BOSTON UNIVERSITY
Global Development Policy Center
Economics in Context Initiative

Population and the Environment

By Jonathan M. Harris, Brian Roach and Anne-Marie Codur

An ECI Teaching Module on Social and Environmental Issues in Economics

Global Development Policy Center
Boston University
53 Bay State Road
Boston, MA 02155
bu.edu/gdp

Suggested citation: Harris, Jonathan M., Brian Roach, and Anne-Marie Codur. 2025. "Population and the Environment." An ECI Teaching Module on Social and Environmental Issues in Economics, *Economics in Context Initiative*, Global Development Policy Center, Boston University.

Students may also download the module directly from:
https://www.bu.edu/eci/education-materials/teaching-modules/

Comments and feedback from course use are welcomed:

Economics in Context Initiative
Global Development Policy Center
Boston University
53 Bay State Road Boston, MA 02215
https://www.bu.edu/eci/

Email: eci@bu.edu

NOTE – terms denoted in bold face are defined in the **KEY TERMS** section at the end of the module.

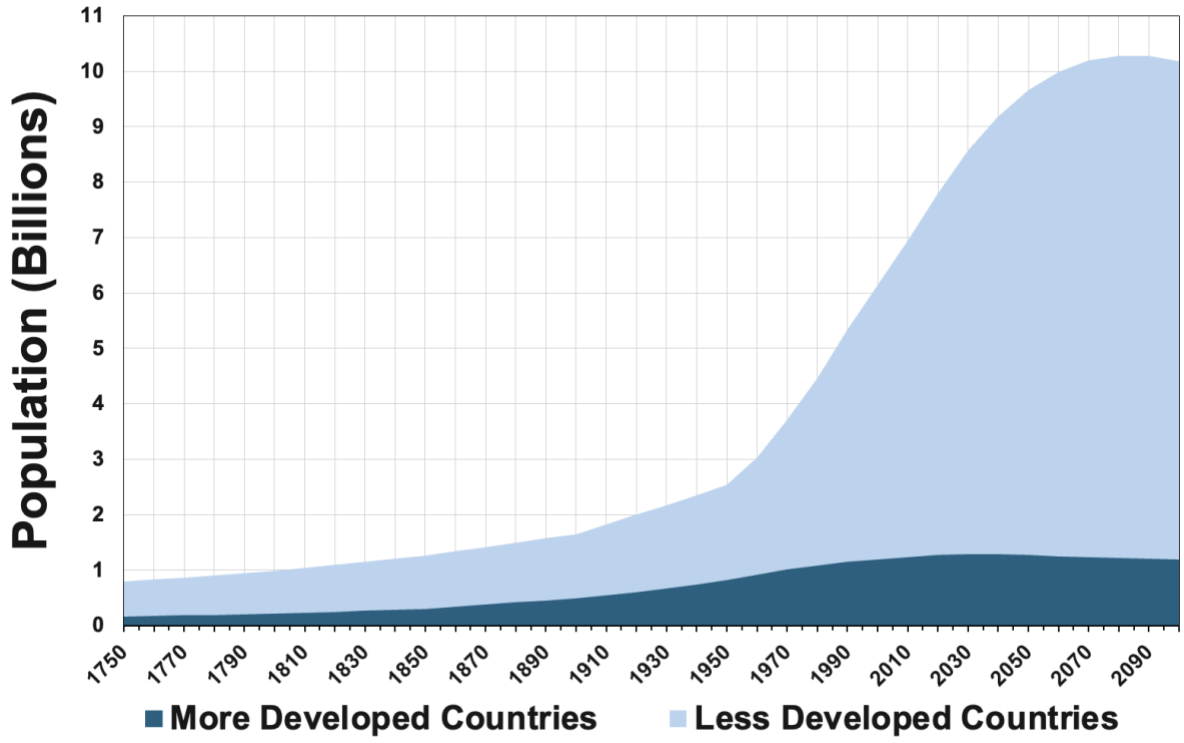
Table of Contents

1. THE DYNAMICS OF POPULATION GROWTH

Human population grew slowly throughout most of our history. Only within the past 200 years has rapid global population growth become a reality. Figure 1 shows the history of global population increase since 1750, together with a United Nations "medium variant" projection for the twenty-first century.[1]

In the past 100 years, population growth has accelerated at a pace unprecedented in global history. The rate of growth is now slowing, but as the projections show, considerable further increase is expected before population stabilization. As we will see, there can be significant variation in population projections, but it is virtually certain that global population will continue to grow for decades.

Figure 1. *Global Population Growth and Projections, 1750–2100*



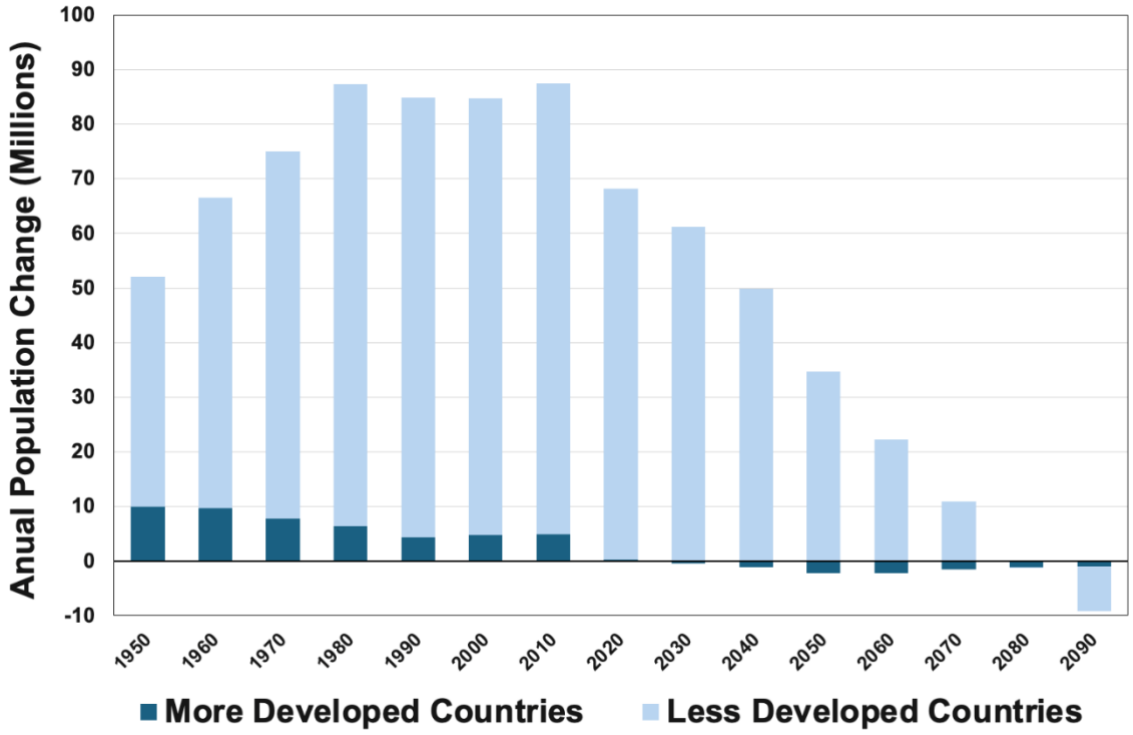
Sources: Caldwell, John C., and Thomas Schindlmayr. 2002. "Historical Population Estimates: Unraveling the Consensus." *Population and Development Review*, *28*(*2*):183–204; United Nations Department of Economic and Social Affairs, Population Division. 2024. *World Population Prospects 2024.*

Note: Population is projected to peak in more developed nations by 2030, and in less developed countries around 2084.

In 1800, global population stood at about 1 billion after many centuries of slow growth. By 1950, the total had reached 2.5 billion. Rapid acceleration in growth rates after World War II doubled world population to 5 billion in less than 40 years. By 2000 world population had passed 6 billion. It reached 7 billion in 2011, and passed 8 billion by the end of 2022, reaching 8.2 billion in 2025.[2]

Extraordinarily rapid population growth—about 2% per year—occurred from 1960 to 1975. At first glance, 2% may not sound so remarkable, but at this rate of growth, population doubles in about 35 years.[3] After 1975, the growth rate slowed, falling below 1% per year by 2020, but the much larger size of total population meant that the absolute number of people added each year did not decline significantly until about 2020, and is still over 60 million per year (see Figure 2).

Figure 2. *Net Annual Increase in Population by Decade, 1950–2100*



Source: United Nations *World Population Prospects 2024*.

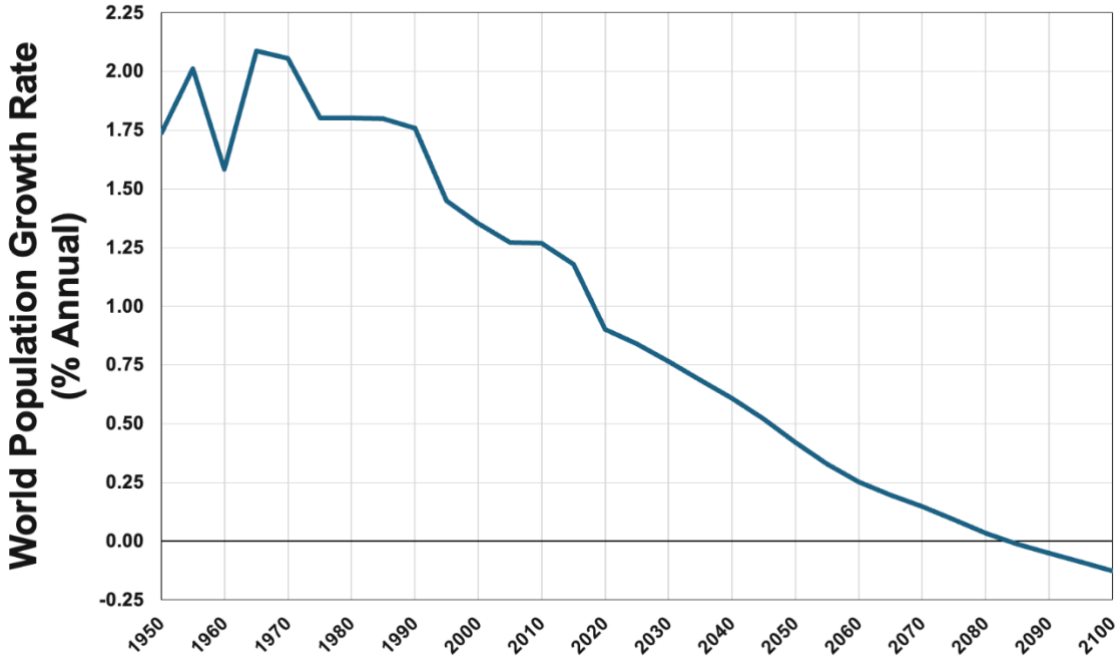
Note: Figures for 1950 to 2020 are actual; figures from 2020 to 2100 are projected. Population change is projected to become negative in more developed nations by the decade of the 2030s, and for the world as a whole by the decade of the 2080s.

During the period of extremely rapid growth, various authors sounded the alarm regarding the dangers of **exponential growth**. A population of 5 billion that continued to grow at 2% per year, for example, would reach 20 billion in 70 years and 40 billion in a little over a century. Finding food, water, and living space for such a vastly increased population would be impossible.

Starting in the 1960s, authors such as Paul and Anne Ehrlich warned that humanity was on a collision course with the natural world and that runaway population growth could overcome all the benefits of modern science and economic growth, leaving a devastated and miserable planet—revisiting the nineteenth-century predictions of Thomas Malthus that population growth would outrun food supplies.[4] This **neo-Malthusian perspective** gained much attention, and provides the starting point for the modern debate on population growth.

Those who find this perspective overly negative often point out that **population growth rates** have been declining since the 1970s. The overall global growth rate had fallen below 1% by 2020, reaching 0.86% in 2024, and is projected to continue to decline in the coming decades (Figure 3). This has shifted the population debate, with more attention focusing on a possible end to global population growth, and projected population decline in major areas such as Europe and China. In some regions such as Africa, however, rapid population growth continues, and the neo-Malthusian concerns of excessive population impact on the environment are still very relevant.

Figure 3. *World Population Growth Rate, 1950–2024, with Projections to 2100*



Source: United Nations, *World Population Prospects 2024*.

Note: Decline around 1960 represents a period of famine in China associated with the "Great Leap Forward" agricultural collapse. Global population growth rates become negative after about 2084.

According to UN figures, the global **gross annual population increase** as of 2024 was 69 million. This annual addition to the planet's human inhabitants is the equivalent of approximately the entire population of France (68 million in 2024). Annual population increase today is still higher than it was than during the 1960s, when the rate of growth (expressed in percentage terms) was highest (see Table 1 and Figures 2 and 3). The equivalent of adding a new France every year, and a new China in about 20 years is hardly cause for complacency.

The structure of global population growth has shifted, however, since the 1960s, with more developed areas projected to see population start to decline by about 2030, while population in the developing world, especially Africa, is projected to continue to increase through about 2080.

Table 1. *Global Population Growth Rates and Average Gross Annual Increase*

	1950s	1960s	1970s	1980s	1990s	2000s	2010s	2020s
Population growth rate (%)	1.80	2.00	1.90	1.80	1.40	1.23	1.18	0.86
Average annual increase (millions)	50.6	65.7	75.6	85.3	81.6	76.5	84.1	68.2

Sources: For all decades before 2010s: United Nations Department of Economic and Social Affairs, Population Division. 2015. *World Population Prospects: The 2015 Revision*. For 2010s and 2020s: United Nations Department of Economic and Social Affairs, Population Division. *World Population Prospects 2024.* The figures for 2020s is based on the median projections of the UN.

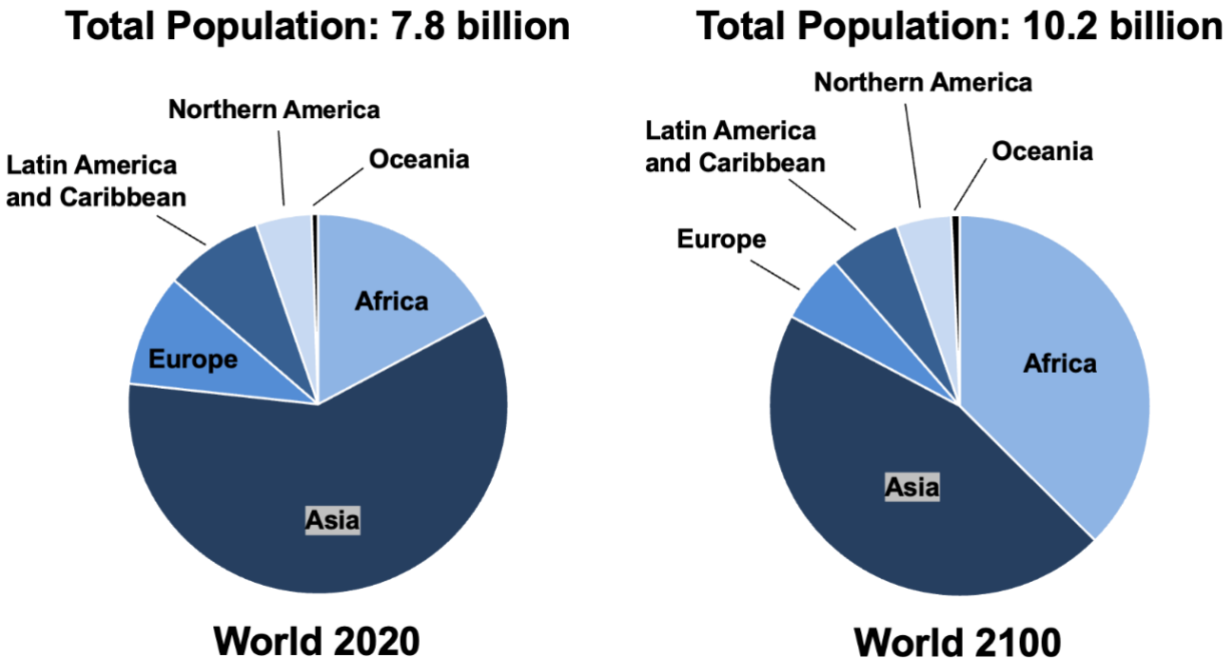
Current medium-variant projections presented in the 2024 United Nations Population Report show population peaking around 2080 at a level of about 10.3 billion, and then slowly declining to about 10.2 billion by 2100 (as shown in Figure 1).[5] The medium-variant scenario presented by the UN rests on the assumption that no rapid reduction in population growth rates will occur in the near future.

The future, however, may not reflect this assumption. As growth rates have sharply declined since the 1990s, the UN median-variant scenario, updated each five years, has continuously made downward revisions of its long-term projections. Other scenarios suggest a much earlier stabilization if growth rates were to decline faster than expected. We will examine this possibility in more detail later.

A very important aspect of population growth is its regional pattern. Population growth is most rapid in the lowest-income countries, but is already close to zero in Europe (see Table 2). Population growth is also slowing in Asia, where population will peak at 5.3 billion around 2054, according to the UN median-variant scenario, and then start declining. Asia's share of world population, currently 59%, would decline to 45% by the end of century (see Figure 4).

The African continent will be the driving force of population growth throughout the remainder of this century. Africa's population of 1.5 billion in 2024 (representing 18% of world population today) is projected to add another billion in the next 25 years to reach 2.4 billion in 2050, and add yet another 1.4 billion in the second half of the century to reach 3.8 billion by 2100--representing 37% of world population (Figure 4).[6] Meanwhile, the share of Europe (including Russia) would decrease from 10% today to about 6% in 2100.

Figure 4. *Distribution of the World Population in Six Major Geographic Areas, 2020 and 2100 UN Medium-Variant Projection*



Source: United Nations, *World Population Prospects 2024*.

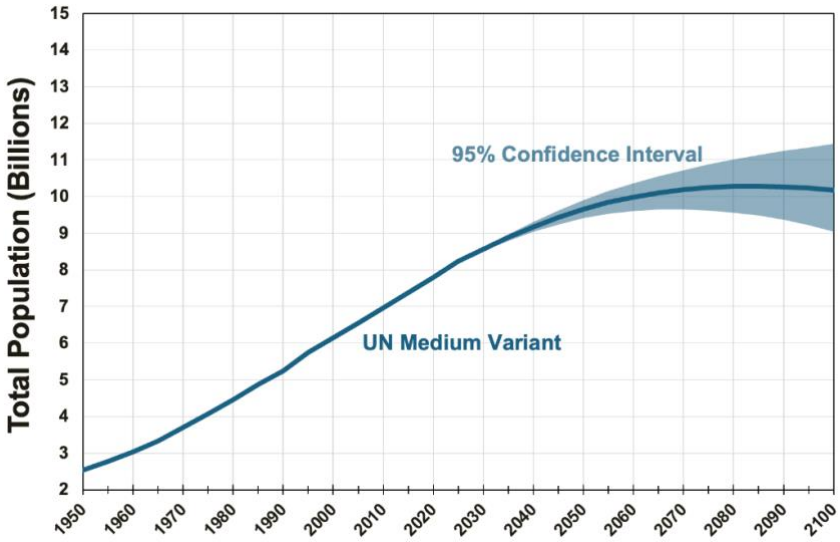
Many of the countries that are experiencing the fastest demographic growth, especially in Sub-Saharan Africa, already have trouble providing adequate food supplies and basic goods to their present population. The population growth that these countries are poised to face in the next decade will undoubtedly put even more pressure on already scarce resources. At the same time, projected declining populations in Europe, China, and possibly other areas pose major issue of how to manage population decline and support elderly populations.

Recent commentary on population trends has focused on the problems likely to be caused by a "baby bust" – declining populations in many countries, especially richer nations but also now including India and China. Political leaders "worry about shrinking workforces, slowing economic growth and underfunded pensions; and the vitality of a society with ever-fewer children."[7] In Japan and South Korea, birth rates have fallen so far that significant population decline is already occurring, with more drastic decreases projected for the coming decades. Although it will likely take decades before world population as a whole starts to decline, the problems of diminishing birth rates and increasing proportions of elderly people are already reality for many countries.

2. PREDICTING FUTURE POPULATION GROWTH

How well can we predict future population growth? Figure 5a shows a baseline medium-variant projection with a confidence interval of 95%, which means that the UN estimates that there is a 95% chance that the future will be between the lower and the higher of the two dotted lines that surround the medium-variant scenario. Could the actual figures be much higher or much lower?

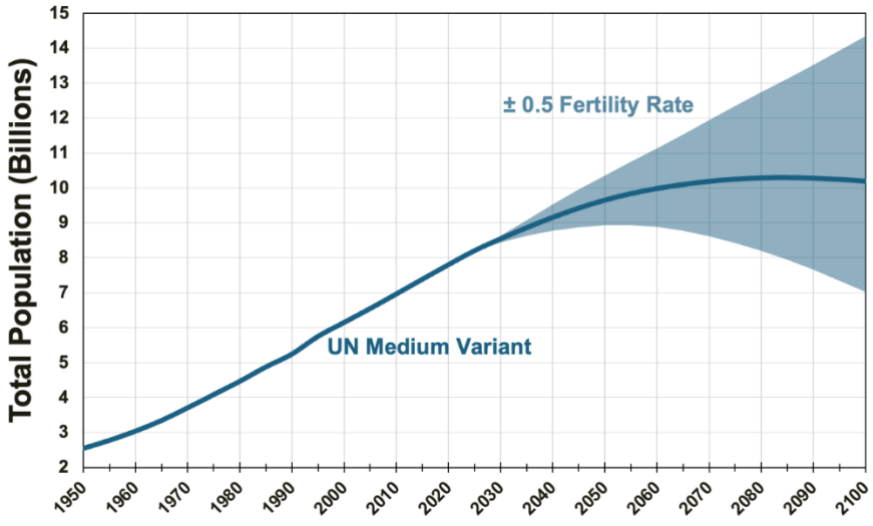
Figure 5a. *United Nations Estimates for Future Population*



Source: United Nations, *World Population Prospects 2024*.

Note: Solid line represents U.N. medium-variant scenario; shaded area shows 95% prediction interval.

Figure 5b. *The United Nations Population Scenarios with Varying Fertility Rates*



Source: United Nations, *World Population Prospects 2024*.

Note: Upper and lower shaded areas show the effect of a 0.5% increase or decrease in fertility rates.

As Figure 5b shows, assumptions about changes in birth rate significantly influence projections. Projections made by the Population Division of the United Nations are based on various hypotheses about the future path of fertility (births per woman). The medium-variant projection takes into account the past experience of each country. But actual future fertility rates could be significantly higher, or lower, than in this median scenario.

In the high variant, total fertility is projected to reach a fertility level that is 0.5 births above the total fertility in the medium variant, which would make world population shoot up to over 14 billion by the end of the century. In the low variant, total fertility is projected to remain 0.5 births below the total fertility in the medium variant, which would lead to a peaking of world population around 2050 at less than 9 billion, followed by a decline to 7 billion by the end of the century. While the extreme scenarios are unlikely, Figure 5b clearly shows a very large potential difference in global futures.

Organizations such as the International Institute for Applied Systems Analysis in Vienna have projected population peaking earlier and at lower levels than the U.N. median estimate, around 2070 at about 9.7 billion, then declining to below 9 billion by the end of the century. This could include a dramatic decline in population in countries such as Japan, South Korea, Thailand, Italy, and Spain. These forecasts would lie in the lower half of the range shown in Figure 5b.[8]

Table 2. *Population and Growth Rates by Continent (2024)*

Region	2024 Population (million)	Percent of World Population	Annual Growth Rate (%)
Asia	4,806	58.9	0.60
Africa	1,515	18.6	2.30
Europe	745	9.1	−0.08
South America	432	5.3	0.59
North America	613	7.5	0.70
Oceania	45	0.6	1.15

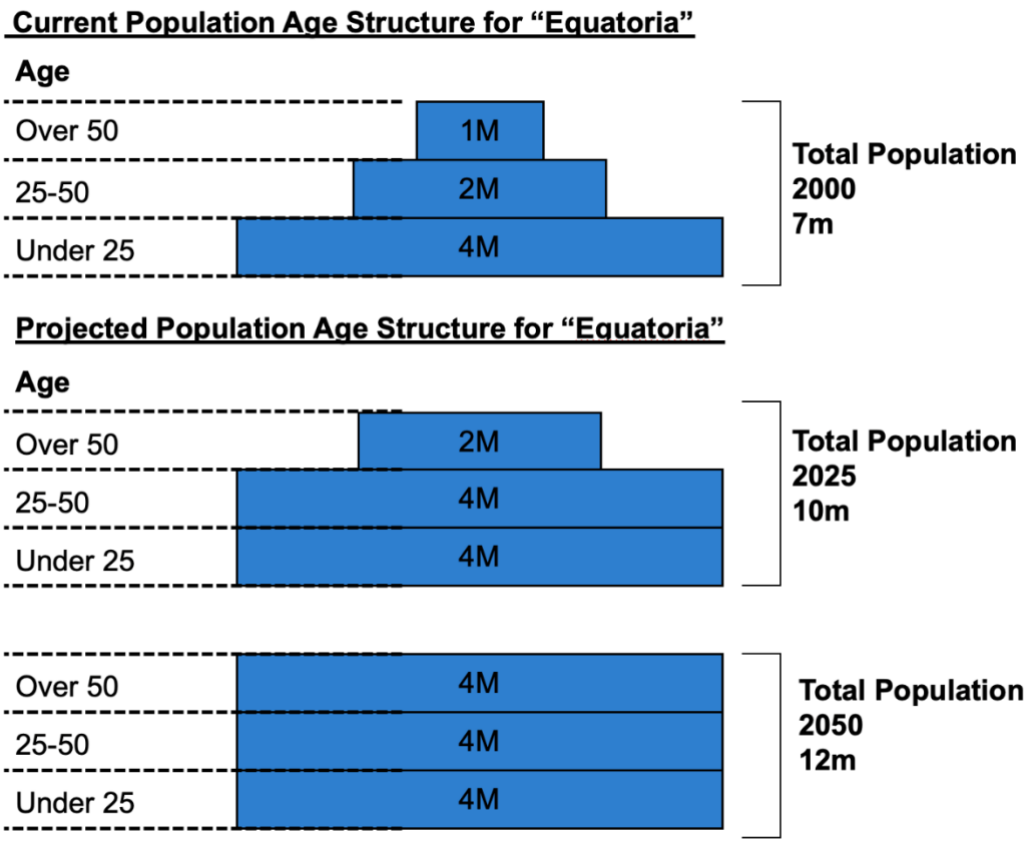
Source: United *Nations*, Department of Economic and Social Affairs, Population Division. 2024. *World Population Prospects 2024*.

Fertility patterns are not random but strongly affected by policies on education and family planning, as well as other social, economic, and political factors. Within the broad range of possible demographic futures, the major factor lending credibility to projections of continued population growth is the phenomenon of **population momentum**.

To understand population momentum, let's consider a hypothetical country, Equatoria, which has been experiencing rapid population growth for several generations. For the sake of simplicity, we define a generation as equal to 25 years and divide the population of Equatoria into three age categories: under 25, 25–50, and more than 50 years old. The population age structure in Equatoria depends on the birth rate in previous generations. Suppose that, up to the present, each generation has been roughly twice as large as the preceding generation. This will create a **population age profile** shaped like a pyramid (top diagram in Figure 6). With this age structure, the total population will double every 25 years, since each new generation is twice as large as its parents' generation. The overall population growth rate of the country will average about 3% per annum.[9]

This is a high but not unprecedented rate in developing countries—the current population growth rates in Niger, Democratic Republic of the Congo, and Somalia, for example, are more than 3% per year (4.2% in Chad).

Figure 6. *Projected Population Age Structure for "Equatoria"*



Now consider the future demographics of Equatoria. If this growth rate continues, with the population doubling every 25 years, there will be a situation of exponential growth. If the population was 7 million in 2000, as shown in our diagram, it will be 14 million by 2025, 28 million by 2050, 56 million by 2075, and 112 million by 2100 – well over

tenfold growth in a century. No country can long withstand the environmental and social pressures of such growth. But, of course, the growth rate may decline.

For this to happen, the average **fertility rate** must fall. The fertility rate is defined as the number of children borne by the average woman during her lifetime. The fertility rate in Equatoria must be around 5 children per woman to account for such rapid rates of growth.

Again, this is not unusual in developing countries. The average fertility rate in Sub-Saharan Africa is estimated at 4.6 children per woman in 2023. In other parts of the world, high levels of fertility can be found in countries such as Afghanistan (5.4 children per woman), Pakistan (3.4), Iraq (3.4) and Yemen (3.7).[10]

Stabilizing population requires achieving a **replacement fertility level**, which is just over two children per woman (the precise number depends on the rate of infant and child mortality and female mortality in childbearing years). The replacement rate is 2.1 in rich countries, and slightly higher in developing countries, around 2.2, where fewer girls than boys are born, and more mothers die during their childbearing years.

At replacement fertility level, each new generation will be exactly the size of the preceding one. Lowering the fertility rate usually takes many years in a country such as Equatoria. Suppose that Equatoria reaches this goal. Does this mean that the population growth problem is over? Absolutely not!

Imagine a fantastically effective population policy that lowers fertility to replacement level *immediately*. Equatoria's demographic future would then be as shown in the second and third parts of Figure 6. Each new generation would be exactly the size of the last. The current generation of under-25s, however, is Equatoria's largest ever. Even at replacement-level fertility rates, the population will continue to grow for two more generations.

The next generation of children will be four times as large as the current over-50 generation, meaning that the birth rate will be several times as high as the death rate for another 25 years. For the 25 years after that, the birth rate will still be around double the death rate. The population growth rate, which is the difference between the birth and death rates, will continue to be positive. Only when people aged 0–25 in the first diagram reach the end of their life span will *their* grandchildren no longer outnumber them. Equatoria's population will therefore continue to grow for 50 years, reaching a total of 12 million, 71% higher than its current level, before it stabilizes.

This is the meaning of population momentum. When a country has a history of rapid population growth, continued growth for the next several generations is virtually guaranteed, short of some massive Malthusian catastrophe that dramatically raises death rates. A more realistic projection for Equatoria might be that fertility rates, rather than falling instantaneously as in our hypothetical case, would take about a generation to

reach replacement level. In that case, population would continue to grow for 75 years, finally stabilizing at a level that would be more than double the 2000 level.

The case of Equatoria is not merely an abstract example (see Box 1). As Figure 7a shows, the simplified population pyramid described is very close to the reality for most countries in Sub-Saharan Africa, whose population is projected to double by 2050. (Use Figure 7a to visualize a future Africa in which all population age groups or **population cohorts** are at least as large as the present cohorts of young children.)

Figure 7a. *Population Age Structure for Sub-Saharan Africa, 2024*

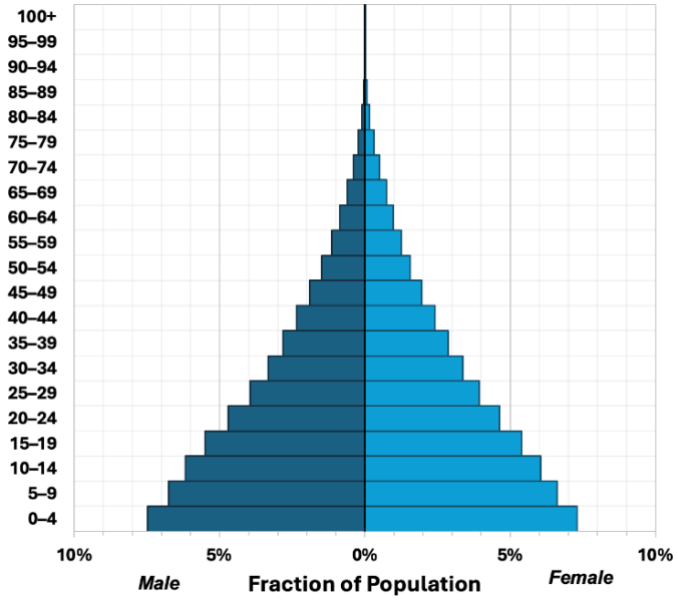
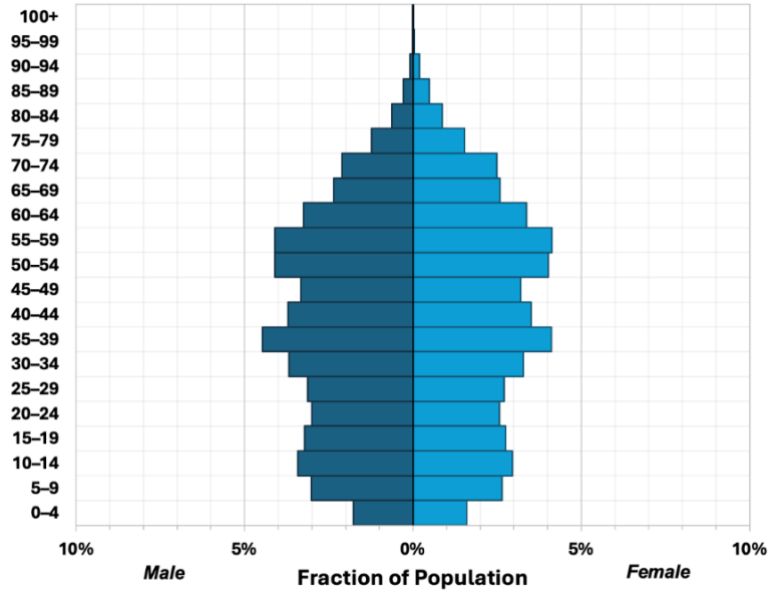


Figure 7b. *Population Age Structure for China, 2024*



Source: United Nations, *World Population Prospects 2024*.

China's population age structure, shown in Figure 7b, gives a very clear illustration of a change in population momentum. It shows a sharp decline in the size of population cohorts born in the 1970s and early 1980s (aged 45-49 in 2024) compared with the size of previous generations. This resulted from the very strict and coercive "one-child policy" implemented in those years, which enforced a sudden decrease in fertility rates.

But we can also observe that the population cohorts born in the late 1980s and early 1990s (aged 35–39 in 2024) are larger in size than the previous cohorts, mirroring the size of the generation born in the 1960s and 1970s. This second "wave" corresponds to the children of these larger cohorts, born before the one-child policy. Even with a lower fertility rate, just by the mere fact of their sheer size, this earlier generation gave birth to a young generation of about the same size as they were. The population momentum from the size of the generations from the 1960s and 1970s is, therefore, automatically replicated as a rippling effect into another generation born in the 1980s and 1990s.

The relatively small size of cohorts born in the 1980s is also mirrored in the size of the generation of their children (aged 15-24 in 2024), smaller than the one that preceded it in the 1990s. It is noticeable that the current cohort of infants and toddlers (aged 0-4 in 2024), children of the generation born in the 1990s, is the smallest of all generations.

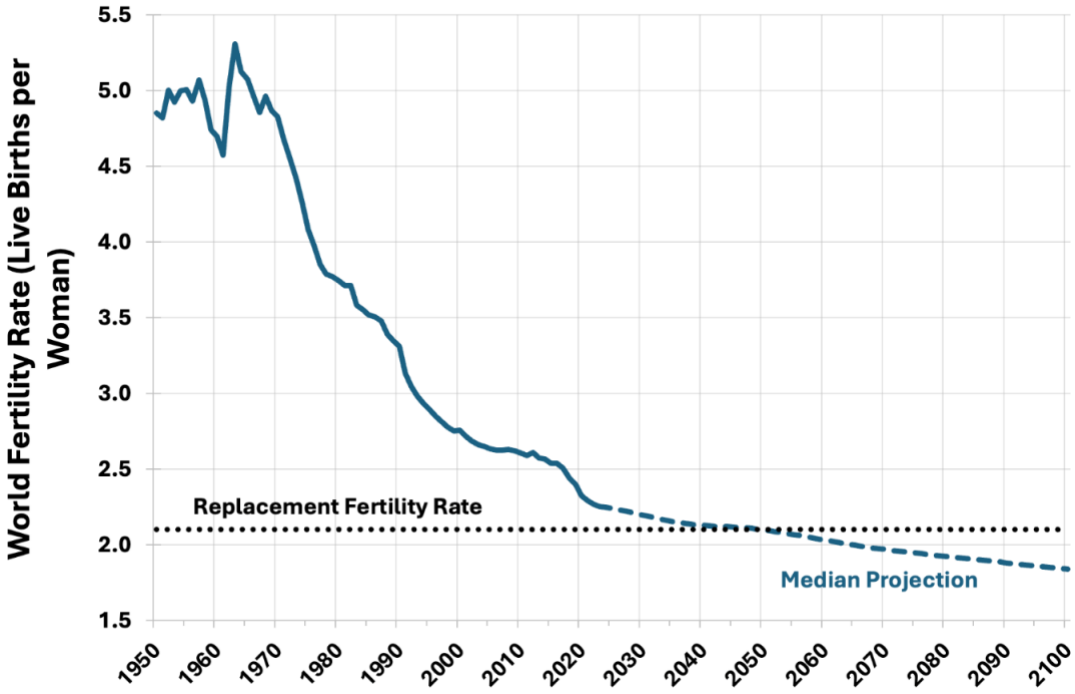
Population momentum – especially in Africa – makes an overall substantial increase in global population inevitable, but a huge difference remains between "low" and "high" forecasts for 2050 and beyond (see Figure 5b). The critical variable in these differing projections is the rate of future fertility decline. If fertility falls rapidly throughout the developing world, the global population age structure could approach a more stable pattern within the next 25 years. If not, global population momentum will continue.

Figure 8 show the dramatic decline of fertility rates globally in the past 50 years, from 5 children per woman on average in the 1970s to 2.3 children per woman in the early 2020s, slightly above replacement rate.

The UN medium-variant scenario described earlier assumes that fertility rates will reach replacement level (2.1) globally in 2050, as shown in Figure 8. But there is a range of possibilities for fertility rates, which could slightly bounce back up before declining again or, on the contrary, continue the trend observed recently (2017−2023) of a sharp decline, reaching replacement level perhaps as early as 2030.

The Wittgenstein Center in Vienna forecasts that a scenario with stalled economic development (especially in Africa) would correspond to the UN upper assumption, carrying population momentum into the 22nd century. A more positive scenario of rapid development with universal access to education and to reproductive health care (including family planning) would cause fertility rates to drop so fast as to shrink the base of the age pyramid before 2050 and stabilize world population by mid-century. These two contrasting scenarios are shown in Figure 9.[11]

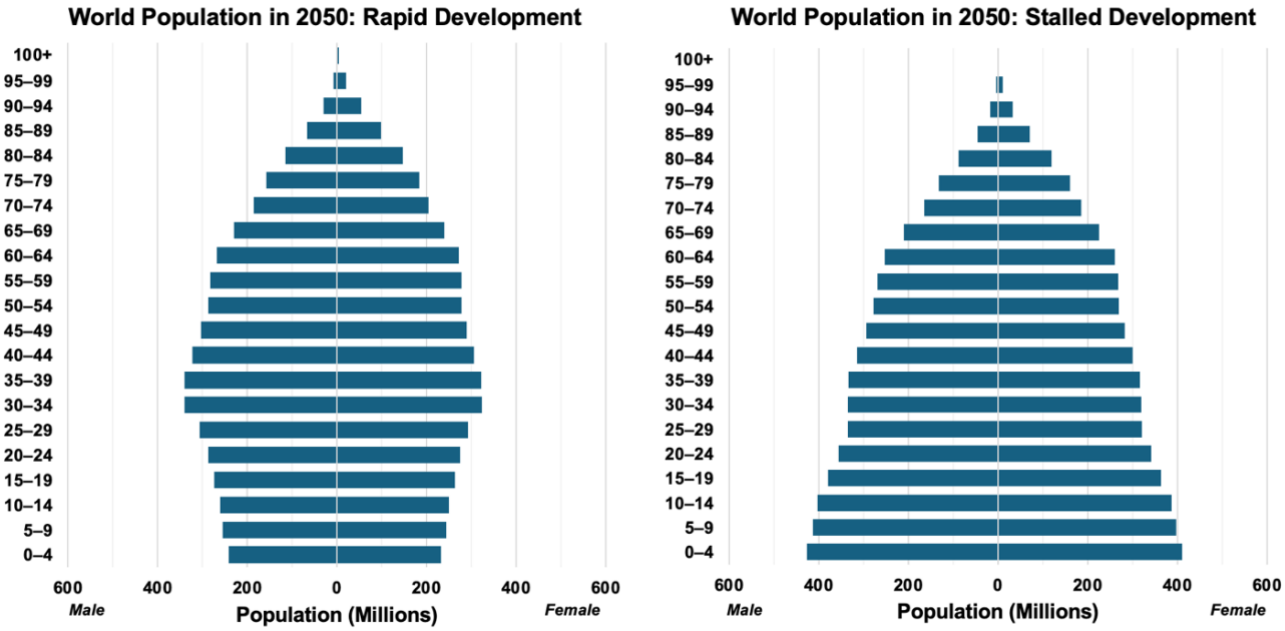
Figure 8. *The Rapid Decline of Fertility Rates*



Source: United Nations, *World Population Prospects 2024.*

Note: Median projections through 2100 shown. Horizontal line at fertility of 2.1 represents replacement fertility rate.

Figure 9. *Two Scenarios for the Future of World Population*



Source: Adapted from Wittgenstein Center Human Capital Data & Graphic Explorer Version 3.0, https://iiasa.ac.at/models-tools-data/wcde and International Institute for Applied System Analysis. 2024. "Updating the Shared Socioeconomic Pathways (SSPs) Global Population and Human Capital Projections" https://pure.iiasa.ac.at/id/eprint/19487

BOX 1. RAPID POPULATION GROWTH IN SUB-SAHARAN AFRICA

Nigeria's population reached 222 million in 2024 with a median age of 18.1 (meaning that half of the population is under 18 years old). Nigeria's fertility stands at 5.1 children per woman.

The economy cannot meet the needs of this rapidly growing workforce. According to the World Bank, unemployment grew from 6.4% in 2010 to more than 40% in 2023, and the situation is particularly dire for the young. If fertility remains at a high level, population will double in one generation, passing 400 million by mid-century.

John Oyefara, a Professor of Demography at the University of Lagos, expresses the challenges facing the young generation: "the resources available are unable to meet the basic needs of the growing population. This has resulted in inadequate facilities in our health sector, food security, housing, transportation and employment."[12]

Nearly 12% of the world population in extreme poverty lives in Nigeria. This situation has led to a massive emigration among Nigerian youth, seeking opportunities in Europe (including through the dangerous path of illegal immigration). This is termed the "Japa syndrome" ("Japa" means escape in Yoruba language). Close to 1.5 million Nigerians emigrate each year, 51% of whom have a college education, which represents a worrisome brain drain for the country.

Similar patterns are observed all over Sub-Saharan Africa, a continent booming with youth whose enormous creative potential could be harnessed by the economies of these countries if they had the means to invest in their human capital.

A more optimistic view of this population boom in Africa is proposed by Edward Paice in his book "Youthquake", describing the countless opportunities for development offered to the continent, which is rapidly urbanizing and transforming into a major hub for industry and commerce. Businesses from China, Russia, the US, the EU, Turkey, and the Gulf countries are chasing Africa's tens of millions of new customers each year, competing to get the best shares of this new booming market. Within the next decade, Africa will have the world's largest work force, surpassing China and India. By the 2040s, it will account for two out of five children born on the planet. As summarized by the New York Times, "the world is becoming more African".

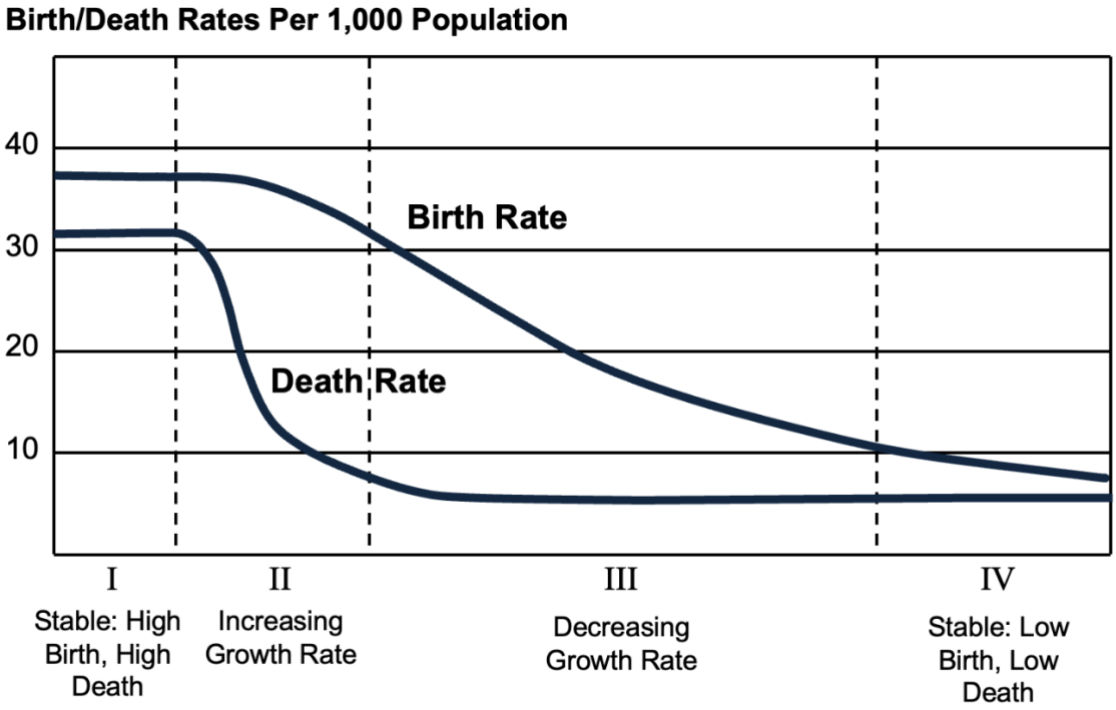
Sources: Newuh, Mimi Mafo. 2023. "Nigeria's Population Boom: Path to Poverty or Prosperity?" https://www.dw.com/en/nigerias-population-boom-path-to-poverty-or-prosperity/a-66186900; Akinyemi, Akanni Abukun. 2023. "Nigeria's Growing Population can be an Advantage, with Better Data and a Policy Focus on Young People." *The Conversation*, 11 July; World Bank Open Knowledge Repository. 2021. "Expanding Legal Migration from Nigeria to Europe: from Brain Drain to Brain Gain"; Edward Paice, *Youthquake: Why African Demography should Matter to the World*. London: Head of Zeus, 2021; Walsh, Declan. 2023. "The World is Becoming More African." *New York Times*, October 28.

3. THE THEORY OF DEMOGRAPHIC TRANSITION

As we have seen, there are very different possibilities for future global population growth. Can historical experience tell us anything about future prospects? Much thinking about the relationship of population to economic growth rests on the experience of Western Europe. Western Europe's current situation is considered the final stage of a **demographic transition** from high to low birth and death rates. Figure 10 shows the pattern of this demographic transition.

In the first stage, corresponding to pre-industrial Europe, both birth and death rates are high. Large families are common, but medical care is poor, and many children die young. On average, a family produces only two surviving children. The population thus remains stable from generation to generation. These social conditions resemble the state of nature, in which birds and animals typically produce numerous progeny to offset high rates of predation and disease. It is a harsh but ecologically stable regime.

Figure 10. *The Demographic Transition*



In the second stage, industrialization takes off, as in nineteenth-century Europe. Death rates fall rapidly as standards of living, public health, and medical care improve. Birth rates remain high, however, because families still view a large number of children as valuable, both to work on the farm or in the factory (child labor is still legal and common) and as a form of old-age insurance (no social security institutions exist). Since net population growth rate is equal to the birth rate minus the death rate (the distance between the two lines in Figure 10), the result is a rapidly growing population.

Is growing population a good or bad thing for the country as a whole? If resources are abundant, the country's leaders may welcome it. A large labor force promotes rapid economic growth, making it possible to take advantage of unexploited resources and new technology. However, this period of rapid population and economic growth probably contains some self-limiting factors.

One such factor is the improvement in social conditions that is likely to accompany economic growth. This development, by no means automatic, often requires hard-fought battles for social and economic reform. Eventually, however, the country may achieve social changes characteristic of economically developed countries, including child labor laws, unemployment compensation, social security systems, private pension plans, and greater educational opportunity.

The third phase of the demographic transition corresponds to a changed social and cultural atmosphere. Smaller families are seen increasingly as more desirable. In this phase, economic opportunity costs of childbearing are more and more considered as a burden rather than a benefit. As greater opportunities arise, especially for women, family size shrinks (see Box 2). And, as indicated in Figure 10, during the third phase the population growth rate declines.

Figure 10 shows only the *rate* of population growth (the difference between birth and death rates). The total population, of course, is considerably larger in the third stage, so a lower *rate* of growth may still mean a higher net addition to population (gross annual population increase) each year. Population, as we have seen, could double or triple during this period of declining birth rates. But if birth rates continue to decline, eventually the country will reach the fourth and final stage of stabilized population with low birth rates and low death rates.

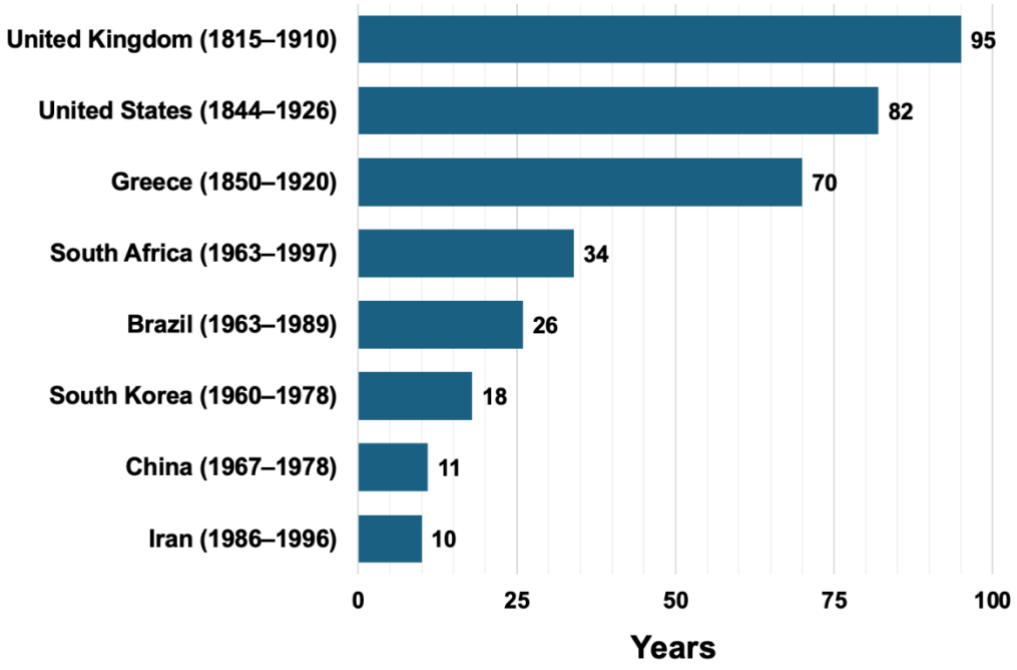
In the last phase of the demographic transition, a phenomenon of "baby bust" may emerge. Once fertility rates have dropped under replacement levels, they may remain lower than 2.1, which may bring concerns about the future shrinking of workforces and the aging of the population. Many countries today have reached this stage, and we will discuss some of the implications of this later in this module.

Figure 11 shows the length of the demographic transition for several countries. It took more than 80 years for the UK and the US (in the 19th century and early 20th century) to go from more than 6 children per woman to less than 3. That shift took less than a generation for most developing countries during the second half of the 20th century, and in some cases only about a decade – 11 years for China, and 10 years for Iran (see Box 3).

As a retrospective view of European history, the process of the demographic transition appears relatively benign. Despite the great hardships involved in the early stages, overall it appears that population growth, economic growth, and social progress went hand in hand and that population growth was eventually self-limiting. The Malthusian

vision failed to be realized—on the contrary, larger populations typically led to better living conditions.

Figure 11. *Length of The Demographic Transition*



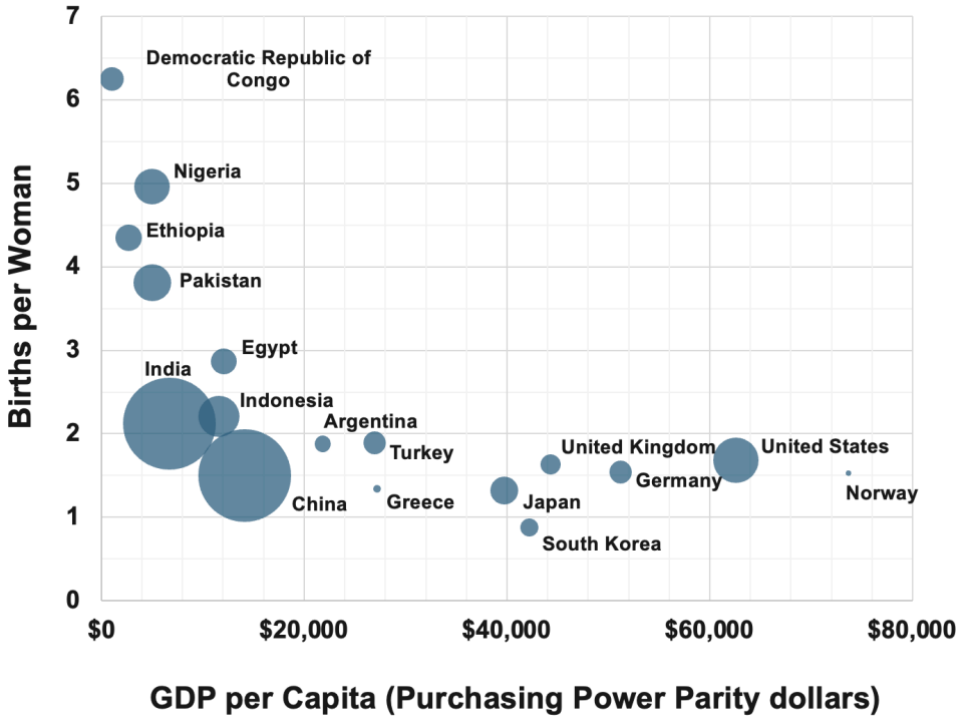
Source: https://ourworldindata.org/fertility-rate

Note: The bars show how many years it took for fertility to fall from more than 6 children per woman to fewer than 3 children per woman

In both Europe and the United States, the third phase of the demographic transition, corresponding to the decrease of fertility rates (average number of children per woman), was strongly correlated with an improvement in living conditions. A strong relationship between better economic conditions and lower fertility is universally observed, both in long-term trends and in comparative perspectives. Figure 12 shows this pattern for all countries in the world, with fertility rates (*y*-axis) generally falling with increasing GDP per capita (*x*-axis). This well-established correlation is the basis for the statement that "development is the best contraceptive."[13]

Other analysts have noted that, more than the growth in GDP per capita itself, improvement in other dimensions of human capital, including education (especially women's education) and health care (especially reproductive health), are key determinants for a sharp decline in fertility rates (see Boxes 2 and 3).

Figure 12. *Fertility Rate versus GDP per Capita*



Source: United Nations *World Population Prospects 2024*; processed by Our World in Data https://ourworldindata.org/grapher/children-per-woman-fertility-rate-vs-level-of-prosperity.

Note: GDP = gross domestic product, PPP = purchasing power parity. PPP adjusts GDP to take account of price levels for domestically consumed goods and services. These data are from 2019, but the general pattern indicated—an inverse relationship between fertility and GDP/capita—remains the same.

BOX 2. WOMEN'S EMPOWERMENT AND THE FERTILITY TRANSITION

A key change in society that promotes a decrease of fertility rates is the increasing level of women's empowerment in terms of whom they marry, when they marry, and when they have children. Their degree of independence relative to the male members of their families (father, brother, husband) is positively correlated with the level of women's education and participation in the job market, allowing greater financial independence.

Better-educated women tend to marry later, have more knowledge about and access to contraception, use contraception more effectively, have greater autonomy in reproductive decision-making, and are more motivated to postpone childbirth because of the higher opportunity costs of unintended childbearing. Even in cultural settings that are religiously conservative, high education levels for girls and women, accompanied by a health care system that makes contraception available, can lead to a rapid fertility transition, as suggested by the extraordinary demographic trajectory of Iran (see Box 3).

In Sub-Saharan Africa, urbanization and the internet have given even women in traditional male-dominated villages a glimpse of societies where fewer children and a higher quality of life are the norm. In rural Ghana, women are seeking contraceptive

implants or injections, which they prefer to the pill as it frees them from worry, and it is private. The UN estimates, however, that 19% of women of reproductive age in Sub-Saharan Africa have unmet contraceptive need.

Globally it is estimated that there were 121 million unintended pregnancies annually between 2015 and 2019, notably among young women (15-19 years old) due to lack of sexual and reproductive health care and information, and lack of modern contraceptives. If major investment to close this gap for unmet need for contraception were provided worldwide, fertility rates would likely fall very rapidly.

Sources: Bongaarts, John. 2010. "The Causes of Educational Differences in Fertility in Sub-Saharan Africa." *Vienna Yearbook of Population Research*, *8*:31–50; W. Lutz and V. Skirbekk, "How Education Drives Demography and Knowledge Informs Projections," in Lutz, Wolfgang, William P. Butz, and Samir K.C, eds. 2014. *World Population and Human Capital in the Twenty-First Century*. International Institute for Applied System Analysis. Oxford: Oxford University Press; Stephanie Nolen. 2024. "More Women in Africa are Using Long-acting Contraception, Changing Lives." *New York Times*, June 17; Yusuf Olushola Kareem et al. 2024. "Assessment of the Trends and Factors Associated with Unintended Pregnancy among Women of Reproductive Age: An Analysis of the Nigerian Demographic Health Survey. *Journal of Sexual Health,* 36:3; World Health Organization, Sustainable Development Goal Target 3.7 Sexual and Reproductive Health https://www.who.int/data/gho/data/themes/topics/sdg-target-3_7-sexual-and-reproductive-health

BOX 3. IRAN'S FERTILITY REVOLUTION

After the Islamic Revolution of 1979, the new regime, led by an assembly of very conservative clerics, suppressed family-planning programs. As a result, fertility rates, already high at six children per woman, rose even higher, to seven children per woman. At those rates, population growth is extremely rapid (about 3% per year, implying more than a doubling of population each generation).

Government officials realized that population growth could not continue at this very high level without producing major negative consequences for economic development. Reluctantly, conservative Islamist leaders accepted a strong family-planning policy. With religious leaders actively supporting the new program, its promotion in all regions of the country and at the village level meant that it could be delivered effectively and efficiently to most women in the country.

What these clerics might not have anticipated is how quickly Iranian women would seize their new opportunities, creating the most rapid fertility transition ever recorded, from 7 children per woman in the early 1980s to 1.9 children per woman in 2006. After about 2006, the government reversed its policy to encourage a "pronatalist" approach of promoting larger families, embodied in the 2021 "Youthful Population and Protection of the Family" law, but as of 2024 the fertility rate remained below replacement level.

Source: Abbasi-Shavazi *et al*., 2006. *The Fertility Transition in Iran, Revolution and Reproduction*. London: Springer; Asadisarvestani, Khadijeh and Tomáš Sobotka. 2023. "A Pronatalist Turn in Population Policies in Iran and its Likely Adverse Impacts on Reproductive Rights, Health and Inequality." *Sexual and Reproductive Health Matters* 31:1. https://www.tandfonline.com/doi/full/10.1080/26410397.2023.2257075.

How well does the theory of demographic transition apply to present global population trends? The first two stages of the demographic transition theory apply well to the developing world's experience in the second half of the twentieth century. Death rates fell much faster than birth rates; fertility and population growth rates rose to historic highs between 1950 and 1975. Since then, strong evidence indicates that most countries have entered the third phase, with overall growth rates falling. In many respects, though, currently developing countries are going through their demographic transition in a significantly different and more difficult context than Europe's:

- The total population numbers in developing countries are much larger, unprecedented in history.
- In their expansion, Europe and the United States drew on the rest of the world for supplies of natural resources. The currently developed countries have disproportionately exploited the global environment's waste absorption capacities (contributing by far the highest cumulative proportion of greenhouse gas emissions, ozone-depleting chemicals, and other environmental pollutants). The developing world obviously will not have these options.
- There is significant uncertainty concerning the pace of fertility decline. Factors that contribute to fertility decline, such as education of girls and women, access to health care, and access to contraception, may be present in some countries but absent in others. Current fertility rates vary widely, with rates in Africa and some parts of Asia still very high (see Figures 12 and 13).
- The rapid economic growth that accompanied population growth in Europe has occurred in some developing countries but not in others. Countries in Africa, in particular, have experienced high population growth together with limited gains in GDP and food production per capita. In places where economic growth has been strong, its benefits have often not "filtered down" to the poor, resulting in increased inequality and a greater absolute number of people living in extreme poverty.

These significant differences between the experience of Western Europe and the current global population transition suggest that "looking back" to the history of population and economic growth offers insufficient insight into the population-related issues of the next 40 to 50 years. Social, economic, and environmental factors intertwine with demographics to create varying demographic experiences.

The impacts of population growth are not limited to developing countries; the United States faces significant continuing population growth based on a combination of natural increase and immigration (see Box 4). We cannot simply wait for the second, global process of demographic transition to play itself out. Rather, we must apply the best analysis and policy response possible to an issue of fundamental importance to the economic and environmental parameters of the twenty-first century.

BOX 4. U.S. POPULATION CONTINUES TO GROW

When we think of population problems, we tend to focus on rapid population growth rates in developing countries. But population has not yet stabilized in the United States. Although Europe has completed the demographic transition to stable population levels, both natural increase and immigration keep the U.S. population growing. U.S. fertility rates are now below replacement levels, but population growth since 1950 has generated large cohorts of people who are still in their reproductive years, creating significant continuing population momentum.

A large increase in U.S. population began in the 1990s, surpassing even the baby boom decade of the 1950s. Population grew from 248 million in 1990 to 337 million in 2025. The U.S. population is projected to continue growing, but at a slower pace after 2030. In that year, all baby boomers will be more than 65 years of age, and by 2034, the U.S. Census Bureau projects that older adults will outnumber children for the first time in U.S. history. Beyond 2030, the U.S. population is projected to grow slowly, to age considerably, and to become more racially and ethnically diverse. In its medium-variant scenario, the population is expected to reach 360 million by 2050.

These long-term projections depend on the future of fertility and on immigration. The fertility rate is assumed to remain significantly below replacement rate (it fell from 1.8 in 2017 to 1.62 in 2023) which means that the largest contributor to population growth will be immigration. A high immigration scenario would drive population to 435 million in 2100 whereas a low immigration scenario would see it peak around 346 million in 2043 and decline afterwards, to 319 million by 2100.

Since U.S. residents have a high rate of resource consumption and waste generation, the environmental impacts of consumption by these additional tens of millions of people will be much greater than that of a comparable number in a low-income country.

An increased U.S. population will also put growing pressure on domestic land and resources. The housing crisis that started in 2008 has grown worse, as the housing market has not kept up with demand (especially since the millennial generation arrived on the housing market in the 2010s). The scarcity of housing has driven housing prices and rentals up, making it difficult for households to find affordable homes. Urban and suburban sprawl, overdraft of water supplies, and pressure on conservation areas such as national parks are other significant issues. In considering these various social and environmental issues, we should not forget the underlying importance of population.

Sources: U.S. Census Bureau. 2020. *Demographic Turning Points for the United States: Population Projections for 2020 to 2060*. www.census.gov/library/publications/2020/demo/p25-1144.html; U.S. Census Bureau. 2023. US Population Projected to Begin Declining in Second Half of Century. Nov 9; Population Reference Bureau, 2024. *World Population Data Sheet* https://2024-wpds.prb.org; Conor Dougherty. 2024. “What Kalamazoo reveals about the Nation’s Housing Crisis.” *The New York Times*, August 22; Marie-Rose Sheinerman and Nick Mortoupalas. 2025. “Immigrants drive Population Growth in a Graying America, Census Shows.” *Washington Post*, June 26.

4. POPULATION GROWTH AND ECONOMIC GROWTH

What does economic theory say about population? A standard economic model, the Cobb-Douglas production function, shows economic output as a function of labor input, capital input, and technological parameters:

$$Q_t = A_t K^{\alpha} L^{\beta}$$

where Q is total output, K is the capital stock, L is the labor force, and α and β are parameters related to the productivity of capital and of labor, respectively. A reflects a given state of technology, and t indicates a particular time period. The values of α and β are assumed to be fractions between 0 and 1; if $\alpha + \beta = 1$, the function shows **constant returns to scale**. This means that if labor and capital inputs were both doubled, output would also double.

Suppose that we increase only one factor, labor. Output will also increase, but by a smaller percentage than labor input, because the exponent α is less than 1.[14] If labor is roughly proportional to total population, **per capita output** will decline. As more and more labor is added, the **law of diminishing returns** comes into play, giving smaller output boosts for each additional unit of labor input. So, in this economic model, population increase alone would yield falling living standards. This is a result of **capital shallowing**, which means that each worker has less capital to work with and is thus less productive.

Few economists would view this simple logic as an accurate representation of the effects of population growth. They would point to the capital stock variable K, noting that if K grows at a rate at least equal to that of L, output per capita will remain constant or rise. In addition, they would argue that **technological progress** will increase the variable A over time, leading to greater output for each unit of labor or capital input. In this theoretical framework, provided that **capital formation** and technological progress are adequate, population and labor force growth can be accompanied by a rising standard of living.

What about the issue of **natural resource limitations**? We can modify the Cobb-Douglas production function to take account of **natural capital**—natural resources such as arable land and water for agricultural products, and minerals and fossil fuels as key inputs for all economic activities. If we denote natural capital by N and its productivity by the exponent γ, we get a revised equation:

$$Q_t = A_t K^{\alpha} L^{\beta} N^{\gamma}$$

In this formulation, limitations on natural capital could cause diminishing returns even if labor and capital both increase. For example, if $\alpha = \beta = \gamma = 1/3$, a doubling of labor and human-made capital while natural resources remain constant would increase output by a factor of 1.59, leading to a fall in per capita output of about 20%.[15] This decline could still be avoided by sufficiently rapid technological progress, but the natural resource limitation would be a steady drag on output expansion.

There is some evidence that population growth can actually spur technological progress in some cases, for example by compelling the adoption of more efficient agricultural techniques.[16] At least in the early stages of development, **economies of scale** may prevail; increasing population density may make it possible to develop more productive, larger-scale industry.

From the point of view of economic theory, then, population growth is inherently neither good nor bad. Its effects depend on the context in which it occurs. If economic institutions are strong, markets work well, and environmental **externalities** are not great, then population growth may be economically beneficial, and can be accompanied by higher living standards.

Does Population Growth Promote or Retard Economic Development?

Economic theory also recognizes a number of ways in which population growth may negatively affect economic development, including:

- *Increased dependency ratios*. Comparing the total number of people who are not working (primarily children and elderly) to the total population gives the dependency ratio for a country. A growing population typically includes a high proportion of children. Families must spend more on supporting dependent children and thus have less to save, lowering the national saving rate. Higher spending on health and education is required, reducing funds available for capital investment. These effects tend to slow capital accumulation and economic growth. As population stabilizes, dependency ratios are increased by a high proportion of elderly people, creating a different set of economic problems (see Box 5).
- *Increased **income inequality***. A rapidly growing population creates an excess supply of labor, which brings down wage rates. High rates of unemployment and underemployment are likely, and a large class of extremely poor people may receive no benefit from economic growth. This situation prevails in many Latin American countries as well as in India, where unemployed rural laborers migrate to large cities in search of jobs, creating vast slums surrounding city centers.
- *Natural resource limitations*. As previously noted, the inclusion of **fixed factors**, such as a limited supply of land or nonrenewable natural resources, in the production function can lead to diminishing returns to labor and capital. In general, economists have tended to assume that technological progress can overcome these limitations,[17] but as resource and environmental problems become more pervasive and complex, this assumption may not hold. Planetary limits and problems such as global warming and biodiversity loss can create a situation of "overshoot", which will be worsened by increasing population.
- ***Market failure***. Increased population may accelerate resource depletion through excessive demand. Where private or social property rights are poorly defined, as in the African Sahel or the Brazilian Amazon, population pressure can contribute to rapid desertification and deforestation. In situations where externalities such

as air and water pollution are uncontrolled, population growth will worsen existing pollution problems.

This more complex view of the relationship between population and economic development places an emphasis on the interaction of rapid population growth with social and environmental issues. Economic and social policy also plays a crucial role. Lower fertility in India, for example, has gone hand in hand with improvement of women's status and economic well-being. Stabilizing populations also reduces pressure on scarce water supplies, arable land, and other resources. Some optimist views consider that the African continent has the potential to follow the same route by investing heavily in its youthful boom, while fostering family planning leading to a rapid fertility decline, as discussed in Box 1.

BOX 5. THE BABY BUST AND THE AGING OF WORLD POPULATION

Fertility, the most volatile variable in population projections, has declined worldwide, in many countries at a faster rate than expected. In some regions the "population problem" has gone into reverse, raising concerns that that there aren't enough babies being born.

In areas like Europe and Japan, fertility rates have largely fallen below replacement levels. These countries face the prospect of a high dependency ratio of elderly people, with a diminished workforce to support them. Many government leaders see this as a matter of national urgency. They worry about shrinking workforces, slowing economic growth and underfunded pensions.

In Japan, the birth rate has been in sharp decline since the 1950s and by 2024 the fertility rate had reached an all-time low at around 1.2 births per woman. If these trends continue, the population of Japan is projected to fall from 124 million in 2024 to 105 million by 2050. The proportion of elderly has been growing steadily; by 2040 more than a third of the population will be older than 65. The prime minister of Japan warned that his society was on the verge of dysfunction. South Korea similarly has a very low fertility rate and population has already started to decline.

The problems of supporting an increasing number of elderly people with a shrinking workforce also affect Europe. Italy, with a fertility rate of less than 1.5 since the 1980s (1.2 in 2024), is expected to have 12% fewer people by 2050, Caregivers in Italy are experimenting with robots to look after the aged.

In the developing world, a number of countries are now approaching, or have reached, replacement fertility levels. Slower population growth is likely to be beneficial in at least some of these developing countries, lowering the child dependency ratio, and providing a higher proportion of working-age people to contribute to national

productivity. But within the next several decades the baby bust phenomenon will also impact the developing world, and is already affecting China.

Sources: Eberstadt, Nicholas. 2012. "Japan Shrinks." *Wilson Quarterly*, (Spring):30–37; Greg Ip and Janet Adamy, "Suddenly There Aren't Enough Babies. The Whole World is Alarmed. *Wall Street Journal*, May 13, 2024; Population Reference Bureau, 2024; *World Population Data Sheet*. https://2024-wpds.prb.org; Jason Horowitz. 2023. "Who Will Take Care of Italy's Older People? Robots, Maybe." *New York Times*, March 25.

5. ECOLOGICAL PERSPECTIVES ON POPULATION GROWTH

In view of our observations on possible negative impacts of population growth, the question arises: Were the positive effects of population growth mainly characteristic of an earlier period in world history, in which resources and environmental absorptive capacities were abundant relative to the scale of the human economy?[18] As global population rises to 9 billion or more, will the negative impacts become dominant?

Answering these questions requires a consideration of a broader, more ecologically oriented perspective on population growth. Whereas the standard economic perspective sees no inherent limitations on population or output growth, the ecological approach is based on the concept of **carrying capacity**, which implies some practical limits to the population that can occupy a certain region.

The carrying capacity concept was developed to describe animal populations in nature. If, for example, a herd of grazing animals exceeds the land's carrying capacity, food will run short, many individuals will starve, and the population will be reduced to more sustainable levels. Predator species are even more tightly constrained in numbers, based on the available prey populations. Since animals live by consuming either plants or other animals, all life on earth depends on the ability of green plants to capture solar energy. The available **solar flux**, or flow of sunlight to the earth's surface, is thus the ultimate determinant of carrying capacity.

Can human populations escape the logic of carrying capacity? We have certainly been very successful at stretching its limits. The use of artificial fertilizers has greatly increased agricultural outputs. Fossil fuels have historically provided far more power for industrialization than solar flux captured either directly through solar energy systems or indirectly through hydroelectric and wind power. Through these means, over 8 billion people can live on a planet that a century ago supported only 2 billion.

This expansion of carrying capacity, however, has a significant ecological cost. The extraction of large quantities of fossil fuels and mineral stocks causes environmental degradation both in production and through the waste products generated. Some of the wastes and pollutants are cumulative—their negative environmental effects build up over time. A prime example is global climate change caused by burning fossil fuels. Soil erosion, depletion of aquifers, and buildup of long-lived toxic and nuclear wastes are also cumulative processes. While increasing the earth's carrying capacity today, we create problems for the future.

The Impacts of Population, Affluence, and Technology

We can conceptualize the interrelationship of population, economic growth, and environment in an equation linking all three, which has come to be known as IPAT. The equation states that:

$$I = P \times A \times T$$

where:

I = Ecological impact (e.g., pollution or natural resource depletion)
P = Population
A = Affluence measured as output/population
T = Technology variable measuring ecological impact per unit of output

This equation is an **identity**, a mathematical statement that is true by definition. The right-hand side of the equation can be mathematically stated as follows:

$$\text{Population} \times (\text{Output/Population}) \times (\text{Ecological Impact/Output})$$

"Population" and "Output" cancel each other out since they occur in both the numerator and the denominator, leaving only ecological impact—which is the same as the left-hand variable. Thus, we cannot argue with the equation itself. The only questions are what the levels of the variables will be, and what determines them. What do we know about these questions?

We have seen that global population (P) is projected to increase by around 2 billion, or about 25%, over the next 50 years, according to the UN medium-variant projection (see Figure 5). We also know that average per capita consumption (A) is steadily increasing throughout the world. If per capita consumption grows at 2% per year, which most development economists would view as a minimally satisfactory rate, it will increase by a factor of 2.7 in 50 years. The combined impacts of A and P will therefore multiply the right-hand side of the equation by a factor of 3.5 or more.

What about T? Improved technology could lower the ecological impact per unit of GDP—let us say by a factor of 2. This would still leave us with a significantly increased level of overall environmental impact (in terms of carbon emissions, pollution, and pressure on natural resources, land, water, forests, biodiversity, etc.). Given the current level of concern about environmental problems, this seems unacceptable. In order to project a lower overall environmental impact, we will need technological improvements that would lower the environmental impact by a factor of 4 or more.

Of course, a mathematical abstraction such as IPAT gives little insight into the specifics behind these very broad concepts. IPAT has been criticized because it assumes that P, A, and T are independent of one another when in fact they are related—the true nature of that relationship being a subject of controversy, as we have seen earlier.

While the IPAT formulation has been mostly used by scientists (biologists, ecologists, engineers, etc.), it has faced strong criticism from social scientists and economists on the grounds that it covers up some basic issues concerning causes of population growth, consumption, distribution, and the working of markets. The field of industrial ecology has focused its attention mostly on *T* in the IPAT equation, emphasizing the need for a major technological leap forward that would reduce *T* by a factor of at least 4, but maybe as much as 10.[19]

One obvious concern is highly unequal consumption per capita throughout the world. Poverty, a lack of basic health services, and poor education in many developing countries contribute to high population growth rates. This suggests a crucial need to focus on issues of inequality rather than only on total population or economic output.

Developed countries currently create the greatest environmental impact through their high per capita demand on resources, as well as pollution generation. If developing countries succeed in raising living standards for their expanding populations—as China and other East Asian countries have done—their per capita demands for food and resources, as well as their pollution generation, will also increase. The combined effects of population and economic growth will significantly increase environmental pressures, in ways that will rapidly become unsustainable.

The rate of population growth will also have a major impact on future climate change. According to one study, the slowing down of population growth from feasible reductions in fertility could yield the equivalent of at least one gigaton (billion tons) of reduction in carbon emissions by 2050, and significantly more in later years.[20] Population policies based on a rapid implementation of universal education for both boys and girls would be a positive outcome for the developing world, regardless of climate mitigation, but if in addition, it also contributes to mitigating climate change, this constitutes an important "win-win" strategy.[21]

6. POPULATION POLICIES FOR THE TWENTY-FIRST CENTURY

In recent years, the discussion of population policy has shifted. Past debate was dominated by the conflict between "optimists," who saw no problem in increasing population, and "pessimists," who predicted catastrophe. Now, elements of consensus are emerging.

Most analysts accept that rapidly increasing population places extra stress on the environment and resources and agree that slower population growth is generally beneficial – although actual population decline can be problematical. This implies that areas where population is still growing rapidly, such as Sub-Saharan Africa, need to reduce the rate of growth, while other regions need to stabilize population without drastic declines. How can this be accomplished?

Countries have sometimes attempted to control population growth by government compulsion. The most prominent example of this is China's draconian "one-child" policy. Such policies have been discredited both on human rights grounds and because they fail to alter basic incentives regarding fertility. Rather than changing people's desires to have children, they rely on penalties including forced abortions and sterilization of women. The policy, started in 1980, was phased out by the Chinese government starting in 2015, as it had created perverse effects and a high level of discontent among the population (see Box 6).[22] The decision also appears to have been driven by concerns that the country's low fertility rate would create a demographic crisis in the decades to come, with young generations not big enough to handle the costs of an aging population. China has now shifted to policies intended to promote birth rates, with some regions offering cash incentives for couples to have more children.[23]

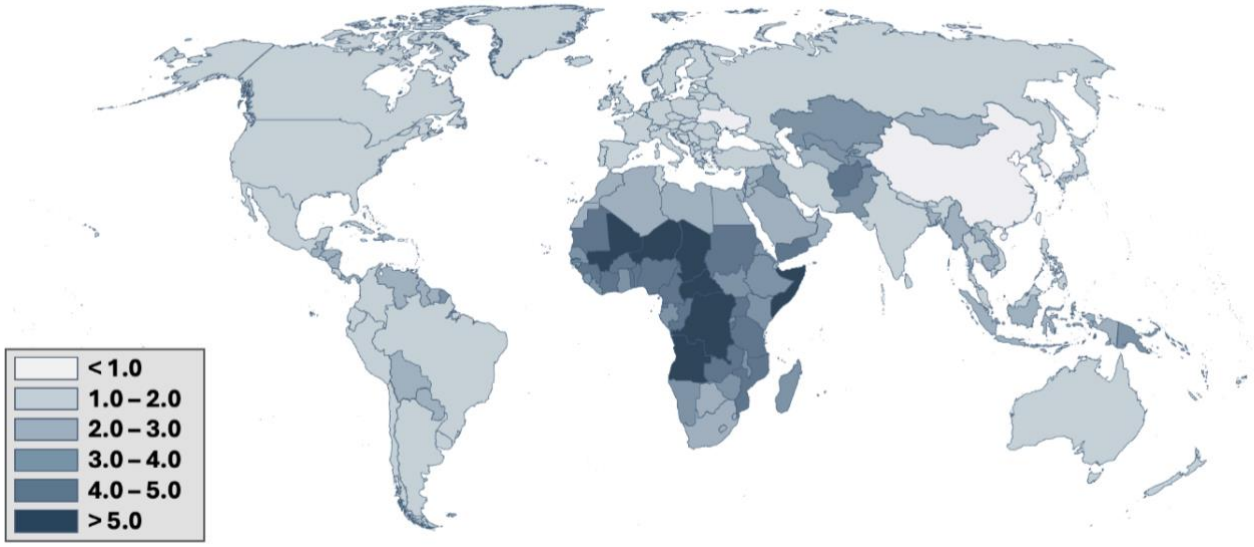
Similar drastic compulsory population policies have been used to a lesser extent in India, with several campaigns of sterilization in rural areas in the 1980s. A backlash against compulsory family-planning policies led to a reversal of this approach in the mid-1990s. The Cairo Conference of 1994 (International Conference on Population and Development or ICPD), the last of the major international gatherings on the issue of population policy, reached a consensus of not considering population goals in numeric and quantitative terms any longer, but taking population as one of the dimensions of development policies, and focusing on qualitative development goals.

International donors shifted their focus to promoting general health care reform—including fighting HIV/AIDS and other deadly diseases. Revisiting the Cairo conference 20 years later, in 2014, the United Nations did not significantly change its language, and it reassessed the importance of broader development goals without mentioning population policies.[24]

Critics argue that by making fertility decline an incidental by-product of the sustainable development goals rather than an explicit goal, the Cairo program has weakened the political and financial backing for population stabilization efforts. As shown in Figure 13, fertility rates remain very high in Africa as well as in parts of Asia. With the potential for a doubling of the population of Africa between now and 2050, these critics suggest that the "population-neutral" language and policy used by the UN since the 1990s should be reconsidered.[25]

A few African countries have recently experienced faster fertility decline, including the island of Mauritius and the North African countries of Tunisia and Morocco. Southern Africa now has a fertility rate of about 2.5 children per woman, but moderating population growth in other African countries, where fertility rates are generally above 4 children per woman, would require a concerted effort. It is not necessary to apply coercive policies with the perverse effects they had on human rights, such as in China. The experience of numerous countries (as discussed in Boxes 2 and 3) shows that birth rates can fall rapidly when people—especially women—reach higher levels of education and literacy and enjoy better employment opportunities and access to family planning.

Figure 13. *Total Fertility Rates by Country (births per woman), 2023*



Source: United Nations, *World Population Prospects 2024*.

BOX 6. PERVERSE EFFECTS OF COMPULSORY POPULATION POLICIES

The Chinese "one-child" policy created terrible side effects. Chinese culture favors male children over female children; sons typically take care of their elderly parents, while daughters, once married, only take care of their in-laws. Therefore, the "investment" in a daughter, especially for the poorest rural couples, could be seen as a net loss in the long term. This resulted in large numbers of infanticides of baby girls in the 1980s and, once the technology of ultrasound examinations was more broadly available in the 1990s and 2000s, large numbers of selective abortions of female fetuses.

As a result, men outnumber women in China by about 35 million. In addition, couples who have had two or even three children in contravention of the law were often forced to hide these children in the countryside, often with older family members. It is estimated that at least 13 million children in China have not been registered and do not legally "exist," and therefore have no access to education or health services.

Selective abortion of female fetuses as well as baby girl infanticides are also observed in other countries (including India, Pakistan, Bangladesh, Indonesia, and Nigeria), and it has been estimated that more than 125 million women have been "missing"—through abortion, infanticide, or neglect resulting in untimely death—throughout the world.

Sources: Taylor, Adam, 2015. "The Human Suffering Caused by China's One Child Policy." *The Washington Post*, October 29; Gordon, Stephanie. 2015. "China's Hidden Children." *The Diplomat*, March 12. https://thediplomat.com/2015/03/chinas-hidden-children/; Bongaarts, John, and Christophe Guilmoto. 2015. "How Many More Missing Women? Excess Female Mortality and Prenatal Sex Selection, 1970–2050." *Population and Development Review*, 41(2):241–269.

Significant voluntary reduction in the birth rate in many East Asian countries as well as in many parts of India has resulted from higher levels of basic education, health care, and job security.[26] There is no inherent reason why African countries should not follow a similar path, but this depends on effective development policies, including specific attention to health, nutrition, education, women's empowerment, and contraceptive availability (see Box 1).

Policies such as these can be viewed as "win-win" policies—benefitting both the economy and the environment through voluntary moderation of population growth. Sound macroeconomic policies, improved credit markets, and improved conditions for agriculture are also important in promoting broad-based growth and poverty reduction, which in turn is critical for population/environment balance.[27]

Urban areas, where population growth is most rapid due to a combination of natural increase and migration, often experience major social and infrastructure problems. Urban populations are projected to increase from 55% to 68% of global population by 2050, with the increase concentrated in developing countries such as India, China and Nigeria.[28] Inadequate housing and sanitation, congestion, air and water pollution, deforestation, solid waste problems, and soil contamination are typical of large cities in developing countries. Moderation of overall population growth can be an essential component of efforts to achieve urban sustainability.[29]

Population growth was a major factor in shaping development patterns during the second half of the twentieth century and will continue to play a central role during the twenty-first century. The differing perspectives of economists, ecologists, demographers, and other social theorists can all contribute to the development of effective policies aimed at population stabilization and an appropriate population/environment balance.

SUMMARY

Global population grew very rapidly during the second half of the twentieth century. Although population growth rates are now slowing, total annual additions to global population are still close to all-time highs, with a global population of 8.2 billion in 2025. Growth is projected to continue for at least the next three decades, reaching a level of 9–10 billion by 2050, with some longer-term projections of 11 billion or more by 2100. More than 90% of the projected growth will be in the developing countries of Asia, Africa, and Latin America.

Population projections offer no certainty about actual future numbers, but the population momentum phenomenon guarantees significant further growth. Currently, average fertility rates (number of children per woman) are still high throughout Africa and parts of Asia. Although fertility rates are generally falling, it will be decades before the population stabilizes. Some projections based on more rapid fertility decline, project

global population reaching 9.7 billion around 2070, then declining to below 9 billion by the end of the century.

In Europe, the demographic transition from rapid population growth to relatively stable population has already been achieved. In the United States, growth continues due to both population momentum and annual immigration. In the developing world, the demographic transition is far from finished, and significant uncertainty remains about future birth rates. Economic growth, social equity, access to contraception, and cultural factors all play a role.

The economic analysis of population growth emphasizes the potential of other factors, such as technological progress, to offset the effects of population growth. Under favorable conditions for economic and technological progress, population growth may be accompanied by rising living standards. But rapid population growth accompanied by social inequity and significant environmental externalities may lead to a decline in living standards.

An ecological perspective recognizes more stringent limits to the population carrying capacity of regional and global ecosystems. Greater population increases the demand for materials, energy, and natural resources, which in turn increases pressures on the environment. Given the extent of existing environmental damage, especially where this damage is cumulative or irreversible, the need to provide for a significantly larger population poses severe challenges to the earth's ecosystems.

Compulsory population control policies generally fail to alter basic incentives regarding fertility. More effective population policy measures include improved nutrition and health care, greater social equity, women's education, and availability of contraception.

KEY TERMS

capital formation addition of new capital to a country's capital stock.

capital shallowing a decrease in the availability of capital per worker, leading to reduced productivity per worker.

carrying capacity the level of population and consumption that can be sustained by the available natural resource base.

constant returns to scale a proportional increase (or decrease) in one or more inputs results in the same proportional increase (or decrease) in output.

demographic transition the tendency for first death rates and then birth rates to fall as a society develops economically; population growth rates first increase and eventually decrease.

economies of scale an expanded level of output increases returns per unit of input.

exponential growth a value that increases by the same percentage in each time period, such as a population increasing by the same percentage every year.

externalities effects of a market transaction that have impacts, positive or negative, on parties outside the transaction.

fertility rate the average number of live births per woman in a society.

fixed factors factors of production whose quantity cannot be changed in the short run.

gross annual population increase the total numerical increase in population for a given region over one year.

identity a mathematical statement that is true by definition.

income inequality a distribution of income in which some portions of the population receive much greater income than others.

law of diminishing returns the principle that a continual increase in production inputs will eventually yield decreasing marginal output.

market failure situations in which an unregulated market fails to produce an outcome that is the most beneficial to society as a whole.

natural capital the available endowment of land and resources, including air, water, soil, forests, fisheries, minerals, and ecological life-support systems.

natural resource limitations constraints on production resulting from limited availability of natural resources.

neo-Malthusian perspective the modern version of Thomas Malthus's argument that human population growth can lead to catastrophic ecological consequences and an increase in the human death rate.

per capita output the total product of a society divided by population.

population age profile an estimate of the number of people within given age groups in a country at a point in time.

population cohort the group of people born within a specific period in a country.

population growth rate the annual change in the population of a given area, expressed as a percentage.

population momentum the tendency for a population to continue to grow, even if the fertility rate falls, as long as a high proportion of the population is in young age cohorts.
replacement fertility level the fertility level that would result in a stable population.

solar flux the continual flow of solar energy to the earth.

technological progress increases in knowledge used to develop new products or improve existing products.

DISCUSSION QUESTIONS

1. What criteria would you use to evaluate the argument between the neo-Malthusians, who see population growth as the major problem facing humanity, and those who argue that population growth is a neutral or even positive factor for economic development? How would you assess the relative urgency of population concerns in the United States (population growth rate 0.5% per annum), India (1.0% per annum), and Somalia (3.2% per annum)?
2. "Every extra mouth brings with it an extra pair of hands. Therefore, we do not have to worry about growing population." Relate this statement to the more formal economic analysis of labor force and production. To what extent is the statement true? To what extent is it misleading?
3. The concept of carrying capacity is a useful one for the ecological analysis of animal and plant populations. Is it also useful for the analysis of human population growth? Why or why not?

WEBSITES

1. **https:// www.prb.org** Homepage for the Population Reference Bureau, which provides data and policy analysis on U.S. and international population issues. Its World Data Sheet provides demographic data for every country in the world.
2. **https://population.un.org/wpp** Website for the United Nations Population Division, which provides international information on population issues including population projections.
3. **https://www.populationconnection.org** Homepage for Population Connection, a nonprofit organization that promotes population stabilization through ensuring access to health care and contraception.

NOTES

[1] United Nations Department of Economic and Social Affairs, Population Division. 2024. *World Population Prospects 2024.* New York: United Nations. Medium Variant. https://population.un.org/wpp/Download/Standard/MostUsed/

[2] United Nations Population Division. 2022. "Day of Eight Billion." https://www.un.org/development/desa/pd/events/day-eight-billion; Population Reference Bureau. 2024. *World Population Data Sheet* https://2024-wpds.prb.org; World Population Clock. 2024. "8.2 Billion People." https://www.worldometers.info/world-population/

[3] A given population P growing at 2% per year means that the next year this population will be $1.02 \times P$, the year after that $1.02 \times (1.02 \times P) = (1.02)^2 P$, and so on. In the 35th year the population will be $(1.02)^{35} P = 2P$. The population has doubled in 35 years.

[4] Ehrlich, Paul R. 1968. *The Population Bomb*. New York: Ballantine Books; Ehrlich, Paul R. , and Anne H. Ehrlich. 1990. *The Population Explosion*. New York: Simon and Schuster; Ehrlich, Paul R. , and Anne H. Ehrlich. 2004. *One with Nineveh: Politics, Consumption, and the Human Future*. Washington, DC: Island Press.

[5] United Nations, 2024. https://population.un.org/wpp/Download/

[6] United Nations, 2024. https://population.un.org/wpp/Download/

[7] Ip, Greg, and Janet Adamy. 2024. "Suddenly There Aren't Enough Babies. The Whole World is Alarmed". *Wall Street Journal*, May 13.

[8] Adam, David. 2021. "How Far will Global Population Rise? Researchers Can't Agree." *Nature News Feature* September 21.

[9] With a growth rate of 3% per year, the population doubles in 25 years: $(1.03)^{25} = 2.09$. Using the "rule of 70," $25 = 70 / x$ and $x = 70 / 25$ or about 3%.

[10] Population Reference Bureau, 2023. *World Population Data Sheet*. https://2023-wpds.prb.org/wp-content/uploads/2024/01/2023-World-Population-Data-Sheet-Booklet.pdf

[11] Wittgenstein Center Human Capital Data & Graphic Explorer Version 3.0. https://iiasa.ac.at/models-tools-data/wcde

[12] John Oyefara, quoted in Newuh, Mimi Mafo. 2023. "Nigeria's Population Boom: Path to Poverty or Prosperity?" https://www.dw.com/en/nigerias-population-boom-path-to-poverty-or-prosperity/a-66186900

[13] This was first expressed by India's minister of population at the United Nations Population Conference in Bucharest in 1974.

[14] If, for example, $\alpha = \beta = 1/2$, then a doubling of labor alone would increase output by a factor of 1.414. A doubling of both labor and capital would increase output by a factor of 2.

[15] Since in this example output increases by a factor of 1.59 while labor increases by a factor of two, the change in per capita output can be calculated as 1.59/2.00 = 0.795, or a decline of about 20%.

[16] Boserup, Ester. 1981. *Population Growth and Technological Change: A Study of Long-Term Trends*. Chicago: University of Chicago Press.

[17] See, for example, Solow, Robert. 1986. "On the Intertemporal Allocation of Natural Resources." *Scandinavian Journal of Economics*, 88(1):141–149.

[18] Daly, Herman E. 1996. *Beyond Growth: The Economics of Sustainable Development*. Boston: Beacon Press, chap. 2.

[19] Von Weizsäcker, Ernst, Amory B. Lovins, and Hunter Lovins. 1997. *Factor Four: Doubling Wealth, Halving Resource Use*. London: Earthscan.

[20] O'Neill, B.C., *et al*. 2010. "Global Demographic Trends and Future Carbon Emissions." *Proceedings of the National Academy of Sciences*, 107(41):17521–17526.

[21] Wheeler, David, and Dan Hammer. 2010. "The Economics of Population Policy for Carbon Emissions Reduction in Developing Countries." Center for Global Development. Working Paper 229, November.

[22] Taylor, Adam, 2015. "The Human Suffering Caused by China's One Child Policy." *The Washington Post*, October 29.

[23] Yoko Kubota and Lian Qi. 2025. "Inside the Chinese City That Said Cash Rewards Brought a Baby Boom." *Wall Street Journal*, April 9.

[24] Population Council. 2014. "Cairo+20: The UN on Population and Development beyond 2014," *Population and Development Review* (December): 755–757.

[25] Engelman, Robert. 2016. "Africa's Population Will Soar Dangerously Unless Women Are More Empowered." *Scientific American*, February 1.

[26] The cases of China and Kerala are reviewed in Sen, Amartya. 2000. *Development as Freedom*. New York: Alfred A. Knopf., pp.219–224. For India, see Pandya, Rameshwari ed. 2008. *Women, Welfare and Empowerment in India: A Vision for the 21st Century*. New Delhi: New Century Publications.

[27] See Birdsall, Nancy, Allen Kelley, and Stephen Sinding. 2001. *Population Matters: Demographic Change, Economic Growth, and Poverty in the Developing World*. New York: Oxford University Press; Engelman, Robert. 2008. *More: Population, Nature, and What Women Want*. Washington, DC: Island Press Halfon, Saul. 2007. *The Cairo Consensus: Demographic Surveys, Women's Empowerment, and Regime Change in Population Policy*. Lanham, MD: Lexington Books; Singh, Jyoti Shankar. 2009. *Creating a New Consensus on Population: The Politics of Reproductive Health, Reproductive Rights and Women's Empowerment*. London: Earthscan.

[28] United Nations Department of Economic and Social Affairs. 2018. "68% of the world population projected to live in urban areas by 2050." https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

[29] See Harris, Jonathan M., Timothy A. Wise, Kevin Gallagher, and Neva R. Goodwin, eds. 2001. *A Survey of Sustainable Development: Social and Economic Perspectives*. Washington, DC: Island Press, Part IV.