Taiwan, Jamaica). If there are fertility differentials by level of education, future declines in fertility can be expected even if fertility within the educational groups remains constant. One scenario for Cape Verde showed the total fertility rate could decline from 5.1 to 3.6 between 1990 and 2025 simply due to the momentum inherent in the present education system, without any changes in the school transition rates or fertility within the educational groups. In Tunisia, which has lower transition rates in the base year than Cape Verde, the total fertility rate would decrease from 3.4 in 1989 to 3.0 in 2024.

In the case where there are fertility decreases within educational groups, they are compounded by a continued increase in the educational profile of the adult population. Thus, the Gradual scenario for Cape Verde shows that, even with only a 1.5 percent decline annually in fertility within educational groups, the total average annual fertility decline is 2.5 percent from 1990-2025. In the Modern scenario with continued education increases, the total average fertility decline is 3.3 percent, more than double that within group change. In the Gradual scenario for Sudan, the fertility declines at an average rate of 1.25 percent annually in each educational group of women, but the total fertility rate declines at 1.27 percent annually from 1989 to 2024 in the Gradual scenario and 1.42 percent in the Modern.

The above exercise shows some important dynamics of education and fertility change and leads to some optimism about the future decline in fertility. In the past few decades, many countries have taken great strides to increase their education systems, sometimes with superficially disappointing results to date (as on Cape Verde from 1970-1990). But it is only a few decades after increases have been implemented that the fruits become obvious in the population. The efforts of the past two or three decades will become increasingly obvious in the near future. This may lead to some unexpected fertility declines, and other changes associated with higher education. Thus, it is possible that fertility will fall more quickly than expected in aggregate projections, and that populations will grow more slowly than presently expected.

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Technical Note 1

Population Projection with Multiple States -- The Extended Leslie Matrix

The cohort component method of population projection is extensively and well-described in, for example, Keyfitz (1977) or Wunsche and Termote (1978). With this method, the population is divided into two sexes and age groups *(a)* of equal length *x*. The time interval of the projection is also of length *x*. Each age group has age-specific survival rates *S(a),* fertility rates *F(a),* and migration rates. In this section, the survival rates and net-migration rates are both included in *S(a)* for clearer representation. They will be discussed in more detail below. The survival and net migration rates are each applied to the relevant age category for the length of one period.

At the beginning of a time period *t*, the population is represented by a vector of 2*n* length, males and females separated into *n* age groups. The purpose is to project the size of the population in time *t*+*x*. To do this, the *x*-year survival (and migration) rates are applied to the relevant age group. After a period of *x* length, each member of an age group *(a)* is *x* years older--that is, the population of each age group has moved to the next age group (*a*+*x)*, and has been decreased in size by less than complete survival.

The age-specific fertility rates provide the total number of births which is put into the youngest age category according to the known ratio of male:female births, *r*. The number of births is the product of the birth rates in age group *a* and the number of female survivors in age group *a*. In any given time interval, a woman on average spends half of that interval in the age group she is in at the beginning of the interval, and half of that period in the subsequent age group. Therefore, for each age group an average of the fertility of the beginning age group and the subsequent age group is calculated weighted by the survival rates in the two age groups. This is represented in the Leslie matrix below by $F(a)S_f(a)$. The newborns also experience mortality and migration during the projection period, *S(0).* The extended notations are discussed in the literature. These movements of birth and dying are summarized in the Leslie matrix, which is shown in Figure A1.1.

Figure A1.1. The Leslie matrix with two genders and *a* age groups.

0	0	$[rF(10)S_f(10)]\frac{5}{2}S_f(0)$	$[rF(15)S(15)]\frac{5}{2}S(0)$	...	0	0	...	...	...	...	0
$S_f(5)$	0	0	0	...	0						
0	$S_f(10)$	0	0	...	0						
M	M	M	M	M	0						
0	0	0	...	$S_f(a)$	0						0
0		$[(1-r)F(10)S_f(10)]\frac{5}{2}S_m(0)$	$[(1-r)F(15)S_f(15)]\frac{5}{2}S_m(0)$			0	0			...	0
0						$S_m(5)$	0	0	0	...	0
0						0	$S_m(10)$	0	0	...	0
0						0	0	$S_m(15)$	0		0
M						M	M	M	M	...	0
0	0	...	...			0	0	0	0	$S_m(a)$	0

The Leslie matrix is used with a population distinguished only by sex and age. The transitions are: into the population through birth, and out of the population through death. However, much demographic and socio-economic study, including this one, is interested in more than the size and age structure of the population, namely, with its socio-economic characteristics. As in this paper, the concern is with the pattern of educational achievement in the population. There

> ...is an underlying concern with the transitions that people experience over time in the course of passing from one state of existence to another: for example, transitions from being single to being married, from being alive to being dead, from being employed to being unemployed, from being in school to having graduated... Recent work in multi-state demographic analysis has produced a generalization of classical demographic techniques that unifies most of the methods for dealing with transitions between multiple states of existence... It is... clear that projections of populations classified by multiple states can be carried out using a common methodology of multi-state projection, in which the core model of population dynamics is a multi-state generalization either of the continuous age-time model of Lotka..., or of the discrete age-time model of Leslie....
>
> (Rogers and Wilson 1980)

It was found that the scalars for survivorship in the Leslie matrix, *S(a)*, or scalars for mortality, can be replaced by a matrix in each age group which includes all the transitions. The transitions refer to movements from one socio-economic state to another and are distinct from mortality or its inverse, survivorship. Each transition can be called $T_{ij}\,(a)$ which means the transition rate into state *i* out of state *j* in age group *a*. In every period, each person is exposed to a certain probability of making a socio-economic transition and to dying. Thus, in the matrix of transitions, survivorship *S(a)* and the transitions $T_{ij}\,(a)$ are included. Figure A1.2 shows the multi-state transition matrix for age group *a*. Along the diagonal are the survivorship of state *i* multiplied by the population which does not make a transition from *i* to another state *j*. All the other cells concern the movers and their survivorship. The careful reader of the matrix will note that all transitions are made at the beginning of the projection interval, since the movers take on the survivorship of the receiving state. This simplifying assumption is used in this paper and earlier studies on Mauritius (Prinz and Wils 1994; Wils and Prinz 1996) and Cape Verde (Wils 1996). The assumption is not disturbing when mortality rates are identical or very similar in different states. In our work so far, this has been the case. One can expect similar mortality in many cases of socio-economic states except in cases such as two states of sick and of healthy people.

Figure A1.2. The multi-state transition matrix with *n* states for age group *a*.

$$\begin{matrix} S_1(a)[1-\sum_{i\neq 1}^{n} T_{i1}(a)] & S_1(a)T_{12}(a) & \cdots & S_1(a)T_{1n}(a) \\ S_2(a)T_{21}(a) & S_2(a)[1-\sum_{i\neq 2}^{n} T_{i2}(a)] & \cdots & S_2(a)T_{2n}(a) \\ \vdots & \vdots & & \vdots \\ S_n(a)T_{n1}(a) & S_n(a)T_{n2}(a) & \cdots & S_n(a)[1-\sum_{i\neq n}^{n} T_{in}(a)] \end{matrix}$$

This matrix can be called the *T(a)* matrix and is analogous to the *M(a)* matrix in Rogers which uses notation for mortality rather than survivorship in a continuous time model (Rogers 1975; Rogers and Wilson 1980; Keyfitz 1985).

In the population with multiple states, differential fertility behavior of the different states can be included in the population projection. The total fertility is the weighted average of the state-specific fertility. When the weights of the different states change, as occurs in the educational groups discussed in this paper below, then the average fertility level can change without any changes in behavior within the states. Usually, the weights of the states are changing together with fertility behavior within the states.

In general, babies are born to women either in the same state that the woman is in, for example a geographical region, or a religious group, or in some initial state, such as illiterate or never married. This too, can be captured in an age-specific fertility matrix which is shown in Figure A1.3. The fertility rates along the top row represent the births of babies into an initial state which may be different from that of the mother (but not necessarily so). The fertility rates along the diagonal represent the case where babies are born into the same state as their mothers. Theoretically, all combinations of births and mothers in the matrix are possible, but they are less usual and therefore not shown. This matrix can be called the birth matrix for age *a, B(a).*

Figure A1.3. The birth matrix, *B(a),* with *n* states.

$$\begin{matrix} [rF_{11}(a)S_1(a)]\frac{5}{2}S_1(0) & [rF_{12}(a)S_1(a)]\frac{5}{2}S_1(0) & \cdots & [rF_{1n}(a)S_1(a)]\frac{5}{2}S_1(0) \\ 0 & [rF_{22}(a)S_2(a)]\frac{5}{2}S_2(0) & & 0 \\ \vdots & \vdots & & \vdots \\ 0 & 0 & \cdots & [rF_{nn}(a)S_n(a)]\frac{5}{2}S_n(0) \end{matrix}$$

To get a multi-state projection matrix, the fertility scalars in the Leslie matrix are replaced by the *B(a)* matrices, and the survivorship scalars are replaced by the transition matrices *T(a).* The single state population vector, *P*, is replaced by an extended multi-state population vector which we call Ψ. The Ψ vector is made by extending each scalar of the single state population to the *n* number of states.

The projection equation with the new extended Leslie matrix with multiple states, and the multi-state population vector are shown in Figure A.1.4.

Figure A.1.4. Extended Leslie matrix with multiple states.

$$
\begin{bmatrix} \Psi_{t+x}(0) \\ \Psi_{t+x}(5) \\ \Psi_{t+x}(10) \\ \vdots \\ \Psi_{t+x}(a) \end{bmatrix} = \begin{bmatrix} 0 & 0 & B(10) & B(15) & \cdots & 0 \\ T(5) & 0 & 0 & 0 & \cdots & 0 \\ 0 & T(10) & 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & & 0 \\ 0 & 0 & 0 & 0 & T(a) & 0 \end{bmatrix} \times \begin{bmatrix} \Psi_{t}(0) \\ \Psi_{t}(5) \\ \Psi_{t}(10) \\ \vdots \\ \Psi_{t}(a) \end{bmatrix}
$$

Mortality
The survivorship rates are calculated from empirical mortality rates using conventional life-table techniques (for example, Keyfitz and Foster 1986; Keyfitz and Flieger 1990; or other standard demography works) up until the last age group.

The survivorship and the relative size of the last age group can change dramatically in the course of a scenario period of 30-50 years. If this is so, then it can happen that the original last age group becomes inadequate. Imagine a developing country with mortality data up until the age 65+ in 1990. In the course of the scenario period up until 2050, mortality decreases tremendously and the age group 65+ mushrooms to a significant proportion of the population. In this case, taking the 65+ as one group leads to incorrect population size results towards the end of the scenario period. To avoid this, a technique of mortality extrapolation such as that used by Coale and Demeny (1983:20) for their model life tables is applied for the last age group.

In this technique, the last age group is artificially extended by, for example, three or five age groups. Artificial mortality rates have to be devised and the relative size of the artificial age groups estimated. The mortality rates are calculated by fitting a Gompertz curve through the four age groups previous to the last age group and extrapolating it (following the suggestion by Namboodiri and Suchindran 1987:20) to extend the life table. In the software developed at IIASA, the length of the extrapolation is from the last age group specified by the empirical data to the age group 100+. This extended life table is used to calculate the number of the oldest population members by artificial age groups and then summed up again to provide the number of persons in the original age group.

To do this, an estimation of the age distribution of the last age group is necessary for the starting year. It is assumed that the age distribution is equal to the stable population distribution of the highest age groups implied by the artificial mortality rates of the starting year. The conventional stable population distribution formula, *c(a) = b-r(a)* where *c(a)* is the proportion of the population in age group *a*, *b* is the birth rate, and *r* is that rate of increase, could not be used. To calculate *r*, the stable rate of increase, birth rates are necessary, which do not apply to the few highest age groups. As an alternative, the relative size of the age groups in the stable population is given by the relative size of the *L(a)* values, so that the relative size of each age group in the extrapolation is equal to:

$$P(a) = P(+)\frac{L(a)}{\sum_{a=+}^{100} L(a)}$$

where *P(a)* is the population in the artificial age group *a*, *P(+)* is the total population in the last age group; and *L(a)* are the artificial life-table values for number of years lived in age group *a*.

Technical Note 2

Base Population and Educational Transition Estimation for Method 1

UNESCO (1993) provides educational attainment for the age group 15 and above, divided by 5-year age groups up to the age of 25 and then 10-year age groups. UNESCO defined six categories: no schooling, uncompleted first level, completed first level, entered second level first stage, entered second level second stage, and post secondary. For convenience and as well for reasons of incomplete data for most of these categories, we used the four categories described in Section 4.1.2, i.e. no schooling, primary, secondary and tertiary.

Large age groups were changed to 5-year age groups so that the desegregation was finally consistent with the aggregate of educational attainment above the age of 25, an information provided by UNESCO (1993).

The level of education for the age group 0-14 had to be estimated and was calculated according to the enrollment ratios by educational level, as explained below. The difficulty of calculating the population by age groups and by educational level is that the educational level almost never corresponds to the chosen 5-year age groups: 5-9, 10-14, 15-19; for instance in the case of Tunisia, 6-11 for primary and 12-17 for secondary. Thus, a method for estimating 5-year enrollment was desired.

The population of primary schooling age $P_{Lp:Up}$ calculated as follows:

$$P_{Lp:Up} = (1 - 1/n (L_p - 5))P_{5:9} + 1/n (U_p - 9)P_{10:14}$$

where L_p is the lower limit of the schooling age, U_p is the upper limit, y_p is the duration of schooling, and *P* is the estimated population.

To calculate the population actually in primary school, P_p:

$$P_p = P_p = P_{Lp:Up} \times E_p$$

was used, where E_p is the primary enrollment ratio.[6]

Further, the population of age group 5-9 in primary school $P_{p_{5:9}}$ is:

$$P_{p_{5:9}} = P_p \times \frac{n-(L_p-5)}{y_p}$$

and the population of age group 10-14 in primary school $P_{p_{10:14}}$ is:

$$P_{p_{10:14}} = P_p \times \frac{U_p-9}{y_p}$$

The same calculations are made for secondary school but replacing $L_p - 5$ with $L_s - 10$; $U_p - 9$ with $U_s - 14$; and all *P*, *E* and *y* with the appropriate subscript letter or age group.

To calculate the transitions a few steps are taken. First, the five-year age groups of schooling are divided into five single years. One of these five single years is the age of "normal" transition from one school level to the next (for example, 6 for primary, 12 for secondary, 18 for tertiary).

The transition from no schooling to primary for age group 5-9, $T_{p_{5:9}}$ is calculated as follows:

$$T_{p_{5:9}} = (1 - \frac{L_p-5}{n}) \times E_p$$

where T_p is the transition rate and the other variable notation is as above.

For age group 10-14, $T_{p_{10:14}}$ the calculation is:[7]

[6] When available, net enrollment ratios were preferably used to gross enrollment ratios: "The gross enrollment ratio is the total enrollment, regardless of age, divided by the population of the age group which corresponds to a specific level of education. The net enrollment ratio is calculated by using only the part of the enrollment which corresponds to the age group of the level considered" (UNESCO 1994).

[7] The transition from no-schooling to primary for the age group 10-14 relates to the children who were not yet enrolled in the age group 5-9 because they were below school age. In most countries, starting year is around the age of 6 years old.

$$T_{p_{10:14}} = \frac{\frac{1}{n}(L_p - 5)}{1 - T_{p_{5:9}}} \times E_p{}^2$$

The same calculations are applied for the transition from primary to secondary, and secondary to tertiary, but replacing E_p with E_s and E_t; $L_p - 5$ with $L_s - 10$ and $L_t - 15$; $T_{p_{5:9}}$ with $T_{s_{10:14}}$ and $T_{t_{15:19}}$ respectively.

Base Population and Educational Transition Estimation for Method 2

The second method of calculating population by educational level is based on census data. The base year population is given by a census which distinguishes the population by those enrolled in school or not enrolled in school and the educational level of those no longer in school by age. The moment of interest in this approach is the age at which a person makes the transition out of school. This age is taken into as an approximation of the level of education received by the person. These transitions are calculated as if they were standardized mortality rates: the proportion of the population that left school between age *a* and *a*-1, divided by the proportion of people that were still in school at age *a*-1:

$$Tr(S_{a-1,\,n-1} \rightarrow NS_{a,\,n}) = \frac{NS_{a,\,n} - NS_{a-1,\,n-1}}{S_{a,\,n}}$$

where *Sx,n* is the proportion still in school in period *n* and age group *x*, and *NS* is the proportion not in school. By dividing the proportion into the population with secondary or primary education, transitions to the non-school population with primary education or secondary education are found. These transitions are artificial, because they mix the transition experience of different periods: for example, the 20-24 year olds with primary education who are included in the non-school population at time *n* left school 10 to 15 years earlier. To minimize the error, only the transition rates for the ages 10-14, 15-19 and 20-24 are calculated, after which everybody is assumed to have left school.

If the person leaves school at ages 5-9, the educational level is “primary or less.” If the person leaves school at the ages of 15-19 or 20-24, the educational level is “secondary or more.” The age group 10-14 presents the same problem as discussed in Method 1, and a similar solution is applied.