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The Demographic Transition: Three Centuries of Fundamental Change

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Before the start of the demographic transition, life was short, births were many, growth was slow and the population was young. During the transition, first mortality and then fertility declined, causing population growth rates first to accelerate and then to slow again, moving toward low fertility, long life and an old population. The transition began around 1800 with declining mortality in Europe. It has now spread to all parts of the world and is projected to be completed by 2100. This global demographic transition has brought momentous changes, reshaping the economic and demographic life cycles of individuals and restructuring populations. Since 1800, global population size has already increased by a factor of six and by 2100 will have risen by a factor of ten. There will then be 50 times as many elderly, but only five times as many children; thus, the ratio of elders to children will have risen by a factor of ten. The length of life, which has already more than doubled, will have tripled, while births per woman will have dropped from six to two. In 1800, women spent about 70 percent of their adult years bearing and rearing young children, but that fraction has decreased in many parts of the world to only about 14 percent, due to lower fertility and longer life.[1] These changes are sketched in Table 1.

These trends raise many questions and controversies. Did population grow so

[1] With $e(0) = 27.5$, I assume that women cared for young children from ages 20 to 50, so that the fraction of adult life spent giving care is defined in terms of life table functions as $(T(20) - T(50))/T20 =$ 71 percent, where $T(x)$ is the survival weighted number of person years lived above age x. With $e(0) =$ 77.5, I assume women care for young children from ages 25 to 33, so that the fraction of adult life spent giving care is $(T(25) - T(33))/T(20) = 14$ percent.

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Table 1
Global Population Trends Over the Transition: Estimates, Guesstimates and Forecasts, 1700–2100

	Life Expectancy (Years at Birth)	*Total Fertility Rate (Births per Woman)*	*Pop Size (Billions)*	*Pop Growth Rate (%/Year)*	*Pop < 15 (% of Total Pop)*	*Pop > 65 (% of Total Pop)*
1700	27	6.0	.68	0.50	36	4
1800	27	6.0	.98	0.51	36	4
1900	30	5.2	1.65	0.56	35	4
1950	47	5.0	2.52	1.80	34	5
2000	65	2.7	6.07	1.22	30	7
2050	74	2.0	8.92	0.33	20	16
2100	81	2.0	9.46	0.04	18	21

Source: Population numbers and growth rates for 1700 are taken from Biraben (1980) and for 1800 from United Nations (1999). The figures for TFR and $e(0)$ are best guesses by the author, consistent with the population growth rate based on Coale-Demeny (1983) Model South Female stable populations with an average age of childbearing of 31 and should not be treated as data. The figures on age distribution are likewise based on these model stable populations. Data for 1900 are from Chamie (2001), for 1950–2050 from United Nations (2003) and for 2100 from United Nations (2000).

slowly before 1800 because it was kept in equilibrium by Malthusian forces? Did mortality begin to decline because of medical progress, because of rising per capita income or for some other reason? Did fertility begin to fall because of improved contraceptive technology and family planning programs, or were couples optimizing their fertility all along and reduced it in response to changing economic incentives? Are we approaching a biological limit to life expectancy, or can we expect to see continuing or even accelerating longevity gains? Some predictions suggest that global fertility is projected to fall to 2.0 children per woman, but in Europe it has been only 1.4 for some time, and in east Asia it is 1.8; why should we expect fertility decline to stop at 2.0? Low fertility and increasing longevity cause a dramatic change in the population age distribution, with a ten-fold increase in the ratio of elderly to children. Will the societal costs of the elderly be catastrophic? In the past, there has been great concern that rapid population growth in third-world countries would prevent economic development, but most economists have downplayed these fears. Similarly, environmentalists fear that world population is already above the carrying capacity of the biosphere, while most economists are complacent about the projected 50 percent increase in population over this century. In this paper, I will describe these demographic changes in greater detail, and I will also touch on these questions and controversies.

Before the Demographic Transition

According to a famous essay by Thomas Malthus, first published in 1798, slow population growth was no accident. Population was held in equilibrium with the slowly growing economy. Faster population growth would depress wages, causing mortality to rise due to famine, war or disease—in short, misery. Malthus called this mortality response the "positive" check. Depressed wages would also cause postponement of marriage, resulting in prostitution and other vices, including contraception; this he called the "preventive" check. Since population could potentially grow more rapidly than the economy, it was always held in check by misery and vice, which were therefore the inevitable human lot. Economic progress could help only temporarily since population could soon grow to its new equilibrium level, where misery and vice would again hold it in check. Only through moral restraint—that is, the chaste postponement of marriage—did Malthus believe that humanity might avoid this fate, and he thought this an unlikely outcome.

For preindustrial Europe at least, Malthus seems to have been right. Population was held weakly in equilibrium by the positive and preventive checks. When weather, disease or political disturbance knocked population out of equilibrium, real wages and rents reacted strongly (Lee, 1987, 1997; Lee and Anderson, 2002), and the checks brought population slowly back to equilibrium.

In western Europe in the centuries before 1800, marriage required the resources to establish and maintain a separate household, so age at first marriage for women was late, averaging around 25 years, and a substantial share of women never married (Flinn, 1981, p. 84; Livi-Bacci, 2000, pp. 99–107). Although fertility was high within marriage, the total fertility rate (TFR) was moderate overall at four to five births per woman (Livi-Bacci, 2000, p. 136). Mortality was also moderately high, with life expectancy at birth between 25 and 35 years (Flinn, 1981, pp. 92–101; Livi-Bacci, 2000, pp. 61–90),[2] but this was heavily influenced by high mortality in infancy and childhood. Population growth rates were generally low, averaging 0.3 percent/year before 1700 in western Europe, but sometimes rising above 1 percent in the nineteenth century.[3] In Canada and the United States, marriage was much earlier because land was abundant, and population at first grew rapidly, but then decelerated in the nineteenth century.

Outside of Europe and its offshoots, fertility and mortality were higher in the pretransitional period, and change in fertility and mortality came later. Data on mortality or fertility are only occasionally available for third-world countries before World War II (Preston, 1980). In India in the late nineteenth century, life expectancy averaged in the low 20s and was highly variable, while fertility was six or seven

[2] The Total Fertility Rate is the sum across all ages of the birth rates at each age and, therefore, measures the total number of births a surviving woman would have over her reproductive life, either actually for a generation of women or hypothetically for a given calendar year, which is the more common usage. Life expectancy at birth is the average age at death for an actual generation or hypothetically the average age at death implied by the age-specific death rates in a given calendar year, which is the more common usage.

[3] A population with a Total Fertility Rate of 4.5 and life expectancy at birth of 30 grows at 0.5 percent per year (based on Coale-Demeny, 1983, stable population models with a mean age of childbearing of 31).

births per woman (Bhat, 1989). In Taiwan, the picture was similar around 1900. Widespread data on fertility for the decades after World War II confirm that total fertility rates in the third world were typically six or higher. However, recent work suggests that the demographic situation in China may have been closer to the European experience than previously thought (Lee and Feng, 1999).

Although pretransitional fertility was typically high in third-world countries, its levels were far below the hypothetical biological upper limit for a population (as opposed to an individual), which is around 15 to 17 births per woman (Bongaarts, 1978). The contraceptive effects of prolonged breastfeeding, often combined with taboos on sex while breastfeeding, led to long birth intervals and reduced fertility. Abortion was also important, and sometimes the practice of coitus interruptus had an important effect. In some settings, marriage patterns also limited fertility, although not as strongly as in western Europe.

At the aggregate level, population growth throughout the regions of the world was slow over the past millennium, but there was a puzzling similarity in long swings about the growth path, such as stagnation in the fourteenth and seventeenth centuries and more rapid growth in the fifteenth and eighteenth centuries. While exchanges of disease through exploration and trade may have played some role, global climatic change was probably the main driving force (Galloway, 1986).

Mortality Declines, Fertility Declines and Population Growth

The classic demographic transition starts with mortality decline, followed after a time by reduced fertility,[4] leading to an interval of first increased and then decreased population growth and, finally, population aging. I will consider these major stages in turn.

Mortality Declines

The beginning of the world's demographic transition occurred in northwest Europe, where mortality began a secular decline around 1800. In many low-income countries of the world, the decline in mortality began in the early twentieth century and then accelerated dramatically after World War II.

The first stage of mortality decline is due to reductions in contagious and infectious diseases that are spread by air or water. Starting with the development of the smallpox vaccine in the late eighteenth century, preventive medicine played a role in mortality decline in Europe. However, public health measures played an important role from the late nineteenth century, and some quarantine measures may have been effective in earlier centuries. Improved personal hygiene also helped as income rose and as the germ theory of disease became more widely

[4] There are cases in which fertility declined first, notably the United States and France.

known and accepted. Another major factor in the early phases of growing life expectancy is improvements in nutrition. Famine mortality was reduced by improvements in storage and transportation that permitted integration of regional and international food markets, smoothing across local variations in agricultural output. Secular increases in incomes led to improved nutrition in childhood and throughout life. Better-nourished populations with stronger organ systems were better able to resist disease. Life expectancy is still positively associated with height in the industrial country populations, plausibly reflecting childhood health conditions (Fogel, 1994; Barker, 1992).

The high-income countries of the world have largely attained the potential mortality reductions due to reductions in infectious disease and increases in nutrition. In recent decades, the continuing reduction in mortality is due to reductions in chronic and degenerative diseases, notably heart disease and cancer (Riley, 2001). In the later part of the century, publicly organized and funded biomedical research has played an increasingly important part, and the human genome project and stem cell research promise future gains.

Many low-income populations did not begin the mortality transition until some time in the twentieth century. However, they then made gains in life expectancy quite rapidly by historical standards. In India, life expectancy rose from around 24 years in 1920 to 62 years today, a gain of .48 years per calendar year over 80 years. In China, life expectancy rose from 41 in 1950–1955 to 70 in 1995–1999, a gain of .65 years per year over 45 years. Such rapid rates of increase in low-income countries will surely taper off as mortality levels approach those of the global leaders.

There is a range of views on where mortality is headed during the coming decades. On the optimistic side, Oeppen and Vaupel (2002) offer a remarkable graph that plots the highest national female life expectancy attained for each calendar year from 1840 to 2000. The points fall close to a straight line, starting at 45 years in Sweden and ending at 85 years in Japan, with a slope of 2.4 years per decade. If we boldly extend the line forward in time, it reaches 97.5 years by mid-century and 109 years by 2100.

Less optimistic projections are based on extrapolation of trends in age-specific death rates over the past 50 or 100 years. This approach implies more modest gains for the high-income nations of the world, with average life expectancy approaching 90 years by the end of the twenty-first century (Lee and Carter, 1992; Tuljapurkar, Li and Boe, 2000).

Oddly, some of the most pessimistic estimates of the future improvement in life expectancy come from official government projections. For example, actuaries for the U.S. Social Security Administration project life expectancy of 83 years for 2080 (sexes combined). Their projections are in line with the views of researchers who believe that it will become increasingly difficult to achieve gains as we approach biological limits to human longevity (Olshansky and Carnes, 2001). However, past projections by official government agencies of longevity gains have been systematically too low relative to actual outcomes (Keilman, 1997; National Research Council, 2000). Indeed, old-age mortality has been declining at an accelerating rate in recent decades (Kannisto, Lauritsen, Thatcher and Vaupel, 1994). It is at the younger ages that declines have been slower.

For a closer look at mortality trends, it is convenient to use the United Nations classification of countries according to their recent economic development status as More Developed Countries, Less Developed Countries and Least Developed Countries. The More Developed Countries, with 1.2 billion people, include all of Europe, plus North America, Japan, Australia and New Zealand. The Least Developed Countries, with 0.7 billion, include most of sub-Saharan Africa, plus Bangladesh, Cambodia and a few other countries. All other countries are Less Developed, including India, China and the bulk of the world's population—4.2 billion people.[5] One can question the relevance of using membership based on recent experience to categorize groups of countries in earlier periods or far in the future, but on net, this division seems useful.

Figure 1 plots global trends in life expectancy since 1950 and U.N. projections to 2050. For the Least Developed Countries, life expectancy rises from 35.7 years in 1950–1954 to 48.7 years in 1995–1999, or .29 years per year. For the Less Developed Countries, the increase has been from 41.8 to 65.4 years, or .52 years per year; a very rapid increase, indeed. For the More Developed Countries, the increase has been from 66.1 to 74.8, or .19 years per year.[6]

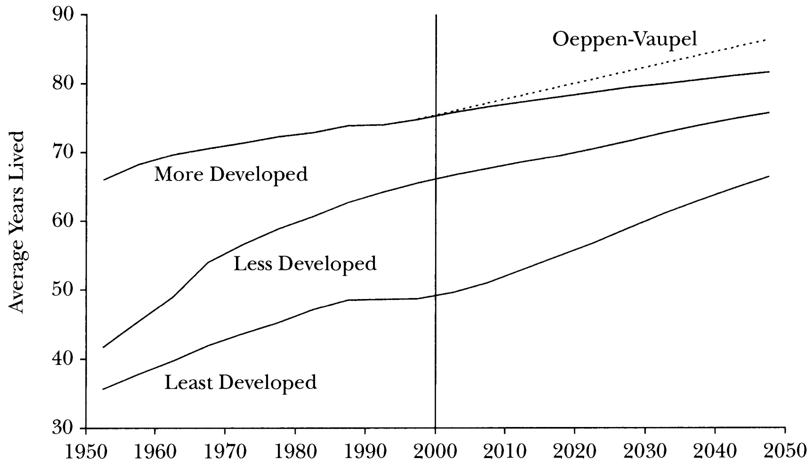
While the overall increase in life expectancy is marked, two recent countervailing trends deserve mention. Figure 1 shows a stagnation in mortality gains for the Least Developed Countries in the 1990s, reflecting increasing mortality from HIV/AIDS in sub-Saharan Africa. In the past 20 years, more than 60 million people have been infected by HIV/AIDS worldwide, of whom 40 million are still alive. Of these cases, only 6 percent are in More Developed Countries, while in sub-Saharan Africa, HIV/AIDS has become the leading cause of death. The United Nations projects that in some African countries, more than two-thirds of children aged 15 years in 2000 will become infected with HIV/AIDS before they reach 50 years of age (United Nations, 2002). For the 35 countries in Africa most affected, life expectancy at birth has been reduced on average by 6.5 years in the late 1990s, an effect that is projected to rise to 9.0 years in 2000–2005.

The other main exception to the generally favorable recent trends in mortality is found in countries of eastern Europe and former territories in the Soviet Union, which have experienced stagnating or declining life expectancy over the past two or three decades, predating the difficulties of the transition to market economies.

[5] In U.N. terminology, the Less Developed Countries include the Least Developed Countries as a subset unless otherwise indicated. In this paper, however, these categories are mutually exclusive.

[6] In this figure, the Oeppen-Vaupel extension starts at the life expectancy level of the average sexes combined in the More Developed Countries rather than that of females in Japan and, consequently, only reaches 86.9 by mid-century instead of the 97.5 referred to earlier in the text.

Figure 1
Past and Projected Life Expectancy at Birth, by Major Development Groups, 1950–2050



Sources: Historical and Middle Series forecasts are taken from United Nations (2003). Record life expectancy trend is taken from Oeppen and Vaupel (2002).

Male life expectancy in the Russian Federation is now 60 years, equal to its level in the early 1950s (United Nations, 2002) and similar to that of India; Russian women have done somewhat better.

As longevity has increased, the female advantage in life expectancy has also risen. In the More Developed Countries, the sex gap in life expectancy has increased from 5.0 years in the early 1950s to 7.4 years today. In the Less Developed Countries, it has grown from 1.7 years to 3.6 years today. In the More Developed Countries, these trends are partly explained by the later date at which women took up smoking, and we can expect some reversal of the growing gap, as is now happening in the United States, where smoking-related deaths of women were rising rapidly from 1975 to 1995, while they fell rapidly for men (Pampel, 2002, pp. 98–99). The sex difference in life expectancy causes an increasing ratio of women to men at older ages and, combined with a younger female age at marriage, causes a disproportionate number of widows. Worldwide, there are 76 percent more women than men at ages 80 to 89, and there are five times as many women as men over 100 (United Nations, 2002, p. 196).

Fertility Transition

Between 1890 and 1920, marital fertility began to decline in most European provinces, with a median decline of about 40 percent from 1870 to 1930 (Coale and Treadway, 1986, p. 44). The preceding decline in mortality may have been partly responsible, although it cannot explain the timing.

Most economic theories of fertility start with the idea that couples wish to have a certain number of surviving children, rather than births per se. If this assumption holds, then once potential parents recognize an exogenous increase in child survival, fertility should decline. However, mortality and fertility interact in complicated ways. For example, increased survival raises the return on postbirth investments in children (Meltzer, 1992). Some of the improvement in child survival is itself a response to parental decisions to invest more in the health and welfare of a smaller number of children (Nerlove, 1974). These issues of parental investment in children suggest that fertility will also be influenced by how economic change influences the costs and benefits of childbearing.

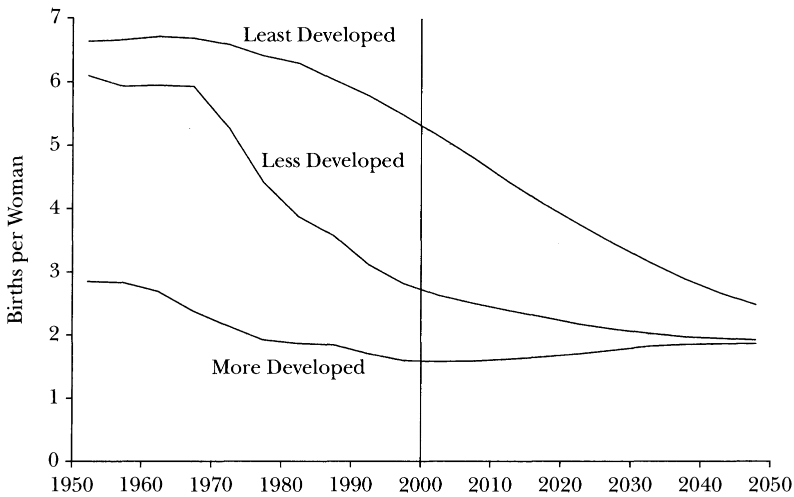
Bearing and rearing children is time intensive. Technological progress and increasing physical and human capital make labor more productive, raising the value of time in all activities, which makes children increasingly costly relative to consumption goods. Since women have had primary responsibility for childbearing and rearing, variations in the productivity of women have been particularly important. For example, physical capital may substitute for human strength, reducing or eliminating the productivity differential between male and female labor, and thus raising the opportunity cost of children (Galor and Weil, 1996). Rising incomes have shifted consumption demand toward nonagricultural goods and services, for which educated labor is a more important input. A rise in the return to education then leads to increased investments in education. Overall, these patterns have several effects: children become more expensive, their economic contributions are diminished by school time and educated parents have higher value of time, which raises the opportunity costs of childrearing. Furthermore, parents with higher incomes choose to devote more resources to each child, and since this raises the cost of each child, it also leads to fewer children (Becker, 1981; Willis, 1974, 1994).

Beyond these tightly modeled theories of fertility, more highly developed markets and governments can replace many of the important economic functions of the traditional family and household, like risk sharing and provision of retirement income, further weakening the value of children.

The importance of contraceptive technology for fertility decline is hotly debated, with many economists viewing it as of relatively little importance. The European fertility transition, for example, was achieved using *coitus interruptus*. This debate extends from the interpretation of the past to prescriptions for current policy (Pritchett, 1994; Gertler and Molyneaux, 1994; Schultz, 1994).

Figure 2 plots fertility for countries by development status since 1950, with United Nations projections to 2050. The transition in the More Developed Countries occurred before this chart begins. Thus, for the More Developed Countries, the chart reflects their baby booms and busts after World War II, followed by what is sometimes called the "second fertility transition," as fertility fell far below replacement level in many industrial nations (Van de Kaa, 1987). The Less Developed Countries began the fertility transition in the mid-1960s or somewhat later. Fertility transitions since World War II have typically been more rapid than those for the

Figure 2
Past and Projected Total Fertility Rate by Major Development Groups, 1950–2050



Source: Historical and Middle Series forecasts are taken from United Nations (2003).

current More Developed Countries, with fertility reaching replacement in 20 to 30 years after onset for those countries that have completed the transition. Fertility transitions in east Asia have been particularly early and rapid, while those in south Asia and Latin America have been much slower (Casterline, 2001). In the 25 years between 1965 and 1990, their total fertility rate fell from six children per woman to three. The Least Developed Countries started from a slightly higher initial level of fertility and started their fertility transition later. By now, it is clear that they, too, have begun the transition, and the question about their fertility transition is no longer "whether," but rather "how far" and "how fast."

Currently, 60 countries with 43 percent of the world's population have fertility at or below the replacement level of 2.1 children per woman. Of these, 43 are More Developed Countries, but 17 are Less Developed Countries. The total fertility rate has fallen well below replacement for almost all the industrialized countries and for many countries of east Asia, including Taiwan, south Korea and China.

When fertility declines, it declines most at the youngest and oldest ages and becomes concentrated in the 20s and early 30s. Currently, two-thirds of childbearing occurs between ages 20 and 35 in the Least Developed Countries, whereas 80 percent occurs in this age range in the More Developed Countries. Birth rates above age 35 are only one-seventh as high in the More Developed Countries as in the Least Developed Countries and only one-fifth as high below age 20. Despite this general reduction in fertility at older ages, age at first marriage and first birth are generally moving to older ages throughout the industrial and much of the developing world. The rising age of childbearing itself depresses the total fertility rate, which is a synthetic cohort measure, below the underlying completed fertilities of generations. When the average age of childbearing stops rising, as it must sooner or later, the total fertility rate should increase to this underlying level. In many countries of Europe, women's mean age at birth of the first child has been rising by 0.1 to 0.4 years of age per calendar year in recent decades, distorting the total fertility rate downward by 10 to 40 percent relative to the eventual completed fertility of generations (Bongaarts, 2001).

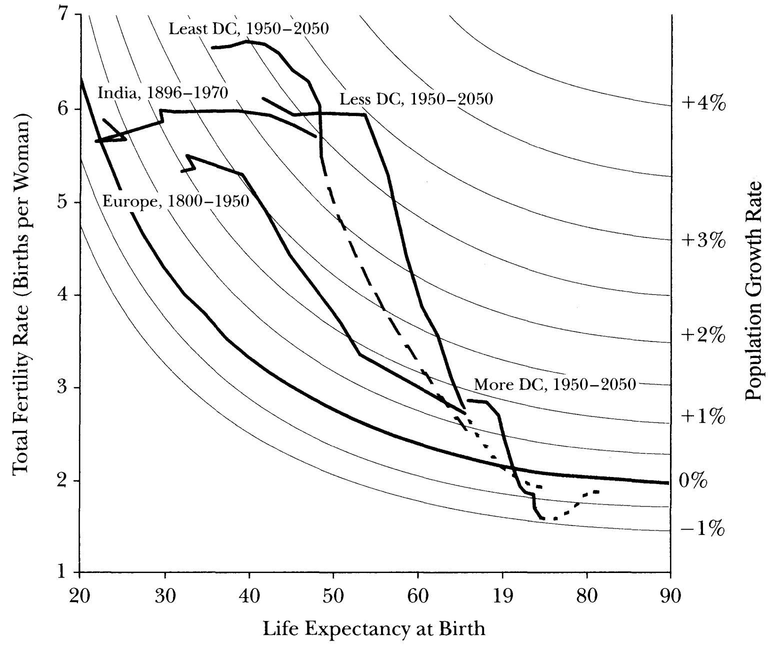
The U.N. fertility projections in Figure 2 show a continuing slow transition in sub-Saharan Africa and the other Least Developed Countries, while fertility decline for the Less Developed Countries decelerates as it approaches replacement level. The fertility of the More Developed Countries is projected to return toward replacement levels. These projections are plausible, but fertility has proven very difficult to forecast in the past. Most of the theories of fertility, as well as the experience of the More Developed Countries, imply that the demand for children will continue to decline in the future. But these theories point to no natural lower bound for fertility. Nor do they provide a mechanism for fertility to respond to economic signals in such a way that population would equilibrate, as I have argued it did in the preindustrial past. In much of the world, fertility has in fact fallen to levels well below the 2.1 births per woman that would just replace one generation by the next, and it is not yet clear whether it will fall farther, rebound toward replacement or stay at current levels.

Population Growth

The combination of fertility and mortality determines population growth, as shown in Figure 3. The horizontal axis of the figure shows life expectancy at birth. The vertical axis shows the total fertility rate. The contours illustrate the steady-state population growth rate corresponding to constant fertility and mortality at the indicated level, where the dark contour represents zero population growth and movement toward the upper right corner indicates increasingly rapid growth. (Caveat: Steady-state growth rates will differ from actual growth rates due to evolutions in the age distribution and to net migration.) On this graph, the demographic transition will first appear as a move to the right, representing a gain in life expectancy with little change in fertility and a movement to a higher population growth contour, then, as a diagonal downward movement toward the right reflecting the simultaneous decline in fertility and mortality, recrossing contours toward lower rates of growth.

Between 1950 and 2050, the actual and projected trajectories for the More, Less and Least Developed Countries are plotted. To add more historical depth, I have added two historical trajectories. One is a trajectory for Europe from 1800 to 1950. The end point of this trajectory in 1950 is quite close to the start point for the more developed countries. I have also added the trajectory for India from 1896 to 1970, illustrating the earlier stages of the demographic transition that are missing for the Less and Least Developed Countries before 1950.

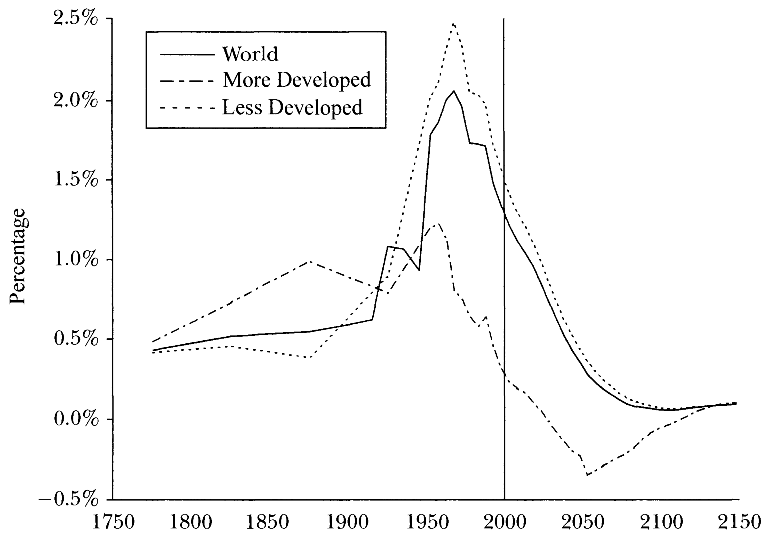
Figure 3
Life Expectancy and Total Fertility Rate with Population Growth Isoquants: Past and Projected Trajectories for More, Less and Least Developed Countries



Sources: Historical and Middle Series forecasts for Least, Less and More Developed Countries are taken from the United Nations (2003). Data for India are taken from Bhat (1989) for the period 1891–1901 to 1941–1951, and from the United Nations (2003) for the period 1950–1970. Data for Europe are based on Tables 6.2–6.5 in Livi-Bacci (2000) for the period 1800–1900 and Mitchell (1975) for the period 1900–1950. For the period 1800–1900, European total fertility rate and $e(0)$ are derived as a population-weighted average of country-specific data. Where unavailable, these data are estimated based on regression using the crude birth rate and death rates to predict total fertility rate and $e(0)$, respectively, for other European countries in this period. For the period 1900–1950, a single series of crude birth rates and death rates for all Europe are assembled. A regression based on data from 1900 to 1950 is used to predict total fertility rate and $e(0)$ based on the crude birth rate and death rate, respectively. The growth isoquants are derived from Coale and Demeny (1983) using the Model West Female life table when the mean age of childbearing is 29.

The starting points of these demographic paths differ somewhat. India had higher initial fertility and mortality than Europe, as did the Least Developed Countries relative to the Less Developed Countries in 1950, which in turn had far higher mortality and fertility than the More Developed Countries in that year. Except for India, the starting points all indicate moderate (for Europe) to rapid (for Least and Less Developed Countries) population growth. But in all cases, the initial path is horizontally to the right—most strikingly for India—indicating that mortality decline preceded fertility decline, causing accelerating population growth

Figure 4
Population Growth Rates, 1750–2150



Source: The population growth rates are calculated as instantaneous (exp(rt)) rates based on population data. The data for 1750–1950 are taken from Tables 1 and 2 of United Nations (1999) and for 1950–2150 are taken from United Nations (2000).

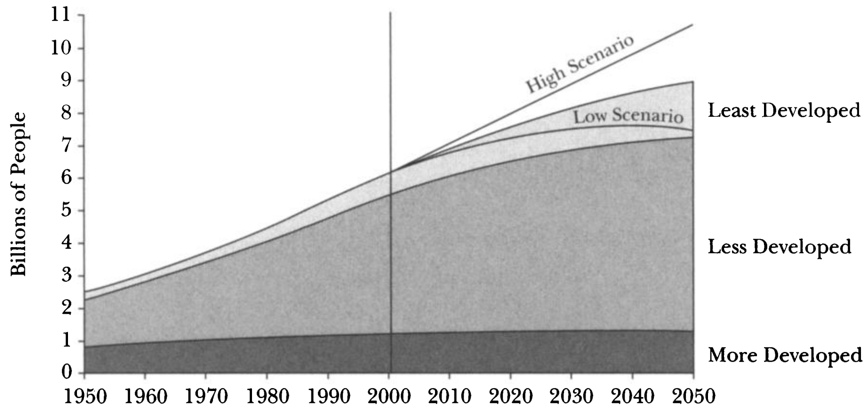
approaching 3 percent for the Less and Least Developed Countries. After fertility begins to decline, the trajectories slope diagonally down toward the right, recrossing contours toward lower rates of population growth. Europe briefly attains 1.5 percent population growth, but then fertility plunges, a decline picked up after 1950 by the group, ending with population decline at 1 percent annually. However, the actual European population growth rate is very near zero: slightly higher than hypothetical steady-state growth rate due to changes in the age distribution and in immigration. All three groups are projected to approach the zero-growth contour by 2050, the More Developed Countries from below and the Less and Least Developed Countries from above.

There has been rapid global convergence in fertility and mortality among nations over the past 50 years, although important differences remain. This convergence of fertility and mortality is in marked contrast to per capita GDP, which has tended to diverge between high-income and low-income countries during this time. Today, the median individual lives in a country with a total fertility rate of 2.3—barely above the 2.1 fertility rate of the United States—and a median life expectancy at birth of 68 years compared to 77 years for the United States (Wilson, 2001).

Actual trends in population growth rates can be seen over a longer time period in Figure 4. Data before 1950 for the Less Developed Countries (which here

Figure 5

Population by Major Development Groups, 1950–2050, with High and Low Scenario Forecasts for Total World Population



Source: Historical and Middle Series forecasts are taken from United Nations (2003), as are High and Low scenarios.

include the Least Developed Countries) are particularly uncertain. Population growth rates in the More Developed Countries rose about a half percent above those in the Less Developed Countries in the century before 1950. But after World War II, population growth surged in the Less Developed Countries, with the growth rate peaking at 2.5 percent in the mid-1960s, then dropping rapidly. The global population share of the More Developed Countries is projected to drop from its current 20 percent to only 14 percent in 2050. Long-term U.N. projections suggest that global population growth will be close to zero by about 2100.

Global population projections are regularly prepared by the United Nations and the U.S. Census Bureau. The method could be described as common sense, informed by careful measurement and inspection of trends and current levels and a distillation of historical patterns of decline for fertility and mortality.[7] The central current projections from the United Nations, which are consistent with some other global projections, anticipate that global population will reach 8.9 billion by 2050 and just below 9.5 billion by 2100—a 50 percent increase from its current size (see Figure 5). The National Research Council (2000, p. 213), based on a careful analysis of past forecasting errors by the United Nations, concluded that there is a 95 percent probability that the actual population in 2050 will fall between 8.2 and 10.2 billion. A comparable analysis cannot be done for the 2100 forecasts, but the

[7] The methods, problems and performance of these projections, as well as earlier ones by the World Bank, are described and analyzed in a recent report from the National Academy of Sciences (National Research Council, 2000).

United Nations' high-low range extends over a very wide interval from 5.2 to 16.2 billion. This great uncertainty must be kept in mind when considering all the projections of fertility, mortality and population size for the twenty-first century.

The population projection for the More Developed Countries population is nearly flat, with population decrease in Europe and Japan offset by population increase in the United States and other areas. Most of the projected population increase takes place in the Less Developed Countries, which gain 1.8 billion, or 43 percent. However, the greatest proportional gain comes in the Least Developed Countries with their higher fertility and more rapid growth. These countries gain 1 billion in population, or 151 percent. The relative shares of the three groups will change a good deal over the next 50 years.

Shifts in Age Distribution: The Last Stage of the Demographic Transition

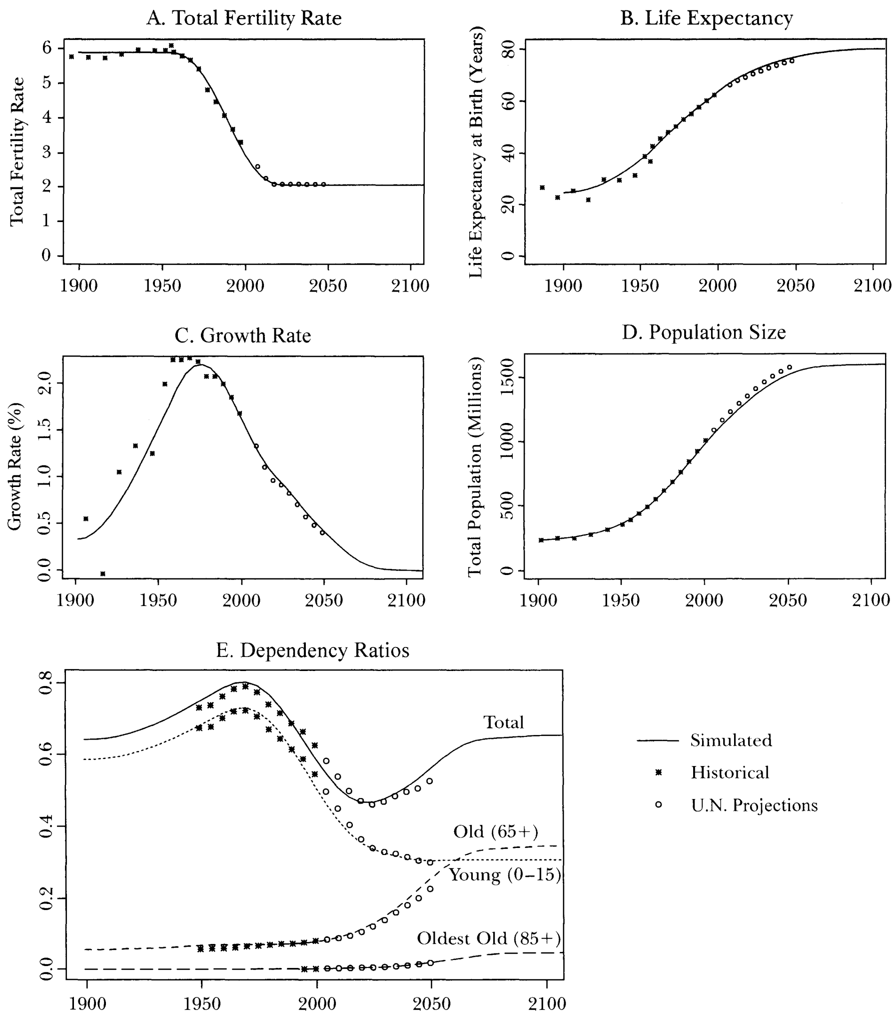
The patterns of change in fertility, mortality and growth rates over the demographic transition are widely known and understood. Less well understood are the systematic changes in age distribution that are an integral part of the demographic transition and that continue long after the other rates have stabilized.

A Classic Example: The Case of India

The panels of Figure 6 display a classic demographic transition, using India as an example. The starred points in the figures are actual data from India from 1896 to 2000. The hollow points are based on the U.N. projections for India's mortality, fertility and population up through 2050. The lines in Panels A and B are simple analytic functions fit to the historic fertility and mortality data, and the lines in the other panels are simulated based on these and the initial population.[8] In India, the pretransitional total fertility rate is about six births per woman (Panel A), and life expectancy is about 25 years (Panel B). India's mortality decline leads its fertility decline by 50 years. The fertility transition here is slow relative to East Asia's, but similar to Latin America's. These trends interact to create a population growth rate that rose from less than 0.5 percent per year in 1900 to more than 2 percent per year by 1950 before starting to decline (Panel C). India's total population quadrupled in the twentieth century and is projected to increase by another 60 percent in the twenty-first century, with the growth rate of the population leveling out to near zero by 2100 (Panel D).

[8] The total fertility rate is modeled as a quintic trajectory, declining from 5.9 in 1953 to 2.1 in 2025. Mortality is modeled using the Lee and Carter (1992) mortality index k, which is fit to a sinusoidal path, with life expectancy going from 24.7 in 1900 to 80.0 in 2100. Many other curves could equally well have been used.

Figure 6
A Classic Demographic Transition: Actual and Projected for India and Simulated, 1900–2100



Notes: The simulation is based on a fertility transition in which the total fertility rate follows a quintic path declining from 5.9 in 1953 to 2.1 in 2025 and a mortality transition in which the mortality index follows a sinusoidal path as *e*(0) increases from 24.7 in 1900 to 80.0 in 2100.
Sources: Actual India data for the period 1891–1901 to 1941–1951 are taken from Bhat (1989). Actual and projected data are taken from United Nations (2003).

But the focus here is on shifts in the age distribution that result from the demographic transition. These shifts can be seen in the "dependency ratios," which take either the younger or the older population and divide by the working-age population. For example, the child dependency ratio is the population aged 0–14 divided by the population aged 15–64.[9] The old-age dependency ratio is usually defined as the number of those 65 and older divided by the population aged 15–64. The "oldest old" dependency ratio looks at those 85 years and older, divided by the working age population. Finally, the total dependency ratio takes the sum of the population under 15 and over 65 and divides it by the population in the intermediate range of 15–64.

In the first phase of the transition, when mortality begins to decline while fertility remains high, mortality declines most at the youngest ages, causing an increase in the proportion of children in the population and raising child dependency ratios, as shown in Panel E. Thus, counter to intuition, mortality decline initially makes populations younger rather than older in a phase that can last many decades and here lasts 70 years. During this phase, families find themselves with increasing numbers of surviving children. Both families and governments may struggle to achieve educational goals for the unexpectedly high number of children.

Next, as fertility declines, child dependency ratios decline and soon fall below their pretransition levels. The working-age population grows faster than the population as a whole, so the total dependency ratio declines. This second phase may last 40 or 50 years. Some analysts have worried that the rapidly growing labor force in this phase might cause rising unemployment and falling capital labor ratios (Coale and Hoover, 1958). Others have stressed the economic advantages of having a relatively large share of the population in its working years, calling these a demographic gift or bonus (Williamson and Higgins, 2001; Bloom, Canning and Malaney, 2000). In India, the bonus occurs between 1970 and 2015. If income per person of working age is unaffected, the decline in dependents per worker would by itself raise per capita income by 22 percent, adding 0.5 percent per year to per capita income growth over the 45-year span. There is considerable controversy about whether this demographic bonus really affects economic development, continuing debates from the 1980s (National Research Council, 1986; Kelley, 1988; Birdsall, Kelley and Sinding, 2003).

In a third phase, increasing longevity leads to a rapid increase in the elderly population while low fertility slows the growth of the working-age population. The old-age dependency ratio rises rapidly, as does the total dependency ratio. In India, this phase occurs roughly between 2015 and 2060—and it would last longer if mortality decline were not assumed to cease in the simulation. If the elderly are supported by transfers, either from their adult children or from a public sector pension system supported by current tax revenues, then a higher total dependency ratio means a greater burden on the working-age population. To the extent that the

[9] In some studies, the boundary for childhood is taken to be 18 or 20, and for working ages it may be taken to be 60. Any boundary is arbitrary, as is the equal weighting of children and elders in forming these ratios.

elderly contribute to their own support through saving and asset accumulation earlier in their lives and dissave in retirement, population aging may cause lower aggregate saving rates as life cycle savings models and some empirical analyses suggest (Williamson and Higgins, 2001; Lee, Mason and Miller, 2000; but also see Deaton and Paxson, 2000). Nonetheless, even with lower savings rates the capital/labor ratio may rise, since the labor force is growing more slowly (Cutler et al., 1990; Lee et al., 2000). This pattern of saving and wealth accumulation may arise either through individual life cycle savings or institutional requirement, as in Singapore. The net effect would then be to stimulate growth in labor productivity due to capital deepening.

At the end of the full transitional process for India shown in Figure 6, the total dependency ratio is back near its level before the transition began, but now child dependency is low and old-age dependency is high. Presumably, mortality will continue to decline in the twenty-first century, so that the process of individual and population aging will continue. No country in the world has yet completed this phase of population aging, since even the industrial countries are projected to age rapidly over the next three or four decades. In this sense, no country has yet completed its demographic transition.

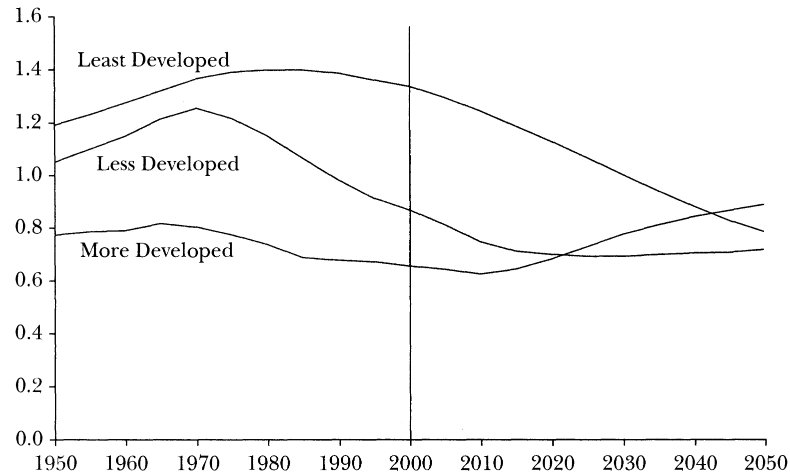
The Transition in Age Distribution by Current Development Category

The past and projected Total Dependency Ratios for the Least, Less and More Developed Countries are shown in Figure 7; that is, the sum of the population under 15 and over 65 years divided by the population in the intermediate range of 15–64 years. Remember that even in 1950, the Least Developed Countries had higher fertility and higher mortality than the Less Developed Countries, and change since then has been slower for them. The Least Developed Countries moved slowly out of the phase of rising youth dependency and entered the bonus phase around 1980. For these countries, the total dependency ratio is projected to fall sharply from 2000 to 2050. At the same time, the median age is projected to rise by nine years by 2050, from 18.1 to 27.1 years.

The Less Developed Countries entered the bonus phase earlier, around 1970, and will finish it around 2020, after which the total dependency ratio will be rather flat, since declining child dependency will offset rising old-age dependency. Their median age is projected to rise strongly by 13.3 years between 2000 and 2050, from 25.2 to 38.5 years.

The More Developed Countries are out of the bonus phase and have already aged considerably. They already have the median age that the Less Developed Countries are projected to achieve by 2050, at which time the median age in the More Developed Countries will have risen another eight years to 45.2 years. The total dependency ratio in the More Developed Countries is projected to rise sharply over the next 50 years as their low fertility increasingly affects labor force size and the baby boom generations move into old age.

Figure 7
Total Dependency Ratio by Level of Development, 1950–2050



Source: Historical and Middle Series forecasts are taken from United Nations (2003).

Lower Fertility or Longer Life Expectancy?

Both low fertility and longer life contribute to the aging of the population. But the implications of these factors for causes of shifts in the population distribution and for how society might react to the aging of the population are rather different.

When population aging is due to declining fertility, it raises the share of the elderly population without altering the remaining life expectancy (or the health status or vigor) of older individuals. Such aging reflects a choice made by individuals to raise fewer children. The desire to have fewer children may be related to the rise of public sector pensions, which disconnect old-age support from individual fertility, and may have played some role in causing low fertility in industrial nations. The Least Developed Countries as a group are in the midst of their fertility decline, which is causing a substantial proportion of their population aging. While lower fertility may go with reduced total parental expenditures on children, it also raises the ratio of elderly to working-age people, other things equal, with no corresponding improvement in health to facilitate a prolongation of working years.[10] For this reason, population aging due to reduced fertility may well impose important resource costs on the population, regardless of institutional arrangements for old-age support.

By contrast, population aging due to declining mortality is generally associated with increasing health and improving functional status of the elderly. While such

[10] If low fertility is associated with increased human capital investments per child, then these might lead to longer life for those children eventually.

aging puts pressures on pension programs that have rigid retirement ages, that problem is a curable institutional one, not a fundamental societal resource problem, since the ratio of healthy, vigorous years over the life cycle to frail or disabled years has not necessarily changed.

Some Consequences of the Demographic Transition

The three centuries of demographic transition from 1800 to 2100 will reshape the world's population in a number of ways. The obvious changes are the rise in total population from 1 billion in 1800 to perhaps 9.5 billion in 2100—although this long-term estimate is highly uncertain due largely to uncertainty about future fertility. The average length of life increases by a factor of two or three, and the median age of the population doubles from the low 20s to the low 40s. Many More Developed Countries already have negative population growth rates, and the United Nations projects that the population of Europe will decline by 13 percent between now and 2050. But many other changes will also be set in motion in family structure, health, institutions for saving and supporting retirement and even in international flows of people and capital.

At the level of families, the number of children born declines sharply and childbearing becomes concentrated into a few years of a woman's life. When this change is combined with greater longevity, many more adult years become available for other activities. The joint survivorship of couples is greatly increased, and kin networks become more intergenerationally dense, while horizontally more sparse. These changes appear to be quite universal so far. However, whether childbearing is concentrated at younger ages or at older ages and whether age at marriage rises or falls seems to vary from setting to setting, and patterns are still changing even in the populations farthest along in the transition. Parents with fewer children are able to invest more in each child, reflecting the quality-quantity tradeoff, which may also be one of the reasons parents reduced their fertility (Becker, 1981; Willis, 1974).

The processes that lead to longer life may also alter the health status of the surviving population, but the change could go either way. For example, mortality decline may permit less healthy or more disabled people to live longer, thereby raising age-specific disability rates. Alternatively, the decline in damage from trauma and disease in earlier life may reduce rates of disability and illness as people age. For the United States, it appears that years of life added by declining mortality are mostly healthy years, and that at any given age, the health and functional status of the population are improving (Costa, 2002; Manton, Corder and Stallard, 1997; Freedman, Martin and Schoeni, 2002). Apparently, years of healthy life are growing roughly as fast as total life expectancy, although this is more clearly true for years free of mild disability than severe. In other industrial populations, the story is more mixed, and no general conclusion is yet possible. Trends in health, vitality and disability are of enormous importance for the economic and social consequences of aging and, indeed, for human welfare more broadly.

The economic pressures caused by the increasing proportion of elderly are exacerbated in the More Developed Countries by dramatic declines in the age at retirement, which for U.S. men fell from 74 years in 1910 to 63 years in 2000 (with the average age of retirement measured by the age at which the male labor force participation rate fell below 50 percent; Burtless and Quinn, 2001). Generous public pension programs permitting early retirement, combined with heavy implicit taxes on those who continue working, have played an important role in causing earlier retirement in industrial nations since the 1960s (Gruber and Wise, 1999). The growing ratio of retirees to workers is bringing various policy responses. So-called "parametric" reforms tinker with pay-as-you-go defined benefit programs, reducing benefits, raising taxes and eliminating the incentives for early retirement. Sweden, Italy and some other European countries have introduced "notional defined contribution" pension systems, whereby pay-as-you-go systems mimic defined contribution programs, removing incentives for early retirement and passing on to individual retirees the financial risks of rising longevity. Other countries, particularly in Latin America, are making the painful transition to funded public systems. Often these policy changes encounter fierce opposition from workers, but population aging makes reform inevitable. In some countries, like the United States, population aging will generate more intense financial pressures on publicly funded health care systems than it does on pension systems. Overall, the proportion of U.S. GDP spent on government programs for the elderly is projected nearly to triple over the next 75 years without reforms, while the public expenditure shares for the children and working age people remain relatively flat (Lee and Edwards, 2002).

Population aging, together with the growth of age-related public transfer systems for pensions, education and health, creates massive positive fiscal externalities to childbearing. In aging high-income nations with generous support for the elderly, the net present value of future taxes minus benefits for an incremental birth may be several hundred thousand dollars (Lee, 2001), giving governments a powerful incentive to encourage childbearing. In developing countries with younger populations and public programs focused on children, the fiscal externalities and incentives run in the opposite direction (Lee and Miller, 1990).

At the international level, there are intriguing issues about the extent to which the flow of people and capital across borders may offset these demographic pressures. As population growth has slowed or even turned negative in the More Developed Countries, it is not surprising that international migration from third-world countries has accelerated. Net international migration to the More Developed Countries has experienced a roughly linear increase from near-zero in the early 1950s to around 2.3 million per year in the 1990s. Of course, these net numbers for large population aggregates conceal a great deal of offsetting international gross migration flows within and between regions (United Nations, 2002).

For example, prior to 1970, Europe was a net sending region, but since then it has been a net receiver of 17 million immigrants. During the past decade, repatriation of African refugees reversed the net flows from the Least Developed Countries. But overall, while More Developed Countries may seek to alleviate their population aging through immigration, U.N. simulations indicate that the effect will be only modest, since immigrants also grow old, and their fertility converges to receiving country levels.

If inflows of immigrants only partially offset population aging, might international flows of capital offer a way of cushioning the financial effects of population aging? Population aging may cause declining aggregate saving rates, but with slowing labor force growth, capital/labor ratios will probably rise nonetheless and profit rates fall, particularly if there is a move toward funded pensions. Capital flows from the More Developed Countries into the Less and Least Developed Countries might help to keep the rate of return earned on pension funds from falling. However, simulations indicate that exporting capital to the younger Less Developed Economies would help the industrial economies only slightly. The much smaller size of third-world economies would limit the gains (Borsch-Supan et al., 2001).

Dramatic population aging is the inevitable final stage of the global demographic transition, part and parcel of low fertility and long life. It will bring serious economic and political challenges. Nonetheless, life in aging, capital-intensive and culturally diverse high-income countries should be pleasant, provided our institutional structures are sufficiently flexible to allow us to adapt our life cycle plans to the changing circumstances and provided we are willing to pay for the health care and the extended retirement that we apparently want.

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