Chapter One

World Population

HOW QUICKLY has the world's population grown? Where is it growing the fastest? How can we characterize world population growth and transitions from high to low mortality and fertility? What are the implications of population growth and what is the ultimate size of the world's population? Starting with a brief review of world population growth, these and other issues are explored in this chapter. The "Focus" section contrasts the current growth regimes in the United States, Germany, and India, and the "Methods, Measures, and Tools" sections explore the graphical presentation of population data and population projection techniques.

A BRIEF HISTORY OF WORLD POPULATION GROWTH

For much of humanity's history, world population was small and population growth was slow (see figure 1.1). Aided by food security, the shift from hunter-gatherer societies to agricultural-based societies (around 8000 BC and 5000 BC) allowed the population to grow, but the population was still probably only slightly more than 200 million around 1 AD. Still, high birthrates were offset

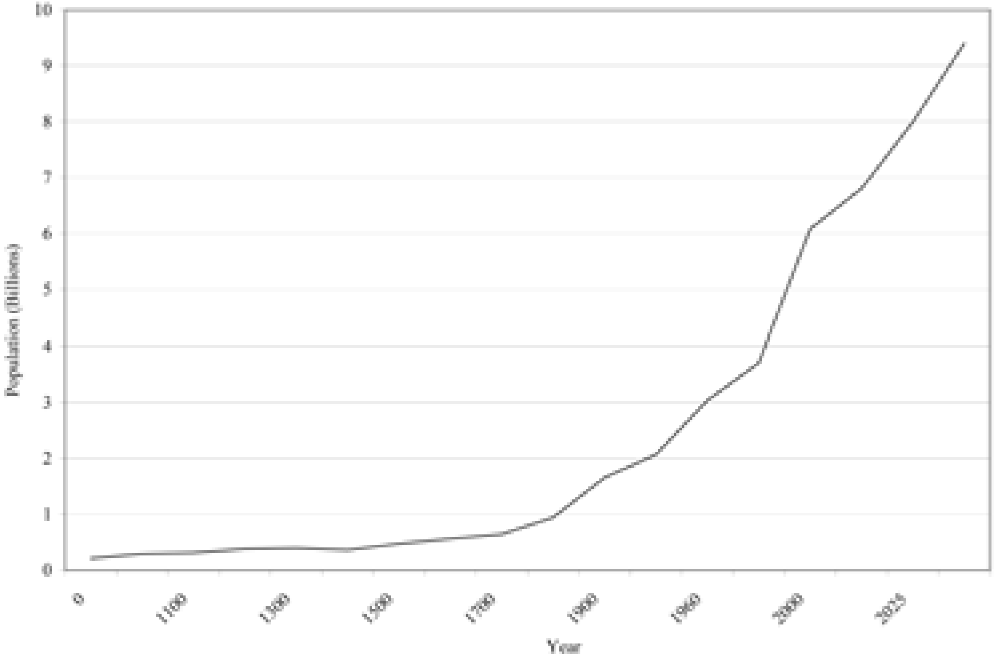


Figure 1.1. World Population Growth
Source: US Census Bureau.

by high death rates from famine, war, and epidemics. It is estimated, for example, that the bubonic plague reduced the populations of Europe and China by one-third to one-half in the fourteenth century.[1] Even by 1600, the world's population was estimated to be only 500 million—not all that much larger than the population of the United States.[2]

Beginning in the mid-1600s, the world's population started to grow more rapidly as life expectancy slowly increased with improvements in commerce, food production and security, and nutrition, with the world's population reaching approximately one billion by 1800. The nineteenth century would, however, bring a surge in population growth, particularly in Europe. Coinciding with the Industrial Revolution, the population of Europe doubled between 1800 and 1900. Fueled by European immigration, North America's population multiplied by twelve in the same period.[3] The population of developing countries grew more slowly during this time, but they already held the bulk of the world's population. Advances in medicine and sanitation increased survival and life expectancies. By 1900, world population was approximately 1.7 billion, increasing to two billion by 1930. The mid-twentieth century saw unprecedented population growth, with the world's population reaching three billion by 1960 and four billion by 1974. The fifth billion was reached just twelve years later. By mid-2009, the total population was over 6.8 billion, and is projected to reach 7 billion by 2012.[4] Up-to-date world and US population figures can be found at www.census.gov/main/www/popclock.html.

Between 1960 and 1998, the world's population doubled from three to six billion. Demographers often refer to the amount of time it would take for a population to double in size, assuming that the growth rate remained constant into the future. A simple way to determine the doubling time is

$$DoublingTime = 1\text{n } 2/r$$

where ln 2 is the mathematical notation for the natural logarithm of 2 and r is the annual percentage growth rate, expressed as a decimal. So, given that Egypt is growing at 1.9 percent, it would take just 36 years for its population to double (from 78.6 million in 2009)! For the United States, the doubling period would be over 116 years, given its 2009 natural growth rate of 0.6 percent. This assumes, however, that the growth rate (r) remains unchanged by shifts in fertility and mortality over the period.

Regional Growth

The population growth patterns that we observe around the world are not the same. We can roughly divide the world into two broad regions, namely the developed world and the developing world. The developed world includes the United States, Canada, western Europe, Japan, and Australia, and the developing world can be roughly identified as all other countries. Most of the world's population growth originates in the developing world, which represents over 80 percent of the world's population and where 98 percent of the world's population growth is now occurring. Put in another perspective, over 121 million children were born in the developing world in 2008, compared to about 13.3 million in developed, industrialized countries.[5]

Even within the developing world, however, there are great differences in terms of population growth regimes. China, currently the world's most populous country, has a growth rate of just 0.5 percent, meaning that while its population continues to grow, it is growing at a much slower rate and could ultimately be faced with population decline. It is already grappling with issues of population aging because of its one-child policy, issues that are explored further in chapter 10. China also has an impressive impact on population statistics. For instance, if China is included in population statistics for the developing world, the fertility rate is just 2.7, compared to 3.1 when China is excluded. As a result, the Population Reference Bureau (PRB) regularly provides statistics that both include and exclude China.

As the world's second-largest country, India has a population growth rate of 1.6 percent and a fertility rate of 2.7, meaning that its population continues to expand rapidly, and it will soon overtake China as the world's most populous country. Elsewhere in the developing world, Africa, and in particular sub-Saharan Africa, has growth rates in excess of 2.5 percent, and fertility rates that exceed 5.0. In short, population growth rates remain high and long-term population growth is ensured. Population growth rates are much lower in Central America, South America, and the Caribbean, although fertility rates remain in excess of 2.1, so that the population continues to grow as well.

In most of the developed world, population growth rates are much lower. The natural growth rate in the United States is just 0.6 percent, and its fertility level hovers near replacement (2.1). Even this, however, is comparatively fast when compared to Japan and some of the western and Eastern European nations, where growth rates are much less. As a whole, Europe's growth rate was zero percent in 2009. In other words, its population was stable—neither growing nor declining. At the same time, several Eastern European countries, including Hungary, Romania, and Russia, had negative growth rates, while the population of western Europe, including France, barely managed to grow. Population decline brings with it multiple questions of state identity, political power, and economic growth that are further discussed later in this chapter.

Urban Growth

Accompanying the world's population explosion has been the explosion in the size and number of urban areas. As recently as 1975, only 33 percent of the world's population lived in urban areas, with most of these living in relatively small cities of less than one million.[6] In 2009, approximately 50 percent of the world's population lived in urban areas. While the developing world lags the developed world in the proportion urbanized (44 percent to 75 percent, respectively), the urban population in the developing world is expected to grow rapidly in the coming decades, with upwards of 61 percent of the world's population living in urban areas by 2030.[7] Placing urban growth in another perspective, the number of cities in the developing world with populations in excess of one million is expected to jump from 345 in 2000 to 480 by 2015. The number of megacities (cities with populations in excess of ten million) has also grown from 8 in 1985 to 20 in 2007, and the number of these superlarge cities is projected to grow to 22 by 2015. Most of these new megacities will be in the developing world, as it becomes home to an increasing proportion of the world's population, with their growth driven by natural increase,[8] net rural to urban migration, and urban reclassification.

THE DEMOGRAPHIC TRANSITION

The population explosion in Western countries during the 1800s marked the beginning of the shift from high to low mortality and high to low fertility, known to demographers as the demographic transition, and formalized by the demographic transition theory (DTT) (figure 1.2). The theory argues that prior to transition, birth and death rates are high, and largely cancel each other's effect, meaning that populations grow slowly. As a society develops and modernizes, death rates decline, but fertility remains high, corresponding to the period of rapid population growth. At the conclusion of the demographic transition, birth and death rates are again comparable, but at a much lower level than prior to transition, and population growth again stabilizes.

Within this theory, the most important determinants of population growth are the pretransition fertility rate and the time lag between the decline in mortality and fertility. That is, while fertility rates remain high and death rates are low, the population can grow quickly. The former captures how far fertility rates must fall, with high fertility reflecting a large demand for children in a society and with fertility reduction generally taking longer in high-fertility societies. The latter effect (the lag between mortality and fertility declines) captures the length of time over which rapid population growth can occur, with longer

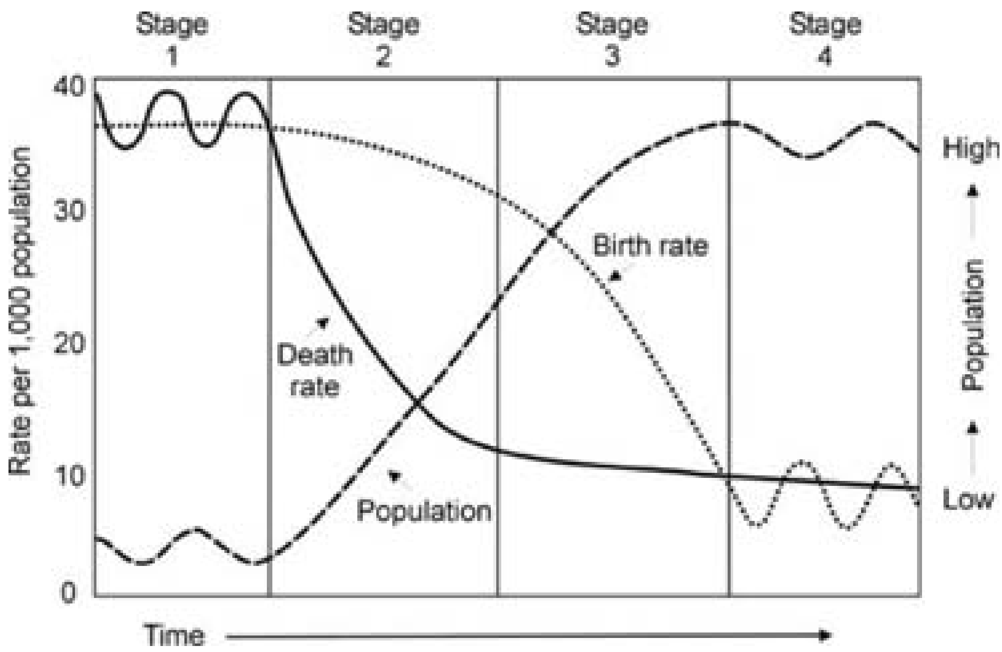


Figure 1.2 The Demographic Transition Theory.
Rapid population growth occurs when births exceed deaths (stages two and three), with total growth reflecting the length of time over which these two stages occur and the difference between the maximum birth and death rates (stage one) and the minimum rates (stage four).
Source: Author.

time periods translating to a longer time period over which the population can grow rapidly.

Although the concept of demographic transition can be roughly applied to all countries, with a decline in mortality rates followed by an eventual decline in fertility rates, the timing, pace, and triggers of the transition vary. Within the developed world, shifts in mortality and fertility occurred in the later parts of the nineteenth century and early twentieth centuries as the Industrial Revolution progressed and as major public health improvements led to declines in infant mortality rates and increased life expectancy. Fertility rates were somewhat slower to change since social and behavioral change defining the desired family size tend to be slower, but fell rapidly after 1900 as more children survived to adulthood, marriage patterns changed, women moved into paid work, and parents placed greater value on the education their children received. In the United States, the total fertility rate dropped from an average of four or five children in 1900 to approximately two children per woman by the 1930s. Canadian and European rates followed a similar pattern.

This demographic transition has generally not yet finished in the developing world, where rapid population growth continues. On the one hand, mortality rates in the developing world have generally fallen rapidly from the 1950s onward, particularly with the introduction of antibiotics, immunizations, and better medical care and nutrition. On the other hand, fertility rates largely remain above replacement level, and average approximately three children per woman in the developing world, with higher rates in sub-Saharan Africa. Even as mortality and fertility rates in the developed world stabilized and low and stable rates of population growth were realized, much of Africa, Asia, and Latin America were still experiencing relatively high mortality and fertility levels.

As countries in the developing world started their demographic transition, they frequently had higher levels of birth and death rates than those observed in developed countries a century earlier, with fertility rates in many countries continuing to average more than six children per woman. Fertility reduction in the developing world has also typically been slower than experienced in the developed world (i.e., the lag between the decline in mortality and fertility has been longer). Instead, it varied across countries, defined by differences in social, cultural, and religious expectations; literacy rates; female participation in the workforce; family and economic considerations; and the availability and acceptability of family-planning programs. Rates of natural increase (the birthrate minus the death rate, indicating the annual rate of population growth) remain high in much of the developing world.

Although the demographic transition theory has been widely applied, it has also been extensively criticized because of its Western-centric biases. It was, for all intents and purposes, validated on the demographic experiences of Europe and assumes that all other countries would progress similarly through its stages. In the developing world, the triggers for fertility reduction differ, including differential access to education and employment and differential roles for women within society. It is also relatively unable to account for myriad variations such as higher fertility levels, alternative forces associated with the decline in mortality, or social and cultural issues.[9]

FUTURE POPULATION SCENARIOS: WHO GAINS AND WHO LOSES?

At the dawn of the twenty-first century, there was some evidence that the developing world was finally transitioning from high to low fertility, evidenced by a 2009 total fertility rate (TFR) of 2.7 (3.1 if China is excluded), a rate that is considerably lower than that observed just a quarter of a century earlier.[10] With the expectation that fertility rates will continue to decline, some analysts have concluded that the risk of population growth has been greatly diminished.[11] Indeed, some authors have suggested that the new problem is a population *deficit* and an aging of the world's population,[12] and others have suggested that the threat of world population growth is now more regional than global and of consequence only in countries such as Pakistan and India where high fertility regimes remain.

While the world's population growth rate did peak in the 1960s and has declined since then, the global population is still rapidly expanding, evidenced by a global growth rate of 1.2 percent. In effect, to say that it is a regional problem allows the Western world to ignore the problem, but only at its peril. The current fertility rate in the developing world translates to a growth rate of 1.4 percent (1.7 percent excluding China). This allows the population in the developing world to double in approximately forty-nine years (assuming growth continues at its current rates) or forty years if China is excluded. Even as fertility rates have dropped in Asia, Latin America, and the Caribbean, they remain stubbornly high in the world's least developed countries, with a 2009 TFR of 4.6. In sub-Saharan Africa, the 2009 TFR was 5.3. Moreover, in countries where fertility rates have dropped quickly, the young age structure of the population will ensure growth for the next two to three decades. Put another way, a huge proportion of the world's population have not started having children. Instead, they *are* children. Consequently, a total world population of 8 billion by 2025 likely cannot be avoided, and most projections place world population between 7.3 and 10.7 billion by 2050, with nearly all of this growth occurring in the developing world (table 1.1). So, while population growth is indeed slowing, we must still feed, clothe, and shelter a growing population, a task that it is unclear whether the world can accomplish.

Table 1.1. Current Population Statistics by Selected World Regions, 2009

	Population mid-2009 (millions)	*Total fertility rate*	*Natural increase (annual, %)*	*Doubling time (years)*	*Projected population 2025 (millions)*
World	6,810	2.6	1.2	58	8,087
North America	341	2.0	0.6	116	395
Central America	152	2.5	1.7	41	179
South America	386	2.2	1.3	53	443
Caribbean	41	2.5	1.2	58	46
Oceania	36	2.5	1.1	65	45
Northern Europe	99	1.9	0.3	231	109
Western Europe	189	1.6	0.1	693	192
Eastern Europe	295	1.5	-0.2	—	278
Southern Europe	155	1.4	0.1	693	157
Asia (excludes China)	2,786	2.7	1.5	46	3,382
Asia (includes China)	4,117	2.3	1.2	58	4,858
Western Asia	231	3.1	1.9	36	293
South Central Asia	1,726	2.8	1.7	41	2,148
Southeast Asia	597	2.5	1.4	50	712
East Asia	1,564	1.6	0.5	139	1,704
Sub-Saharan Africa	836	5.3	2.4	29	1,184
Northern Africa	205	3.0	1.9	36	257
Western Africa	297	5.5	2.7	26	420
Eastern Africa	313	5.4	2.6	27	455
Middle Africa	125	6.1	2.8	25	189
Southern Africa	58	2.8	0.9	77	63

(—) indicates data not available or applicable.
Source: Population Reference Bureau, *2009 World Population Data Sheet*.

While many developing countries in Asia still have above-replacement TFRs, China, South Korea, Taiwan, and Thailand have fertility levels lower than replacement. China is, in fact, an important exception to the generally high fertility rates of the developing world. With a population of 1,331 million in mid-2009 and an annual growth rate of 0.5 percent, China is the world's most populous country. Despite fertility levels that exceeded 7.0 recorded as recently as the 1950s, China's fertility rate has plunged to below replacement level (1.6), largely attributed to its one-child policy, which has artificially lowered fertility levels since its inception. India, too, has attempted fertility control policies, but has had much less success.[13] Although it has a smaller population (1,171 million), India is growing at a rate of 1.6 percent, meaning it will surpass China's population by the middle of the twenty-first century. In other parts of Asia, there has been little change in fertility in places such as Iraq and Pakistan. In

Africa, the transition to a lower fertility regime is still in progress. Total fertility rates still exceed 6.0 in countries including Mali, Uganda, Somalia, and Malawi, and there is little evidence that a downward shift in fertility is about to occur. Throughout much of Africa, infant mortality rates remain high (74 per 1,000), and life expectancies are short (fifty-five years). In contrast, most developed countries are experiencing slow growth or even population decline, long life expectancies, and low infant mortality rates.

At a very general scale, the developed world is largely characterized by relatively slow rates of population growth, low fertility levels, and controlled immigration. With a current growth rate of 0.2 percent per year, it will take approximately three hundred and fifty years to double the current population, assuming a constant rate of natural increase. Some countries in Europe, and especially Eastern Europe, are experiencing negative population growth rates, meaning that their populations are declining. For example, the Population Reference Bureau projects Latvia's current population of 2.3 million to decline to 1.9 million by 2050, attributed to extremely low fertility levels. Germany's population, currently 82 million, is projected to decline to 71.4 million by 2050.

What do these population trends mean and what are their implications? We will briefly explore issues related to overall population growth. While many are expanded in later chapters, their discussion contextualizes world population growth. For instance, high fertility in much of the developing world ensures population growth, while low fertility in the developing world points to population decline. Urban growth, population aging, and immigration also spill out of these broader trends.

Continued Population Growth

The current distribution of the world's population (figure 1.3), coupled with high fertility in much of the developing world, means that the global population will continue to grow into the near future before leveling off between 7.3 and 10.7 billion later this century, despite falling fertility rates and slowing population growth rates since the 1960s. Rapid population growth in the second half of the twentieth century has meant that the share of the world's population residing in the developing world climbed from 68 to 82 percent. According to United Nations projections, the percentage residing in the developing world will grow to 86 percent by 2050.

The certainty of continued global population growth is grounded in three assumptions. First, improvements in life expectancy (reduced mortality) will contribute to population growth, as individuals survive longer. Longer life expectancies increase a child's likelihood of surviving infancy and childhood and completing his or her reproductive years. Second, the age structure of a

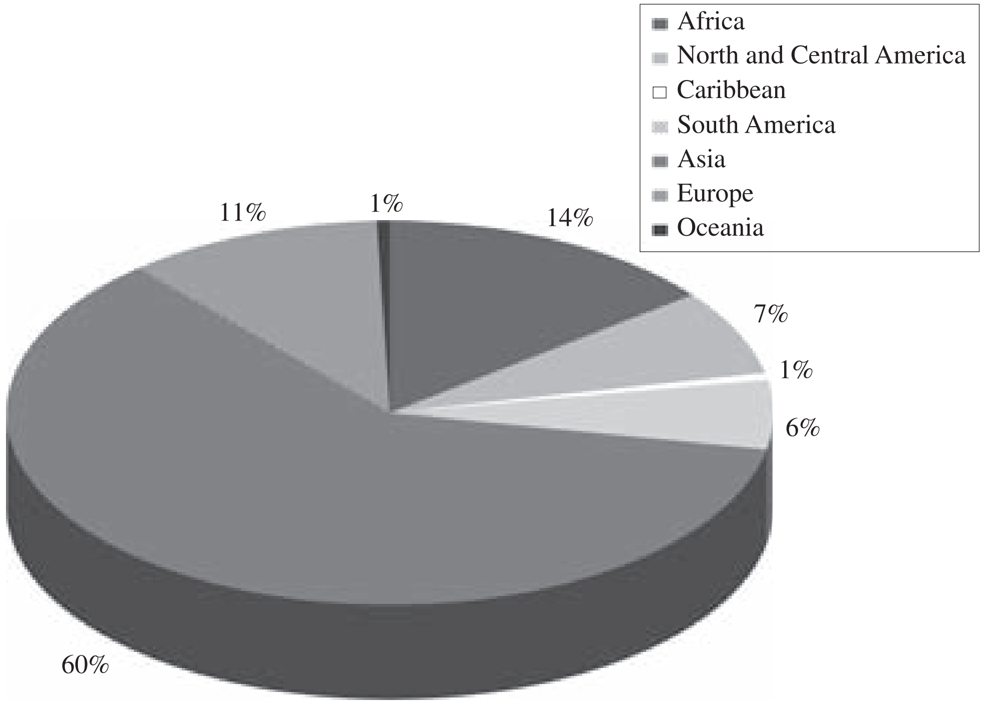


Figure 1.3 World Population Distribution by Major Region, 2009.
Data derived from *2008 World Population Data Sheet* (Washington, DC: Population Reference Bureau, 2009).
Source: Author.

Table 1.2. The Ten Most Populous Countries in the World, 2009 and 2050 (Projected)

2009		*2050*	
Country	*Population (millions)*	*Country*	*Population (millions)*
China	1,331	India	1,748
India	1,171	China	1,437
United States	307	United States	439
Indonesia	243	Indonesia	343
Brazil	192	Pakistan	335
Pakistan	181	Bangladesh	223
Bangladesh	162	Nigeria	285
Nigeria	153	Brazil	215
Russia	142	Congo (Kinshasa)	189
Japan	128	Ethiopia	150

Source: Population Reference Bureau, *2009 World Population Data Sheet*.

population is key to the expected future growth, with populations having a greater number of individuals in their childbearing years tending to grow faster irrespective of the fertility rate. Women may have fewer children than in the past, but there are more women having children. Excluding China, which has seen a shift in its age structure associated with its one-child policy, 33 percent of the population in the developing world is less than fifteen years old. In sub-Saharan Africa, 43 percent of the population is aged less than fifteen years. The young age profile of the developing world means that this population still has to enter its reproductive years. Even if fertility rates decline, population momentum will ensure sustained population growth. In comparison, only 17 percent of the population in the developed world is less than fifteen years old, a proportion that continues to decline.

Third, most demographers expect that fertility rates will eventually decline below replacement, ending the population explosion. Yet, fertility rates continue to remain above replacement in many regions of the world. Declines have been noted, but it is unknown whether further declines in fertility can be expected, with recent surveys in both Bangladesh and Egypt pointing to the danger in assuming that fertility will drop below the level needed to replace the population. Despite early successes in reducing fertility in Bangladesh, with fertility rates dropping from over six children per woman in the early 1970s, fertility rates have remained relatively unchanged since the 1990s. Similarly, Egypt's birthrate has remained equal to or greater than 3.0 since 1993. This trend is far from isolated, with Argentina's birthrate remaining at about 3 children for nearly fifty years, although by 2009 it had fallen to 2.4.[14]

A look at worldwide demographic data quickly highlights the fact that differential population growth regimes are occurring around the world.The combined impact of slowing population growth or decline in some countries and continued growth in others leads to issues associated with population aging and immigration, discussed below.

Population Aging and Decline

It is rather paradoxical that while we talk of continued population growth at the global scale, we also observe population decline in some regions or countries where population aging and fertility decline have emerged as new issues.[15] Globally, the proportion of the population over sixty-five has grown from 5 percent in 1950 to 8 percent in 2009. While seemingly a small change, it is in many ways the tip of the iceberg. By 2050, for example, the Population Reference Bureau expects that approximately 18 percent of Asia's population will be sixty-five or older. In large part, this is driven by China, where its one-child policies have resulted in a dramatic aging of the population, so much so that there was renewed discussion in 2008 of further relaxing its fertility policies.

Likewise, 19 percent of Latin America's population is expected to be aged sixty-five or greater by 2050.

In much of the developed world, population aging is further advanced. Japan as well as much of Europe already have some of the highest proportions of older populations (aged sixty-five-plus). In 2009, Japan's older population share was 23 percent, amongst the highest in the world. The United States, Canada, Australia, and New Zealand are not far behind, as their baby boomers age into retirement and fertility rates remain low. At the same time, numerous countries were already experiencing negative rates of natural increase, including Estonia, Latvia, Germany, Hungary, Russia, and Ukraine. Countries such as Japan and Canada had growth rates that were near zero and were experiencing slowing population growth.

Consequently, population *deficits*, and the economic and social consequences of these, have increasingly emerged as an important issue for some developed countries, with commentators openly worried about the consequences of aging populations and declining population growth.[16] In particular, while it is unclear what impacts aging societies will have, most commentators assume negative consequences, including declining national and international political influence, loss of national identity, altered political agendas that favor older populations at the expense of younger cohorts, slower economic growth, and increasing demands on health and social welfare programs at the same time that the labor force and economically active population is shrinking. Concurrently, countries have looked to policies to actively promote population growth through increased fertility and/or increased immigration.

Immigration

Human populations have been inherently mobile throughout history. In 2005, the PRB estimated that there were 191 million international migrants, meaning that 3 percent of the world's people had left their country of birth or citizenship for a year or more. For the developed world, the number of international migrants stood at 120 million, while approximately 61 million migrants moved within the developing world.[17] Most of these migrations are closely linked to economic opportunities and are encouraged by globalization, which has linked economies and employment around the world, encouraging the use of low-skilled and low-cost workers worldwide. While most countries now attempt to control entry through various pieces of legislation, immigration remains a potentially large source of population change. For developed countries such as Canada and the United States, most immigrants arrive from the developing world, and immigration policies are typically structured to attract "the best and the brightest" immigrants. While benefiting the receiving country, such policies have been criticized because they skim talented individuals from developing-world countries that need them.

The international movement of people has raised concerns within many countries. While not denying past immigration policies that were openly racist and exclusionary, both the United States and Canada have historically been receptive to immigration. In the United States, this history may be in danger, illustrated by the fear of demographic "Balkanization," welfare reform, and the tightening of immigration and refugee policies in a post-9/11 world. Anti-immigrant sentiments are especially visible in Europe, coloring national political debates and economic opportunities. European countries have only recently shifted from being labor exporters to importers of labor, a shift that is difficult to digest. Yet, the demographic realities of low fertility and an aging population mean that European countries are faced with a crisis in their labor force. Increased immigration may be the only option for meeting employment requirements, but it remains an option that carries significant political, social, and cultural problems, since most Europeans continue to associate the foreign-born with unskilled work and unemployment. Most likely, Europe will ultimately need to address its new role as a receiver of immigrants. In addition, both North America and Europe are grappling with illegal immigration, imposing burdens upon local service providers at the same time that illegal immigrants sustain the economy by working for low pay and in positions or conditions that few others are willing to tolerate.

Most governments in the developed world have moved to control immigration, limiting the type of immigrant (i.e., family reunification and economic), origin, and overall number allowed entry over any given year. Despite their efforts through both legislation as well as active enforcement of borders, most countries have found it increasingly difficult to control the entry of immigrants, creating an immigration crisis reflected in what has been described as the "gap" between immigration control policies and their outcomes. The emerging reality is that governments are less able to control immigration now than in the past. Globalization and the increasing flow of labor and capital, the emergence of civil rights and liberalism, and the domestic need for inexpensive labor, which legitimized immigration flows, have contributed to this inability to control both illegal and legal migration flows.

Immigration is also a significant source of labor in the developing world. Laborers from countries such as Indonesia, India, and Pakistan are, for example, attracted to Persian Gulf states for work in the construction and oil industries. These migrants become an important source of income for their families through the money sent back home, which is then invested in new housing or other goods. This money, or remittances, has become an important source of income for families and countries alike.[18] Typically, movement is into a richer developing country for temporary work. Although entry is often unregulated, states in the developing world are increasingly moving to tighten their own entry requirements. Another source of population change is the movement of refugees across international borders.

CONCLUSION

The current rapid pace of world population growth reflects comparatively low mortality levels, fertility rates that remain high in much of the developing world, and the impact of a young population that remains in its childbearing years. The end result is that the world's population will continue to grow for the foreseeable future. While we may be content in this realization, it is only the beginning of our discussion. Why, for instance, are fertility rates relatively slow to decline, while mortality rates declined early and rapidly? What is the outlook for mortality, particularly in the face of HIV/AIDS? How does immigration shift populations from country to country or within countries? What does population growth mean for the development and growth of urban areas and the potential for conflict? These, and other related issues, are explored more fully in the following pages.

FOCUS: POPULATION GROWTH REGIMES IN INDIA, GERMANY, AND THE UNITED STATES

It is easy to recognize that different regions, and indeed different countries, face alternate population growth regimes, with some growing rapidly while others are in decline. We focus here on three different countries: India, a rapidly growing country; Germany, a country faced with population decline; and the United States, a country that is experiencing modest population growth but that has also completed the demographic transition (see table 1F.1).

Like other countries in the developing world, India's population growth exploded in the twentieth century. Between 1900 and 2000, its population grew fourfold, from approximately 238 million to one billion.[1] With a 2009 population of 1,171 million, India's population is growing at a rate of 1.6 percent per year, adding some 18 million to its population each year.[2] Fueled by high total fertility (2.7), a relatively young population (32 percent are aged fifteen years or less), and increasing life expectancies, its population is expected to grow to 1,755 million by 2050, surpassing China's population by 2030. On its own, the country's young age structure will ensure that its population continues to grow due to demographic momentum, given that so many women have yet to enter their childbearing ages. Fertility decline since the 1960s has slowed population growth in India, but there are wide dis-

Table 1F.1. Population Growth in India, Germany, and the United States

	Population 2009 (millions)	*Growth rate (%)*	*Total fertility rate*	*Projected population (millions)*		*Projected population change (%) 2007–2050*	*Percent of population aged*	
				2025	*2050*		*<15*	*>65*
India	1171.0	1.6	2.7	1407.7	1755.2	53	32	5
Germany	82.0	−0.2	1.3	79.6	71.4	−13	14	20
United States	306.8	0.6	2.1	355.7	438.2	44	20	13

Source: Derived from Population Reference Bureau (PRB), *2009 World Population Data Sheet*, www.prb.org.

parities in birth rates between the northern and southern states, with northern states characterized by high birth rates (approximately four children), and the southern states, where, additionally, life expectancy is greater. Fertility is also higher and life expectancy lower in rural rather than urban areas.[3]

Germany presents almost the mirror image to India, having completed its demographic transition. With a much smaller (2009) population of 82 million, its growth rate is -0.2 percent, such that its population is in decline. By 2050, its population is expected to have shrunk to 71.4 million, or a decrease of approximately 13 percent. This population decline is exacerbated by limited immigration and a low total fertility rate (1.3), meaning neither immigration nor natural increase are sources of population growth. Germany's changing population structure also means that its population is rapidly aging, with 20 percent already aged sixty-five and over, with this proportion expected to grow as its population continues to age. In contrast, just 14 percent of its population is less than fifteen years, and the youngest generation (aged zero to four) is half the size of the forty to forty-four year age group.[4] Its age and population structure are similar to those of other western and Eastern European countries, where debates over population trends and policies have focused on increasing immigration levels or increased fertility.[5] Immigration provides a short-term solution, although Germany does not see itself as a destination for immigrants, with some fearing the erosion of culture and nationality, reflecting both Germany's history and experiences with the guest worker program, which imported workers for German factories.[6] Changes to fertility rates, however, are much more difficult to encourage.[7]

While the United States has also completed its demographic transition, population growth has been comparatively rapid relative to other developed countries: its population was just 100 million in 1915, with the next hundred million added by 1967, and 300 million in 2006. As of 2009, its population was 306.8 million, and it is expected to grow to 438.2 million by 2050. Its population growth can be partially attributed to high immigration levels, with approximately one million new arrivals each year. In addition, fertility remains relatively high and approximately equal to the replacement level (2.1). In fact, the fertility rates of ethnic minorities and the foreign-born population—especially Hispanic immigrants—in the United States tends to be somewhat higher than that of the native-born population, pushing the national average rate upward.[8] Fertility rates amongst Hispanics, for instance, were 3.2, compared to 1.9 amongst non-Hispanic whites.[9] Even amongst whites, this is a relatively high fertility rate in comparison to fertility rates observed in other developed countries. While foreign-born Hispanics have higher fertility rates than their native-born counterparts, immigrant fertility rates have been found to decrease sharply in the second generation, related to improved education and income.[10] Although the aging baby boom population is increasing the proportional share of those aged sixty-five and over, this group still only represented 13 percent of the population in 2009, a comparatively low share relative to other countries in the developed world.

METHODS, MEASURES, AND TOOLS: GRAPHICAL REPRESENTATION

Population geographers are frequently faced with a large volume of data that must be presented. What is the best way to portray population statistics? One of the clearest ways to display population information is through mapping, largely because of maps' visual impact and their ability to easily communicate information, along with identifying and illustrating spatial patterns. Maps are used in multiple ways, including in public health (i.e., disease surveillance), transportation (i.e., optimal vehicle routing or analysis of pollution along major arteries), site locations for stores and services, disaster planning, and so on. In many cases, maps are used to highlight the presence of a spatial relationship that can then be explored further through modeling and other techniques.

MAP TYPES

Population *dot maps* provide a simple way to graphically represent the distribution of a population. The basic idea of this sort of map is straightforward: a dot is used to symbolize the location of a person (or group of people or other object) of interest. An early use of this sort of map is John Snow's mapping of London's cholera epidemic around the Broad Street pump in 1854.[1] Snow mapped the locations of the homes of those who died during the outbreak, observing that the majority of cases were located close to the pump, which acted as the contaminant source and was ultimately closed. Dot density maps are most useful for showing where particular data occur. However, caution should be exercised as the dot location does not always indicate the precise location of the data of interest. Instead, they often represent data occurring within a geographical area such as a census tract, zone improvement plan (zip) code, or county.

Choropleth maps, whereby regions are shaded corresponding to the value of interest, provide an alternative representation and are frequently part of the geographer's toolbox. While commonly used, choropleth maps can be misleading due to the artificial boundaries, such as borders between census tracts or counties, that are used to define the map. The fixed geography of these imposed boundaries creates an artificial order on the data. In addition, differences in the size of units in the map can lead to visual distortion. Moreover, choice of class interval (i.e., standard deviation, percentiles, equal interval) (figure 1MMT.1) and/or changing the spatial scale of the map, while still mapping the same phenomenon, can lead to different interpretations (the so-called modifiable areal unit problem, see introduction).

Cartograms are maps where the area is not preserved (figure 1MMT.2). Instead, regions are reproportioned relative to the magnitude of the data displayed (as opposed to their true physical size). For example, population size may be substituted for regional area, distorting the area of the map to convey the information.[2] Finally, population geographers have also consistently made use of *flow maps*, particularly to represent migration streams (flows) from one region to another.[3] Other uses include transportation flows, information exchange, and disease transmission. By changing the width of the lines, flow maps can be used to portray differences in the size of the flow, and directions of the flow are represented with arrows.

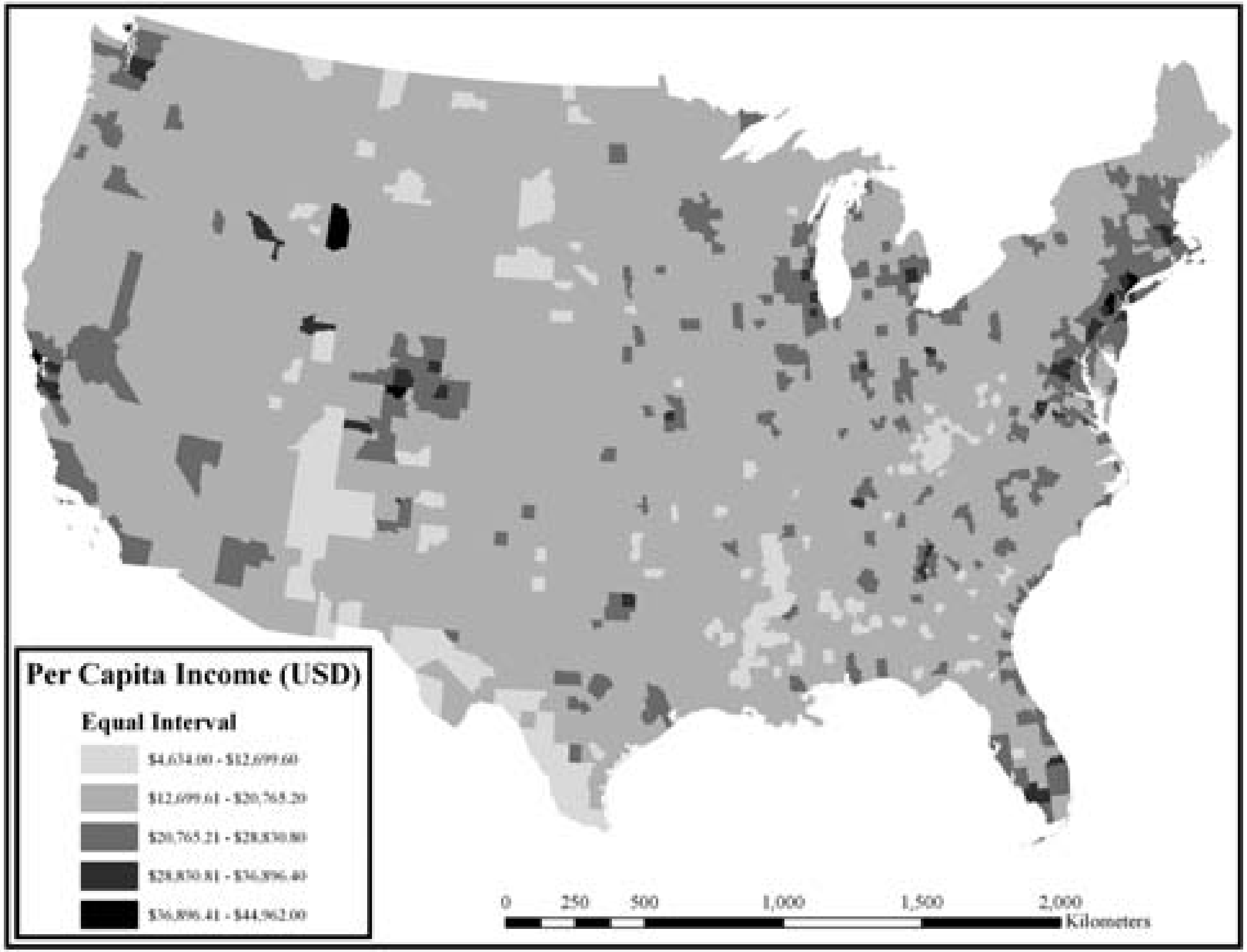
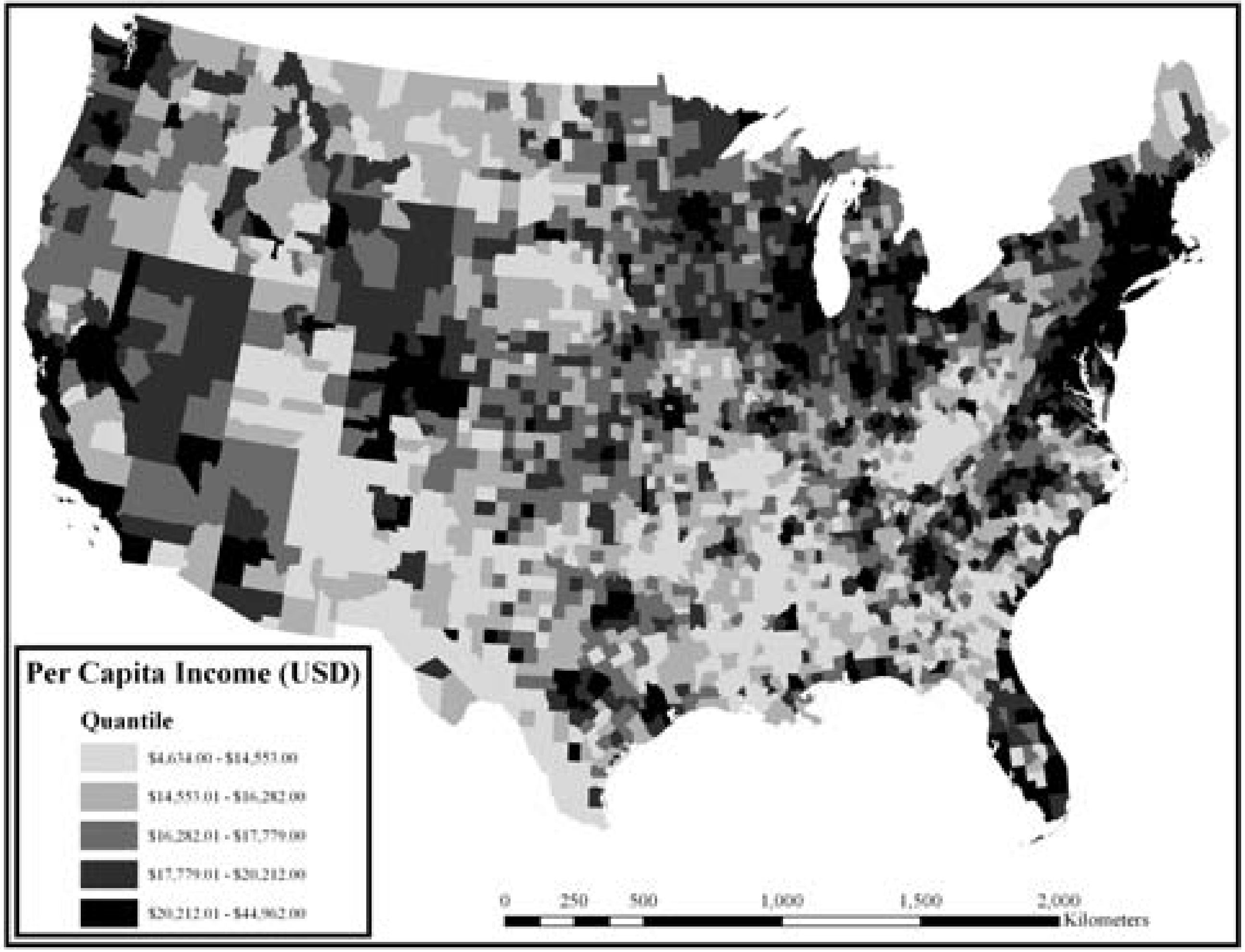


Figure 1MMT.1a



Figures 1MMT.1a and 1b Impact of Changing Class Interval.

These two maps show the impact of changing class intervals in a map projection. Both maps illustrate income by county (1999), with the first using class intervals based on equal intervals and the second based on quintiles.

Source: Author.

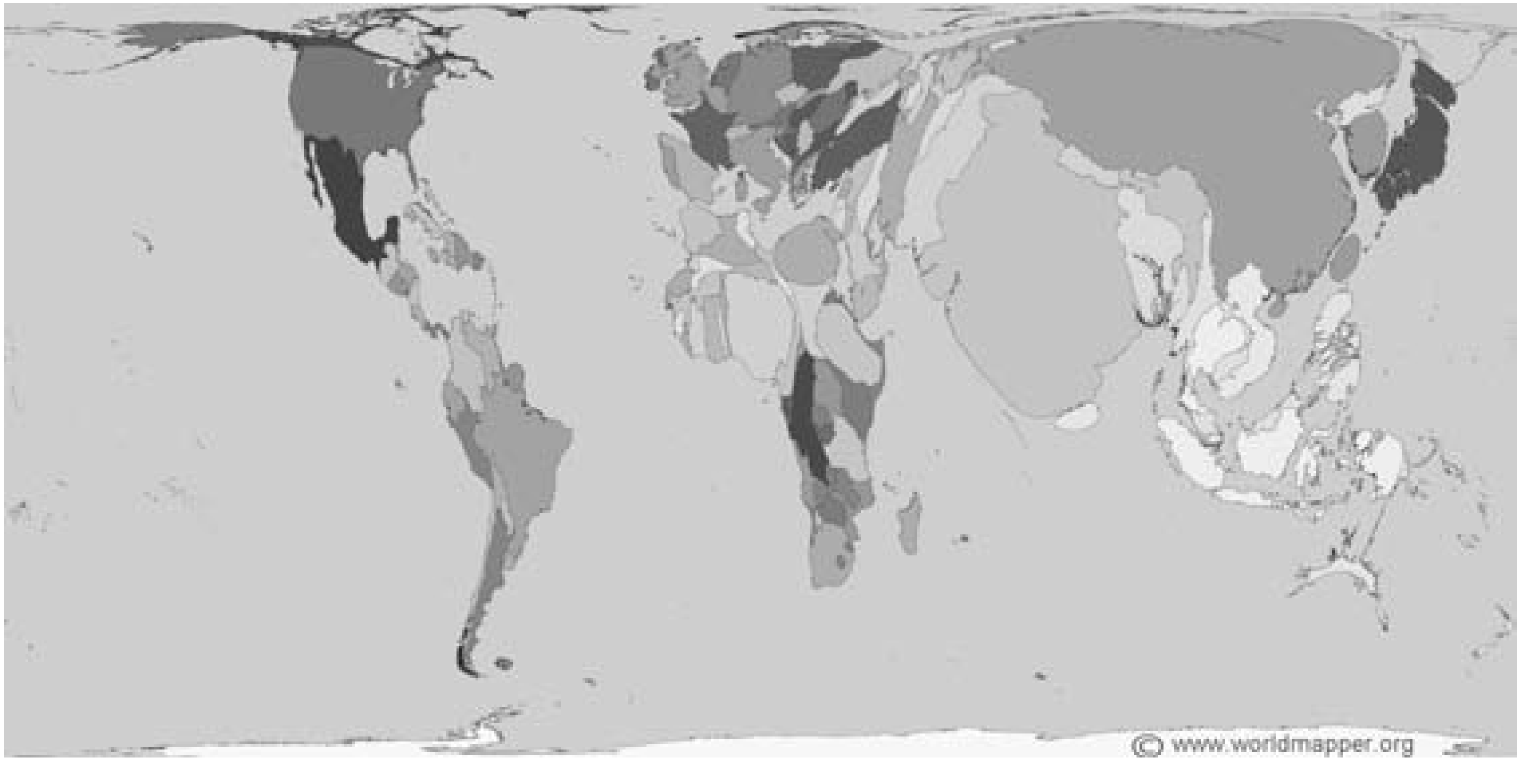


Figure 1MMT.2 Total Population as a Cartogram.

The size of each territory shows the relative proportion of the world's population living there.

Source: Copyright 2006, Social and Spatial Inequalities (SASI) Research Group (University of Sheffield) and Mark Newman (University of Michigan), www.worldmapper.org/copyright.html. Used with permission.

GIS AND MAPPING

Data display, storage, management, and manipulation have been assisted with the increasing availability of geographic information systems (GIS) over the past decade. Using digital maps and geographic information, GIS systems provide the capability to store, retrieve, display, and analyze geographic data. Most mapping and GIS packages, such as MapInfo and ESRI's popular Arc series of programs, provide the user with the quick and relatively automated ability to create and analyze maps. However, the caveat of "garbage in—garbage out" remains, as users must still consider how best to represent the data and which data to present. Changing the nature of the data to be presented, for example by replacing absolute population counts with proportional representation or a population rate, may alter the final product and its interpretation. Similarly, the seemingly mundane choice of color and data categories can result in misleading maps.[4] In addition, the imposition of boundaries between mapped units and variation in the size of the spatial units tends to create a somewhat artificial pattern. Indeed, there is a large geographical literature on the best way to represent data in graphical and map form.[5]

As an alternate to mapping, spatial analytical techniques such as kernel estimation, spatial moving averages, or kriging provide options for a smoother representation of the data that gets around issues associated with borders. Rather than limiting data representation to specific boundaries (such as census tracts or counties), which can result in a biased interpretation since it frequently appears that the value of interest suddenly changes at the boundary, these methods typically work by essentially averaging data over some defined geographic area, and can be found in many popular GIS and mapping programs, as well as more specialized spatial analysis programs such as R, S-Plus, CrimeStat, and GeoDa.[6] These programs are also able to perform more complex analyses that enable understanding and modeling of underlying geographical trends and testing for the presence of autocorrelation, or geographical correlation over space.

METHODS, MEASURES, AND TOOLS: POPULATION ESTIMATES AND PROJECTIONS

Population geographers and demographers are frequently called upon to provide population estimates or projections.[1] Although these two terms are frequently used interchangeably, they differ in important ways. For instance, a *population estimate* is a calculation of the size of a population for a year between census periods or for the current year. Estimates are frequently based on existing census numbers; components of population change such as migration, fertility, and mortality; and other information that reflects changes in population, which may be derived from employment information, postal location, or tax records. *Population projections* are calculations of population size for a future point in time.[2] Information on past, present, and future population size can be used to project the population. In both cases, the accuracy of estimation and projection tools is based on the rules and assumptions of the methods used.

POPULATION ESTIMATES

We can consider the estimation of a population between census periods, using the following

$$P_{t+x} = P_t + B_{t,t+x} - D_{t,t+x} + M_{t,t+x}$$

where P_{t+x} is the population to be estimated at time $t + x$, P_t is the beginning period population, $B_{t,\, t+x}$ is the number of births between t and $t + x$, D is the number of deaths, and M is population change due to migration (international migration and domestic migration if the projection is for a subnational scale) over the same period. In effect, this equation is simply a "residual method" seen elsewhere in this text—the difference in population size over a period of time reflects the demographic processes that occur. However, not all of this information may be available, and estimates may be required. For instance, as most governments do not collect emigration statistics, net international migration (total immigration minus total emigration) would not be available, and estimates of emigration would be required.

Alternatively, midyear population estimates may be made as a simple average between two known years

$$P_e = P_1 + \frac{n}{N}(P_2 - P_1)$$

where P_e is the estimated population size; P_1 and P_2 are the known beginning-of-period and end-of-period population sizes, respectively; n is the number of months from the P_1 census to the date of the estimate; and N is the number of months between the P_1 and P_2 censuses. This method assumes constant (linear) growth between the two census periods, and provided that the period between the two census intervals is relatively small, yields an acceptable population estimate.

A third technique is to apply a known (or estimated) rate of population growth to a population, such that

$$P_e = P_2 - r\,[(P_2 - P_1)/t]$$

where t represents the number of years between the censuses and r is the population growth rate, defined as follows (where ln refers to the natural logarithm).

$$r = [\ln(P_2 / P_1)\,] / t$$

While relatively simple, these methods are also problematic in their inherent assumption of linear population change. In fact, the assumption that population change is smooth is not supported within the literature, given that population mobility has frequently been tied to both short-term and long-term economic events. Moreover, the reliability of such estimates decreases (1) at smaller geographic scales, either because of less reliable data or because they are more subject to short-term shifts in population and (2) with longer periods between censuses.

POPULATION PROJECTIONS

Population projections use past and current census information to project future population size. Projections can be as simple as an extrapolation of current population trends into the future. That is, for example, if we know the population for several past census periods, we can roughly fit a line into the future to project the population. A similar approach is to assume that the current population growth rate can be applied to project the population forward, as follows.

$$P_{t+10} = P_1 + rP_1$$

It should be noted that the above equation assumes that the growth rate, r, is based on a ten-year period (i.e., $n = 10$), with the resulting projection ten years into the future. The projection period can be adjusted to fit other time frames. Nonlinear growth (i.e., exponential, where the population curves upward over time) can also be considered, such as follows.

$$P_{t+10} = P_1 (1+r)^n$$

A related projection technique is to use regression analysis. The advantage of this method is that multiple historical census figures can be used in the analysis, and the analyst can also pursue nonlinear representations of population growth.

While these methods may provide a useful and "rough-and-ready" short-term projection, they do not reference population processes, and are therefore subject to the same problems as discussed with population estimates, namely that the growth rate, r, is valid into the future.

Oftentimes, these methods are used to project populations for some total population, such as a country or state. They can also be applied to multiple subpopulations, which raise an interesting accounting issue. Suppose, for instance, that you have been requested to project the future populations of each state and that you know the overall national population. However, addition of each state population to find the national population would more than likely yield a national estimate that was different from the known estimate, meaning that the estimated state populations would need to be rescaled. This can be done through, for example, apportionment. In this case, the projected state populations can be multiplied by the known (current) state share of population. This is, however, a largely unsatisfactory measure, as it assumes that the proportional distribution of the population does not change over time.

Overall, these simple projection tools require limited information, yet can assist in projecting the total population of a region. They do, however, come with drawbacks. First, they do not distinguish the components of population change, such as fertility, mortality, and migration, separately. Second, information about the age and gender structure of a population is frequently required, and these tools generally do not provide this level of detail. Third, the methods presented above assume that past trends will continue into the future, although short-term and long-term changes to the economy and changing personal preferences can influence future population structures.

COHORT COMPONENT MODELS

As a partial response to the criticisms of the above projection methods, we can turn to cohort component models. These models typically allow age-sex disaggregation of the population, along with the consistent estimation of regional populations and the total population. Two principal concepts underlie the cohort component method. First, the population is typically divided into age and sex cohorts of like individuals. Second, the models focus upon components of change, with the population of each cohort subjected to fertility, mortality, and migration processes that advance the population and change its structure.

Assuming first a single-region cohort component model with no migration, the model can be defined using matrix notation as

$$\mathrm{p}(t + \mathrm{n}) = \mathrm{G}^{\mathrm{n}}\mathrm{p}(t)$$

where $p(t)$ is a column vector of a age-sex groups within the population at time t, $p(t + n)$ is the projected population at time $t + n$, and G is a "growth" matrix containing birth rates and survival probabilities obtained from vital statistics. Note that birth rates are associated only with the childbearing age groups, and all rates are assumed to remain constant throughout the projection. Multiplication of G by $p(t)$ projects the population forward in time, thus "aging" and "surviving" a population over time via extrapolation.

Multiregional cohort projection models use the cohort survival concept to age individuals from one age group to the next while extending the basic model by introducing interregional migration. In a two-region system, for example, each region is linked to each other via migration flows, such that out-migration from one region defines in-migration to the other. Like basic cohort projection models, multiregional population projection models typically involve determining the starting age-region distribution and age-specific regional schedules of mortality, fertility, and migration to which the multiregional population has been subjected to during the past period. Based upon the initial population, the projection procedure is identical to that described above, with fertility, mortality, and migration rates applied to the initial population and projected into the future.

While the matrix equation remains unchanged from that presented above, each of the matrices become increasingly complex as additional regions are added. For instance, population is subdivided into age groups, with each age group further subdivided by region. The structure of the growth matrix is also altered so that the age and location of individuals can be simultaneously modeled. As in the single-region model, the growth matrix is assumed to remain constant throughout the projection period. Commonly, the length of the projection period is equated with the width of the age group. That is, if the migration interval is five years (the interval used in the US, Canadian, and Australian censuses), the age group is defined by an interval of five years, as is the projection period. Therefore, the present number of ten- to fourteen-year-olds who are subjected to the appropriate rates defines the expected number of fifteen- to nineteen-year-olds in a population five years from now. Repeated multiplication of the matrix equation projects the population further into the future, so that projecting the population fifteen years into the future ($n = 3$) may be written as follows.

$$p(t + 5n) = G^3 p(t)$$

While these models are useful short-term projection devices, projections associated with longer time horizons are questionable given the assumptions inherent within the models. Most models assume, for instance, that (1) the probability of movement between regions does not change over time; (2) the population is homogeneous, with each individual governed by the same set of probabilities; (3) the probabilities apply to a fixed time; and (4) the *Markov property* holds, which assumes that the probability of migrating between two areas is dependent only upon the current location.

Clearly, most of these assumptions are unrealistic. First, the stationarity of migration rates over the life of the projection is unlikely, given that different groups (i.e., blacks and whites, immigrants and the native-born) will have differential migration probabilities. Moreover, migration probabilities should reflect shifting economic opportunities or amenities and the general aging of the population. Second, the Markov property assumes that the probability of migration is dependent only upon the current location. In other words, previous locations and behavior do not influence current migration decisions. While simplifying the modeling task, the Markov assumption is problematic given the high mobility of most individuals. The return migration literature,[3] for example, is well documented, with returns to a "home" region invoking the importance of prior migration experiences. Despite these problems, long-term projections utilizing this method offer insight as to where the population is headed, *if* present demographic rates are to hold over the longer term.