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THE AGE *EXPLOSION*: BABY BOOMERS AND BEYOND

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Life Expectancy and Aging Populations: Strengthening the Science of Longevity

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Demographers estimate that gains in average human longevity during the past century have been greater than all those between the Bronze Age and the end of the 1800s. The striking rise in life expectancy actually began in the mid-1800s—as an outgrowth of innovations in industrial and agricultural production and distribution that improved nutrition for large numbers of people. During the late nineteenth century, advancements in medicine and sanitation combined with new modes of familial, social, economic, and political organization to further lower mortality rates.

In the 1900s, countries made enormous strides in extending life expectancy. In Austria and Greece, for example, female life expectancy at birth increased from 40 years in 1900 to more than 82 years in 2000.[1] For Japan, overall average life expectancy at birth (for both sexes combined) now exceeds 81 years, the highest level of all the world's major countries. Levels for the United States and most other industrialized countries currently fall not too far behind (in the 76–79 year range). Beyond these general increases, most countries are now also experiencing a rise in life expectancy at older ages. For example, the average Japanese woman reaching age 65 in 2000 could

Note: The opinions expressed in this article are solely those of the author and do not necessarily reflect the views of the US Census Bureau.

expect to live more than 22 additional years, and the average man more than 17 years. Overall, Japanese life expectancy at age 65 increased 32 percent between 1975 and 2000, compared with an increase in life expectancy at birth of only 9 percent. By contrast, increases in the United States are 11 percent and 6 percent, respectively.

As we celebrate longer lives and, as part of this, a growing number of centenarians and declines in disability rates at older ages, we have reason to view population aging as a success story. Longer and healthier lives represent an important yardstick with which to measure social progress. At the same time, aging societies pose myriad policy challenges, most of which boil down to hard fiscal choices. The historian Theodore Roszak, in his book *The Longevity Revolution*, put his finger squarely on one of society's emerging dilemmas: the dissonance between long life and fiscal fear.[2]

Societies need reliable forecasts of the size and characteristics of their growing elderly populations in order to address the significant fiscal challenges.

With large segments of many populations—such as the baby boom generation in the US—inching closer to older age, this dissonance becomes more troublesome. Elevated levels of pension and health costs loom menacingly on the horizon, affecting everything from intergenerational familial transfers to national security. In anticipation of the coming change, economists strive to determine how—and if—people plan for retirement and how much they need to save. Epidemiologists and medical researchers grapple with changing disease patterns and the optimum balance between preventive and treatment efforts. Bureaucrats try to revise health systems and tax incentives that can adapt and be adapted to our changing demographics. More so than ever before, societies need reliable forecasts of the size and characteristics of their growing elderly populations in order to address the significant fiscal challenges.

The Challenge of Improved Projections

At first, it might seem straightforward to project the numbers of tomorrow's elderly and plan accordingly for their likely needs. After all, these people already have been born, and therefore their projected numbers do not depend on the future course of the birth rate. Moreover, demographers and actuaries have studied mortality for centuries and should have a reasonably good understanding of death rates at older ages. And even though migration into and out of a country can affect the numbers of older persons, historically it has been a very minor factor in the aging of most nations.

Upon closer inspection, however, our knowledge of mortality trajectories and longevity is less certain than might be assumed initially. Scientists have been surprised in recent years by new findings about the pattern of mortality at old age; by the increasing robustness and large increases in the size of the oldest population age groups; by emerging evidence suggesting the existence of various genes that appear to be related to longevity; and by other evidence implying possibilities for modifying the aging process. With the coming global demographic tidal wave of persons reaching age 65 and beyond in the next few decades, we would be well served to evaluate our assumptions and projections of life expectancy and the numbers of tomorrow's elderly so that planners are better able to anticipate the optimum allocation of resources.

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In spite of a long tradition of successful scientific inquiry into patterns of disease and death, accurate longevity projection is complicated by divergent trends in recent human experience. There are reasons to be rather cautious and reasons to be highly optimistic.

On the cautious side, one must recognize that, while global gains in life expectancy at birth have been the norm, unforeseen changes and epidemics may reverse the usual historical pattern.[3] In Eastern Europe and the former Soviet Union, for instance, the pace of life expectancy improvement in the 1950s and early 1960s was extraordinary. Advances in living conditions and public health policies combined to produce large declines in mortality by reducing some major causes of death (e.g., tuberculosis) to minimal levels. However, the trend slowed noticeably in the 1960s, and in the 1970s and

1980s, changes in female life expectancy were erratic while male life expectancy fell throughout the region.

Following the demise of the former Soviet Union, the situation worsened. In Russia, male life expectancy at birth plummeted more than seven years between 1987 and 1994. After somewhat of a rebound after 1994, the most recent data show another decline. The negative change stems primarily from unexpected increases in adult male mortality that usually are attributed to a combination of factors including elevated homicide and accident rates, excessive alcohol consumption, poor diet, and environmental/workplace degradation. Most scientists, however, take pains to point out that clear causal mechanisms remain poorly understood and beg further investigation.

Elsewhere, the HIV/AIDS epidemic has had a devastating impact, particularly in parts of Africa. The effect of the epidemic on life expectancy at birth may be staggering, given that AIDS deaths often are concentrated in childhood and mid-adult (30–45) ages. Projections to the year 2010 suggest that AIDS will reduce life expectancy at birth by more than 30 years from otherwise-expected levels in Botswana, Namibia, South Africa, and Zimbabwe. And while the common perception of AIDS mortality usually associates AIDS deaths with children and younger adults, the epidemic is having a direct and growing effect on older populations. In addition to shortening lives, AIDS is making life harder for older populations as they care for grandchildren whose parents have died.

On the optimistic side of longevity projection is the recent finding that, contrary to previous belief, death rates may actually decline at very old ages. In contrast to empirical studies of the 1800s which imply that the human death rate increases with age in an exponential manner, researchers in the 1990s documented that, at very old ages, the rate of increase tends to slow down. A study of 28 countries with reliable data for the years 1950–90 found not only a decline in mortality rates at ages 80 and over, but also a tendency toward greater decline in the latter half of that time period.[4] Further work has confirmed these trends.

On another optimistic note, evolutionary biologists, armed with evidence from the natural world and new information on possible longevity-linked genes, contend that there is no longevity limit built into the human genome. Future efforts to modify the aging process may have major effects. To take a familiar example, we have known for years that caloric restriction can enhance longevity. Undernutrition such as this, without malnutrition, has been shown to extend both average life expectancy and maximum life span in worms, insects, and mice.[5] Whether such an intervention produces the same result in humans and other higher primates has yet to be firmly established. But the fact that one modification of aging has succeeded in lower species implies that there is a strong possibility that not only diet, but also other modifications related to life style behaviors, drugs, and medical innovations, along with specific gene-focused interventions and unforeseen technological advances (keep an eye on nanotechnology), could have a substantial effect on human longevity.

Unreliable forecasts of numbers of older persons will confuse public debate.

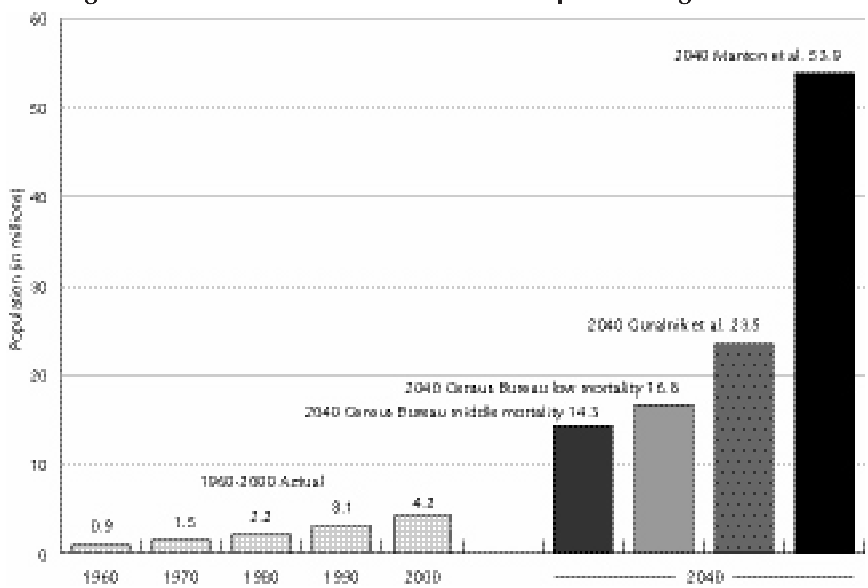
As indicated previously, rising life expectancy translates into strains on existing pension and health systems. Unreliable forecasts of numbers of older persons will confuse public debate about topics such as raising retirement ages, privatizing social security systems, and restructuring the provision of health services and affordable long-term care systems. Hence it is important to ask, how have the population forecasters done in terms of projecting longevity to date?

A comprehensive study by the US National Academy of Sciences reveals that life expectancy has improved more rapidly than national and international forecasters have anticipated in their projection models.[6] Projection models incorporate past patterns of mortality into assumptions about the future course of life expectancy. Projections (especially linear extrapolations) based on past trends will not capture unexpected changes such as the 80+ old-age mortality decline mentioned above. And mathematical projection models generally assume a fixed upper limit to average life expectancy. If this limit is set too low, old-age mortality rates are overstated and the projected number of older individuals is too low. Relatively small errors in mortality projections can have significant effects. For example, analysis of medium-range mortality projections made by the US Social Security Administration since the 1930s indicates that, while projected values of life expectancy underestimated the actual values by two to four years, they produced errors of ten to 15 percent in the projected size of the elderly population.[7]

Another example from the United States further illustrates the range of future uncertainty about the size of tomorrow's oldest old (age 85 and over) population, a group that consumes disproportionate amounts of health and long-term care services relative to its size. The US Census Bureau has made several projections of the future size of this age group. The Bureau's middle-mortality series projection suggests that there will be 14.3 million people aged 85 and over in the year 2040, while the low-mortality (i.e., high life expectancy) series implies 16.8 million. As those who will be 85 or older in 2040 are already at least 40 years old, the difference in these projections results almost exclusively from assumptions about adult mortality rates.

Alternative projections using assumptions of lower death rates and higher life expectancies have produced much larger estimates of the future population of the United States aged 85 and over (see Figure 1).

Figure 1: Forecasts of the United States Population Ages 85 and



Simply assuming that annual death rates will fall at a 2 percent rate results in a projection of 23.5 million aged 85 and over in 2040. Even more optimistic forecasts of future reductions in death rates have been made from mathematical simulations of potential reductions in known risk factors for chronic disease, morbidity, and mortality. A decade ago, Kenneth Manton and colleagues at Duke University used such a method to generate an extreme "upperbound" projection for the United States of 54 million people aged 85 and over in 2040.[9] While such projections are not necessarily the most likely to happen, they do illustrate how changes in adult mortality can impact the future size of the very old population.

An Expanded Emphasis on Longevity Research

Given the fiscal importance of improved projections and the gaps in current methodologies, there is a groundswell of activity aimed at enhancing our understanding of mortality trends and the potential human lifespan. Many academicians and research organizations (notably, the Max Planck Institute for Demographic Research in Germany, the International Institute for Applied Systems Analysis in Austria, and the Human Mortality DataBase project in California) are breaking fresh ground in the study of human as well as non-human longevity. As is often the case, new research uncovers answers but also raises additional questions. The following important topics are ripe for further investigation.

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Probabilistic Forecasts

Because conventional forecasts of mortality (and of population size in general) have not been optimum for planning purposes, increasing attention is being given to projections that result in levels of probability. Extant projections often have high, medium, and low variants, and usually permutations thereof. (Official US Census Bureau projections, for example, once had 32 different scenarios.) While such series seem to produce a range of plausible estimates, the fact remains that each is based on assumptions about underlying and future trajectories. These series do not explicitly take into consideration the probability that actual future trends will fall within the limits of any given combination of scenarios. Scientists seek to improve upon this limitation by using Monte Carlo and other simulation techniques to better gauge the probability that the "true" future estimate will fall within a given range.

From a policymaker's point of view, such probabilistic projections may be a mixed blessing. On the one hand, they ostensibly provide a more accurate range of future possibilities and alert policymakers to the need to think more broadly. On the other hand, they tend to expand the range of possibility, which may make it more difficult to set targets and to allocate resources. Nonetheless, we need a more focused debate about how much uncertainty we are willing to live with when it comes to planning for the aging of the populations.

Underlying Mortality Patterns

One study of the G7 countries[10] during the second half of the twentieth century reached a provocative conclusion: mortality at each age has declined exponentially at a fairly constant rate in each country.[11] The possibility of a "universal pattern" of mortality decline raises important questions about the relationship between social expenditures on health and their effect on death rates and about the likelihood that the mortality decline will be sustained in the future. In a related vein, Michael Marmot and others have identified a socioeconomic gradient in health that applies not only to obvious differences between rich and poor, but within socioeconomic groups as well. The gradient seems to hold across cultures and has led to hypotheses that psychosocial factors and biological pathways may be central to the relationship between social position and mortality/health.[12]

Gender Differences

The widening sex differential as a factor in life expectancy was a central feature of mortality trends in industrialized countries in the twentieth century. In Europe and North America in 1900, women typically outlived men by two to three years. Today, the average gap between the sexes is roughly seven years. Precise explanations of the gender difference in life expectancy still elude scientists because of the complex interplay of biological, social, and behavioral conditions. Greater exposure to risk factors such as tobacco, alcohol, and occupational hazards is cited as a source of higher male mortality rates, suggesting that the gap in life expectancy might decrease if women increase their use of tobacco and alcohol and their participation in the labor force. However, data from industrialized countries still show no clear pattern of change in the gender gap; the gap is widening in most of Eastern Europe and the former

Soviet Union and tends to be narrowing in other developed countries. But in some nations with very high overall life expectancy, gains among females continue to outpace those of males. The issue of how gender differences contribute to longevity offers a rich area for investigation.

Racial and Ethnic Differences

In multicultural societies like the United States, there can be large differences in life expectancy among population subgroups. One detailed analysis showed that life expectancy for white men in the ten "healthiest" counties in the US was roughly 20 years greater than that for black men in the ten least healthy counties.[13] Other analyses have indicated that while mortality rates for blacks are higher than for whites at most ages, there is a "crossover" phenomenon at very old ages: black men and women who reach very advanced ages have slightly higher life expectancies than their white counterparts.[14] Better understanding of the underlying reasons for differences among population subgroups would assist policymakers in reducing disparities.

Environmental Effects

Current controversies about genetically modified foods, water rights, global warming, and deforestation highlight the importance of human-induced environmental change for future survival. As noted earlier, environmental change was a boon to enhanced survival in previous centuries. Today, we tend to think in terms of environmental degradation and its potentially lethal effects on populations. While it is empirically difficult to link environmental changes with specific effects on human health and longevity, these possible influences need to be better understood. Systems analysts and theorists are increasingly involved in developing models that explore such correlations.

Technophysio Evolution

Robert Fogel and Dora Costa have proposed a theory of technophysio evolution that considers the effects of environmentally induced changes on human physiology over the past 300 years.[15] They argue that such changes have increased body size by more than half and have dramatically improved the viability and capacity of our organ systems. Their complex formulation, which, inter alia, involves changes in food supplies, chronic disease evolution, urbanization patterns, and the laws of thermodynamics, suggests that we have by no means reached the end of this process. If so, there is ample opportunity for humans to further alter their environment, their physiology, and, ultimately, their life expectancy. We need an expanded knowledge of this complicated yet potentially very powerful influence.

The Centenarian Explosion

A number of the great debates in gerontology revolve around the concepts of average life expectancy and human life span. Some have argued that average life expectancy cannot rise much beyond 85 years, even if death rates from the major killers (cardiovascular diseases and cancer) are reduced to very low levels. Others point to the fact that average life expectancy for Japanese women has now reached 85 years and shows no sign of leveling off.[16] Studies of certain US population subgroups (e.g., high-ranking members of the Church of Latter-Day Saints, Ivy League graduates) reveal significantly lower rates of age-specific mortality relative to the overall population, suggesting that a mix of lifestyle behaviors, education, and income can lead to enhanced longevity[17]—up to and even beyond 100. The counterargument, of course, hinges on the low likelihood of extending these attributes to a majority of any given population.

We know that the human life span currently can reach 122 years, the age at which Jeanne Calment died in France in 1997. Is this age likely to be surpassed? An analysis of centenarians in France found that there were about 200 such individuals in 1950 and an estimated 8,500 in 2000. Projections imply that there will be 41,000 French aged 100 or over by 2025, increasing to 150,000 in 2050.[18] If these projections are realized, the number of centenarians in France will have multiplied by a factor of 750 in one century. One might suspect that the odds of at least one person surpassing age 122 somewhere in the world will have greatly increased. Whether the human life span can reach beyond the limits we now know is a subject warranting further exploration.

Healthy Life Expectancy

As individuals live longer, the quality of that longer life becomes a central issue for both personal and social well-being. Research on patterns of change in mortality, sickness, and disability has suggested that these three factors do not necessarily evolve in a similar fashion. Discrepancies among the three trends have generated competing theories of health change.[19] Are we living healthier as well as longer lives, or are we spending an increasing portion of our older years with disabilities, mental disorders, and in ill health? And what is the role in old age of risks established earlier in life, even *in utero* or in infancy?[20] Do rising divorce rates or remaining single link to poorer health in old age? In aging societies, the answer to these questions will have a profound impact on national health, retirement, and family systems, particularly on the demand for long-term care.

The topics discussed above suggest the need for a multidisciplinary and longitudinal framework within which to study longevity. Aging and longevity are the result of the complex interplay of many factors. Understanding the linkages among probabilistic forecasts, underlying mortality patterns, gender, racial and ethnic differences, environmental effects, technophysio evolution, the centenarian explosion, and healthy life expectancy will require new modes of investigation that encourage a broader interchange of ideas and perspectives among researchers from diverse fields. Only through this synthesis will we achieve a science of longevity that allows for thoughtful policy formation to address the significant fiscal challenges ahead for pension and health systems.

NOTES

[1] Unless otherwise noted, demographic data in this article come from the International Data Base maintained by the US Census Bureau.

[2] Theodore Roszak, *The Longevity Revolution* (Berkeley: Berkeley Hills Books, 2001).

[3] For a more thorough discussion, see Robert N. Butler, *Threats to Longevity: Could We Lose the Longevity Revolution?* (New York: International Longevity Center, 2002).

[4] Vaino Kannisto, *Development of Oldest-Old Mortality, 1950–1990: Evidence from 28 Developed Countries* (Odense: Odense University Press, 1994).

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[6] National Research Council, *Beyond Six Billion. Forecasting the World's Population* (Washington, DC: National Academy Press, 2000).

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[10] Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

[11] Shripad Tuljapurkar, Nan Li, and Carl Boe, "A Universal Pattern of Mortality Decline in the G7 Countries," *Nature* 405 (2000): 789–92.

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[14] See discussion in Christine L. Himes, "Elderly Americans," *Population Bulletin* 56:4 (Washington, DC: Population Reference Bureau, 2001).

[15] Robert W. Fogel and Dora L. Costa, "A Theory of Technophysio Evolution, with Some Implications for Forecasting Population, Health Care Costs, and Pension Costs," *Demography* 34:1 (1997): 49–66.

[16] James Oeppen and James W. Vaupel, "Broken Limits to Life Expectancy," *Science* 296:5570 (2002): 1029–31. See also Jean-Marie Robine, James W. Vaupel, Bernard Jeune, and Michel Allard, eds., *Longevity: To the Limits and Beyond* (Berlin: Springer-Verlag, 1997).

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