
Original Article

Future trends in human longevity: Implications for investments, pensions and the global economy

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ABSTRACT In the past 150 years demographic events across the globe have had a rippling effect on just about every aspect of our social and economic lives. Foremost among the demographic transitions that have taken place and which are still ongoing is the dramatic increase in how long we live. No one could have predicted the modern rise in human longevity, and the consequences of this unanticipated phenomenon on work, retirement, insurance, national economies, health care, government funding for age entitlement programmes and pension schemes have been alarming. Even more worrisome is the fact that the most dramatic impacts of population aging are looming ahead of us. In this paper we reveal why these global demographic events occurred, discuss how predictions about the future of human longevity are made, describe new investment and hedging opportunities that have arisen in response to these events, and explain why it is important for prospective investors to understand the nuances of demography, biology and the actuarial sciences before investing in what we anticipate will be an explosive market in the coming years.

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INTRODUCTION

During the past 150 years, human ingenuity has set into motion two demographic events that will dramatically change the landscape of global

economic and demographic conditions for the foreseeable future – the extension of life and population aging. The full impacts of these combined events have yet to be realised because they are ongoing. As a result, questions are now being raised about how much longer humans can live and how much further the age structure can shift. Although longer and healthier lives are a boon to individuals and the countries in which

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they live, these benefits have also been accompanied by significant costs to company pension plans, annuity providers and government age-based entitlement programmes whose creators never anticipated that we would or could live this long.

In true entrepreneurial spirit, several financial institutions have created investment opportunities that enable governments and companies that face opposing longevity risks, the ability to offset or hedge their risk relative to each other. A missing ingredient in this economic milieu has been the input from scientists familiar with the subtleties of mortality and its secular changes, and who can place these past, present and future demographic events into their proper context. In the sections that follow, we provide a brief history of human longevity, summarise the various demographic, biological and actuarial views of the future of human longevity, highlight some of the new investment opportunities, suggest how science can provide unique insights into linkages between mortality statistics and investments in short or long longevity, and discuss how global demographics are linked to the current economic crisis and pension obligations.

A BRIEF HISTORY OF LONGEVITY

The modern rise in life expectancy is one of humanity's crowning achievements. After more than 200 000 years of stagnant or slow increases in duration of life, a new chapter in the book of human longevity began in the middle of the nineteenth century when a quantum leap in life expectancy began.¹ The extrinsic forces of death (for example, infectious diseases and accidents) that precluded survival beyond the first few years of life for most people throughout history, were dramatically curtailed as advances in public health and medical technology began to insulate people from the normal hazards of the outside world.² The great fluctuations in mortality in the past were predominantly caused by episodes of highly lethal infectious disease outbreaks punctuated by intermittent periods of less volatile but still high mortality. However, for those who survived childhood even as far back as the Roman Empire, volatility in the age-specific risk of death

early in life was replaced by a more regular age pattern of mortality later in life, enabling them to attain ages that would be considered old even by today's standards.

Although the 30-year increase in life expectancy at birth during the twentieth century was a seminal moment in human history, it was also accompanied by an unwelcomed although not unexpected trade-off; we began to live long enough to experience aging-related diseases such as cancer and cardiovascular diseases. Although this demographic transition did not lessen the inevitability of death, it made the temporal nature of death far more predictable. The evidence for this transition is easily seen in developed nations where the chances of a long life are so high that about 80–90 per cent of all deaths occur after age 65 and anywhere from 30 to 50 per cent of deaths occur past age 85.³

FROM VOLATILITY TO STABILITY IN OUTER REGIONS OF THE LIFESPAN

Evidence of the transformation toward a more stable and predictable pattern of mortality at middle and older ages can be observed in the vital records of nations such as Sweden that have kept reliable vital statistics dating back to the middle of the eighteenth century. Note how the conditional probability of death [$q(x)$] at age 65 for both men and women in Sweden has shifted from unpredictable patterns between 1751 and 1950, to a steady decline observed throughout the last half century (Figure 1).³ This stable pattern of mortality at older ages for both men

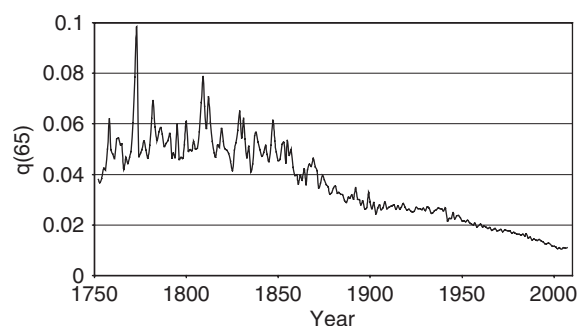


Figure 1: Conditional probability of death at age 65 for men and women combined (Sweden, 1751–2005).

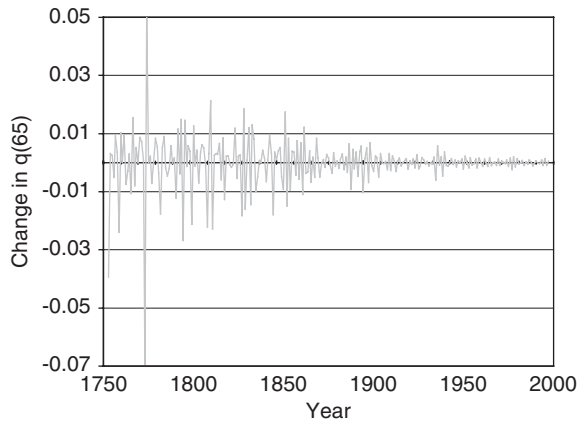


Figure 2: Absolute annual change in the conditional probability of death at age 65 for men and women combined (Sweden, 1751–2005).

and women has become commonplace throughout the developed nations of the world. More importantly, the amplitude of the annual absolute change in $q(65)$ (Figure 2)³ has also experienced a consistent dampening across the centuries. Today, this trend in the movement of death rates for almost all older age-sex groups in low mortality populations has now become highly predictable even over short time frames.

THE BIOLOGY OF PREDICTABLE MORTALITY

As countermeasures to early death from infectious diseases were discovered over the last 150 years, the survivors living into older regions of the lifespan (past age 60) were becoming progressively more exposed to the mortality risks associated with aging. Actuaries who examined this phenomenon found such a remarkable regularity in the age pattern of death among people surviving beyond childhood that they referred to it as a 'law of mortality' – a discovery on par with Newton's law of gravity.⁴ Death still harvests the living with 'law-like' temporal regularity, and scientists are now uncovering the biological reasons for the mathematical regularity.⁵ The significance of this interdisciplinary research is the suggestion that demographic regularity arises from a highly predictable trajectory of biological decline that can now be more accurately referred to as an 'intrinsic' pattern of death.⁶

There was a time when scientists thought aging and the diseases that accompany the passage of time were direct products of natural selection. Under this perspective, the human genome would contain genes whose primary role is to *cause* decrepitude, frailty, illness and ultimately death. Today, scientists now recognise that the ultimate task of all genes is to transform a fertilised egg into a healthy adult capable of reproducing.⁷ Aging is what happens when genes themselves fall prey to the inevitable accumulation of detrimental changes over time.

This view of aging has two important implications. First, aging and age-related diseases are a byproduct of predictable changes in the internal (intrinsic) workings of the body. Diseases of the cardiovascular and central nervous systems, cancers and many other lethal and disabling conditions are 'Achilles' heels' that emerge when the biology we inherit from our ancestors is pushed (by human ingenuity) beyond its normal operating time, the biological equivalent of a warranty period. These fundamental elements to the way in which our bodies operate exist in all of us – they are remnants of clock-like genetic programmes that operate with remarkable precision early in life to regulate growth, development and reproduction, but which later in life inadvertently lead to what all of us recognise as aging and disease.⁸ The inevitable passage of time that affects us all reveals the blueprint of a body that was not 'designed' to fail, but which was also not intended for long-term use.⁹

The second point is equally important for those interested in predicting the future of mortality. In a way we are lucky that aging and death are not products of fixed genetic programmes. If they were, the fate of our biological destiny would be outside of our control. As aging and death are not hardwired into our biology, health and length of life are modifiable through such things as behaviour modification, medical intervention and biomedical technology. In fact, most of the gain in healthy lifespan in recent decades has been manufactured by secular declines in smoking,¹⁰ healthier lifestyles, pharmaceuticals and medical technology.

The downside of having some measure of control over our health is that we can choose lifestyles that are harmful (for example, smoking, obesity, excessive alcohol consumption and so on), or by misfortune of birth or socioeconomic status, we fall victim to harmful behavioural and environment conditions (for example, poverty, differential access to health care, lack of education, pollution and so on). Herein lies the dilemma currently faced by public health officials and, as you will see, prospective hedgers and investors. There is now compelling evidence emerging to suggest that behavioural, environmental and medical conditions for some subgroups of the population will lead them to significantly higher levels of life expectancy than actuarial and demographic forecasts currently anticipate.^{11–16} At the same time, equally compelling evidence suggests that other subgroups of the population are on the verge of the first significant decline in life expectancy in the modern era in developed nations.^{17–19} Uncertainty about the future of both short-term and long-term mortality has resurfaced because our biology is malleable enough to accommodate future *increases* and *decreases* in longevity.

THE FUTURE OF HUMAN LONGEVITY AND RE-EMERGENCE OF UNCERTAINTY

There are three schools of thought that have emerged on the future of human longevity. The *futurists* claim that life expectancy will be dramatically extended for some, physical immortality is on the horizon for others and that some people alive today will literally drink from a yet-to-be-discovered fountain of youth.^{20,21} Futurist reasoning is based on the premise that technological development will continue to increase at a progressively faster rate,²² and that physical immortality accompanied by eternal youth will be achieved for all of humanity in this century. In this future world, people over age 85 will become indistinguishable (physically and mentally) from people at young and middle ages, and old age will cease to exist and the world will become populated only by those who are physically healthy and mentally vibrant. The

only problem is that the futurist line of reasoning is totally dependent on something that does not currently exist – life-extending technologies that yield eternal life. The futurist line of reasoning remains nothing more than wishful thinking and certainly has no influence on short-term (for example, 1–10 years) or medium-term (10–40 year) forecasts of human longevity.²³

Optimists contend that observed steady declines in death rates throughout the age structure over the last century and a half will continue throughout this century, leading to life expectancies as high as 100 years in some countries.¹⁵ Their projection method of choice is extrapolation, which is to say that they develop and use statistical methods of extending past trends in mortality into the future. Advocates of this approach have declared that there are no biological or demographic reasons why death rates cannot decline to zero,²⁴ and biologically imposed upper limits on the life span of individuals and the life expectancy of populations are rejected.¹² Data offered to support these positions include unabated historical increases in the world record for life expectancy at birth (defined by one country annually¹⁵), largely unabated increases in the maximum age at death (defined by one person annually in one country – Sweden²⁵), as well as steady declines in old-age mortality observed in G7 nations.¹¹ Optimists rely on the premise that future declines in mortality will be driven by biomedical technologies that do not currently exist. However, because advances in biomedical technology are occurring at a brisk pace and are likely to continue to do so, there is merit to the optimist's view in the short term.

Realists contend there are competing forces that will lead to simultaneous increases in life expectancy for some subgroups of a population and declines for others. On the one hand, scientists appear to be on the verge of a major breakthrough that will soon make it possible to slow the biological process of aging.^{26–29} This intervention, along with other anticipated advances in the biomedical sciences, will lead to increasingly more effective treatments for diseases and their complications and continued downward pressure on death rates in the coming decades.

On the other hand, there is equally compelling evidence documenting the presence of biological and environmental barriers to radical life extension³⁰ and the deteriorating health of younger cohorts across the globe because of rising levels of obesity, diabetes, indications that coronary artery disease may be on the verge of rising,³¹ the emergence of antibiotic resistant microbes³² and the adverse health impact of environmental pollution. The difference between optimists and realists is that the optimists recognise these negative forces on mortality exist but assume that modern medicine and behaviour modification will overcome them all. Until such fixes exist and evidence emerges for a reversal of negative trends in health that have persisted for the last two decades, realists contend there is no choice but to assume that these negative trends will continue.

Regardless of which camp is eventually proven right, all of the scientists involved in this debate are in agreement that in the short term, progress against most major fatal diseases will continue at a pace that can be measured and modelled with a high degree of reliability by experts who know how to use the scientific tools of demography and public health. It is also worth emphasising that optimists and realists are in agreement that the health and longevity benefits of biomedical progress will not be shared equally, at least not in the short term. Poverty and other social inequities will continue to deny access to longer and healthier lives for the disadvantaged segments of the population. However, health and longevity disparities can be measured and factored into models of mortality for national populations and subgroups with varying access to medical and financial resources.

HOW TO FORECAST MORTALITY

Forecasts of mortality and the survival of individuals and subgroups of the population (for example, insured populations) originated in the early nineteenth century with the development of life insurance and annuities as a method of setting premiums and maximising profits. Forecasts of national populations became important in the early twentieth century with the inception of

age-based entitlement programmes such as Social Security in the United States in 1935. In addition, industries throughout the world that adopted pension schemes, as a means of providing benefits to their employees needed an estimate of how long their covered employees were going to live.

Although the importance of forecasting mortality has risen with the financial liability associated with anticipated shorter or longer lifespans, the methods of forecasting have not changed dramatically since the early 1900s.^{10,33} This is ironic as virtually all insurance companies and national governments rely on such forecasts to set premiums and tax rates and gauge the future solvency of national government programmes and pension schemes. There have been five primary methods of forecasting mortality.

Method 1: Expert advice

The most common method of forecasting death rates and survival is to ask a group of 'experts' who presumably know something about mortality, to estimate (essentially guess) where they think death rates and/or life expectancy will be at some selected time in the future. These views are then averaged to arrive at either a projected level of life expectancy in a given year or an anticipated rate of mortality improvement. Death rates and life expectancy in the intermediate years between the launch and final projection year are typically derived by linear interpolation. This method was popular among the trustees of the US Social Security Administration (SSA) for the first few decades following the inception of the programme.

Method 2: Disease-specific assumptions

This was the most popular method used to forecast death rates in the latter half of the twentieth century, and to some extent is still used today. In this approach, a mortality trend measured from historical data for a specific cause of death is projected to continue into the future. In recent years, this method has led to forecasts that predict heart disease would decline and lung cancer would increase because these are the

trends observed in the past, although recent evidence for the United States indicates that heart disease may soon be on the rise.^{17,31}

Method 3: Linear extrapolation

This variation of Method 2 has become the most commonly used method of forecasting death rates by actuaries and government agencies. Once again, a historical time frame is chosen as a basis for observation and model fitting (based on data in the range of 10–100 years in the past). However, instead of projecting trends for specific causes of death, age-specific trends for all-cause mortality or life expectancy are projected into the future in a linear fashion.

Method 4: Cohort analysis

Although less commonly used, actuaries and others involved in forecasting are becoming more aware of this method. The premise is that people born in different years (cohorts) are exposed to, and carry with them, different mortality risks throughout their lives. Identifying and then quantifying these differences is thought to provide additional insights into temporal trends in mortality. For example, babies born in the United Kingdom in the 1930s have been shown to have lower death rates than the cohorts that preceded or followed them – hence their nickname the ‘golden cohort’.³⁴ Americans born in the 1950s and 1960 appear to carry with them higher mortality risks than the generation that has now preceded them into retirement.³⁵ The advantage of cohort analysis of mortality risks is that it then becomes possible to formulate projections of future mortality for specific cohorts based on health status differentials measured while the cohorts are still living.

Method 5: Targets

When one country or subgroup of the population has lower death rates than another, some forecasters believe that this achievement is simply part of a continuum of global mortality change – as if all humans are on some sort of longevity scale that appears to be forever moving upward. With this method, the lowest death rates observed anywhere in the world then become,

by default, an achievable target for all other countries. For example, Japan currently has the highest life expectancy in the world. The targeting method assumes, therefore, that all other countries in the world will reach the Japanese levels of life expectancy at some time in the future.

IMPROVING FORECASTS OF MORTALITY AND SURVIVAL

The implications of improving forecasts of mortality and survival for pension schemes held by governments and large corporations as well as insurance companies, should be apparent. With financial obligations to pensioners across the globe estimated to be 20 trillions dollars,³⁶ the critical timing of a rapidly aging workforce and general population aging about to begin in 2011, the financial importance of even minor improvements in survival forecasts,¹⁴ and an evolving industry offering a range of longevity/mortality investments that enable companies and speculators to hedge their risk, the time has arrived for new, innovative and more accurate forecasting methods. Indeed, according to a recent survey of 76 UK pension schemes by Aberdeen Asset Management (which, in the aggregate, total US\$271 billion of assets),³⁷ longevity risk is considered second only to investment risk – ahead of both interest rate and inflation risk. More than half the surveyed schemes expect life expectancy to continue to increase, and over 40 per cent think their members will live longer than those of the average scheme. However, these expectations are not reflected in the longevity assumptions used by pensions to calculate their liabilities. There are several ways to bring mortality forecasting into the twenty-first century.

USING BIOLOGY TO INFORM MORTALITY FORECASTS

Although it should be apparent to even the most casual observer that biological processes within our bodies fundamentally influence how long we live, until recently no one has attempted to incorporate this information into mortality forecasts. However, in the early 1990s a new field of scientific inquiry was developed that has

led scientists in this direction. Details of the new field of biodemography have appeared in the scientific literature for years,^{5,38} so there is no need to discuss the fine points here, but what is important is that this knowledge can be used to inform mortality forecasts.

One example of biodemographic reasoning is worth noting – it involves the mortality dynamics of population subgroups. Biologists know that genetically diverse populations such as those represented in national vital statistics such as the United States, are combined together to generate an overall risk of death for the entire population. However, biology informs us that national populations are really composed of genetically diverse subgroups that possess varying mortality risks at birth and later ages that are expressed in early deaths for some and long life for others. What this means is that the unitary trend toward an exponentially rising risk of death with age that actuaries and demographers observe for most low mortality populations, is really composed of a series of different mortality schedules for population subgroups that are added together to look like one schedule for the population. Biodemographers contend that the unitary mortality schedule observed for the population is, in fact, a poor approximation of the diverse mortality schedules that exist for subgroups of the population. Identifying who belongs to which group based on identifiable personal attributes would therefore greatly improve actuarial estimates of survival and death.

MORTALITY RADAR

Extrapolation models applied to extend past trends in death rates or life expectancy into the future are built on the premise that the future will be some variation of the past. This is analogous to forecasting the weather by examining books of weather statistics that report on temperature and precipitation for a given location during the past 100 years, or more crudely, by lifting one's head out of the history book in order to look at the weather approaching on the horizon. A more accurate method of forecasting the weather was developed decades ago when radar was invented – enabling weather

forecasters an opportunity to 'see', with remarkable accuracy, the developing weather patterns hours and days in advance.

The equivalent of mortality radar has been developed that enables one to 'see' (that is, measure with a high degree of accuracy) the changing health status of people that have been alive for the last several decades, who will eventually die during the years in which short-term trends in future mortality will be expressed. This mortality radar is based on the use of nationally representative surveys conducted by highly reputable government agencies and scientific groups that, for decades into the past, have reliably and repeatedly measured the health status of a large representative sample of people in the United States and other countries. *In other words, we suggest it is possible to more reliably predict death rates from the observed health status of representative samples of these same people measured with a high degree of reliability in the decades before they die.*

To place the concept of mortality radar into context, consider the alternative and what one might characterise as a more blunt approach now in use by most actuaries and demographers – which is to track historical trends in death statistics and develop mathematical models to extend the past into the future. Sometimes these models appear to be quite elegant, but they can only be used after death occurs in a population and after they have been published by government agencies – which can often take years. This means those who rely on these models are trying to project forward by looking backwards. This is analogous to trying to predict causes of death for people 10 years from now by examining the results of autopsies of people who died in the past 10 years – which would hardly qualify as a true predictive model. Mortality radar, by contrast, predicts future mortality based on health attributes of living people and existing cohorts.

UNCERTAINTY DRIVES NEW INVESTMENTS IN LONGEVITY AND MORTALITY

The steady increase in longevity in recent decades and the rising uncertainty about whether it will continue has created a unique set of risks as well

as hedging and investment opportunities that did not exist until recently. Major drivers of this new investment environment include the sheer magnitude of the baby boom generation now approaching retirement ages and the impact of their extended survival on the economic health of national economies, the extremely high risk faced by companies and governments with pension schemes that face substantial financial challenges if people live longer than expected, confidence by some that past trends in rising life expectancy will continue, and compelling evidence that the health and longevity of some future generations of older people may be on the verge of deteriorating. Another key factor is the perceived risk and level of comfort and security in developing strategies to successfully exploit this investment opportunity. Also lurking in the background of uncertainty are catastrophic events such as influenza pandemics, the rise and emergence of new infectious diseases (such as HIV/AIDS),³² and environmental perturbations, all of which are expected to have a significant influence on mortality at some time within this century.

The question is not whether these positive and negative mortality-changing events will happen, but *when* will they happen, how long will they last, how lethal or beneficial will they be and what their short-term and long-term mortality implications will be? Indeed, these positive and negative mortality risk events could occur simultaneously with both independent and interacting effects on future trends in survival. Optimism in the favourable trend of demographic and health trajectories has already given way to what we are witnessing already; namely, apprehension by national and state governments, industry pension schemes and insurance companies as they recognise the potential financial consequences of these competing events on human longevity.

It is also important to understand that significant disagreements exist among government agencies responsible for forecasting life expectancy. For example, the United States Census Bureau predicts that the remaining life expectancy of people surviving to age 65 in 2030

will be 20.4 years, which is 1.2 years higher than a prediction made by the US SSA. This seemingly trivial difference has major consequences because each 1-year underestimate in life expectancy at age 65 between now and the middle of this century produces 53 million person-years of unaccounted life lived.¹⁴ In other words, because of dramatic shifts in our demographics and a huge baby boom generation now approaching retirement ages, small differences in projected improvements in mortality that are already built into the forecasting models developed by the actuarial/insurance industry, can rapidly lead to extremely large differences in the number of people expected to draw from retirement schemes.

Among insurance companies and actuarial firms it is common practice to assume that death rates will decline annually by about 1 per cent (with some variation depending on the specific age group chosen), but if these forecasts are off by as little as 0.25 per cent, the demographic error rapidly compounds itself and the financial implications to the companies that rely on these estimates become profound. With some experts estimating that longevity-linked liabilities globally have reached \$20 trillion,³⁶ small errors in mortality forecasting quickly lead to huge liabilities.

The question of great interest to public policy makers, pension fund managers, insurance companies and investors is how much longer people will live who are currently insured, covered by pension schemes, or just part of the general population? The stakes are high. For example, the automobile companies in the United States today face severe financial insecurity because of their large and growing pension obligations – contributing to their current financial crisis. General Motors and Ford recently secured a government-funded loan, in part, to cover an estimated \$14 billion mandatory payment to the United Auto Workers trust fund to cover retiree health care and pension payments. National governments such as the United States, United Kingdom, Germany and the Netherlands have age entitlement programmes whose outlays are poised to rise dramatically as

the baby boom generation approaches retirement ages. Major insurance companies face the prospect of declining revenues if current predictions about declining life expectancy come to fruition as some scientists anticipate.

Developed and developing nations alike are being forced to confront a complex set of competing forces that are poised to wreak havoc with pension-related programmes facing overwhelming financial obligations, and insurance companies who benefit from continuous increases in longevity. Complicating the longevity equation on the one hand are anticipated advances in the biomedical sciences that promise longer (and perhaps even healthier) lives for many. These advances suggest that longevity will continue to rise rapidly (at least through the middle of the twenty-first century) – placing some companies and governments in financial peril. On the other hand, diabetes and its related complications are about to become *the* diseases of the twenty-first century, with the dramatic rise in obesity poised to take away life faster than technology manufacturers it. New and more virulent strains of antibiotic-resistant infectious diseases are already spreading around the globe, and given that pandemics occur with regularity about three times every century, the World Health Organization is already preparing for the next one.³⁹ These trends suggest that at least for some subgroups of the population, we might witness the first drop in life expectancy in a developed nation in the modern era – placing some major insurance companies in financial jeopardy.

Trading in longevity and mortality

In response to the significant financial risks on either side of the longevity/mortality equation,^{40,41} a handful of financial institutions have created indexes that enable companies at risk to hedge their positions, and to provide investors an opportunity to speculate. The financial institutions creating and facilitating investments in the longevity risk market are indifferent to the direction of the investments – they are simply acting as a facilitator between investors with differing risk tolerance profiles or opinions on the future of mortality. As such, they

have created a variety of investment alternatives such as longevity swaps, options and structured notes. Some have even created computer software combined with the latest mortality data so investors can develop their own forecasts.⁴²

Currently, all of these indexes share a common methodology and a common metric based on an actuarial estimate of mortality for either national populations or selected subgroups. However, from this common starting point they then diverge. For example, J.P. Morgan (JPM) has developed an Index of national population mortality rates (called LifeMetrics^{42–44}), and has created a product called q-forward that uses a building-block approach for hedgers and investors to manage their financial exposure to future death rates (known as [q] or the conditional probability of death) for national populations of a chosen gender and any age (such as ages 60, 70–79 and 80–84). Currently, JPM maintains indexes on the populations in the United States, England and Wales, Germany and the Netherlands (with other country indexes in development).

In the q-forward approach, JPM establishes a strike price for the expected mortality rate, at a given time horizon (say 10 years) for the underlying population and age range. This strike price implies a certain fixed rate of mortality improvement over a 10-year time frame for each age group, and investors can then invest, hedge and/or create abitrages on whether the observed death rate will be higher or lower than the established strike for a particular population, subgroup of a population and/or between population groups or subgroups. Investors on either side exchange net payments annually as data is made available throughout the term of the investment. In actual practice, the exchange of payments is made via JPM which minimises counterparty risk of each investor. A hedger can use a combination of q-forwards across various age groups to build a hedge which is highly correlated to its underlying risk profile. JPM has also executed transactions involving survivor swaps, where hedgers and investors exchange actual monthly payments on a portfolio of annuities for a fixed stream of payments.

Both the q -forwards and survivor swaps can be created around either JPM's index (LifeMetrics) or other index or on the mortality of a specified pool of individuals.

Consider the following example: in the Netherlands, the death rate among females aged 65–69 declined by 22.8 per cent during the 10 years from 1950 to 1960. A plot of the annual rate of change in the 10-year moving death rate for this same age-sex group (that is 1961–1971, 1962–1972 ...) documents some volatility, but nevertheless, for 30 of the 46 years, the annual 10-year rate of decline in $q(65-69)$ was 10 per cent or higher (Figure 3). Investors unfamiliar with overall trends in death rates within specific nations might use this example from the Netherlands and conclude that it is safe to assume that death rates in the future will decline at levels that are comparable to those observed during the last half century – which was an average of 12.8 per cent every 10 years for females aged 65–69. What such an investor would not know from this trend analysis is that the Netherlands has been one of the few developed nations that has experienced a stagnation or actual decline in life expectancy at older ages since 1990 (Figure 4).³ Another example of this phenomenon is women aged 65+ in the United States.¹⁸

Goldman Sachs (GS) has created what it calls the 'QxX.LS' index that involves various ways of investing in the prospective survival of a pool of insured US lives over time frames ranging from 5–40 years. Each year a new pool is launched.

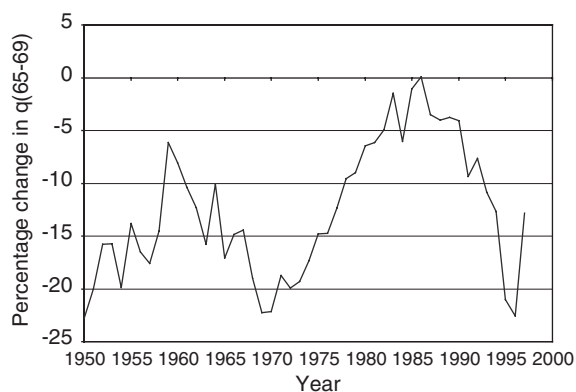


Figure 3: Annual rate of change in the 10-year moving death rate for females aged 65–69 (The Netherlands, 1950–1996).

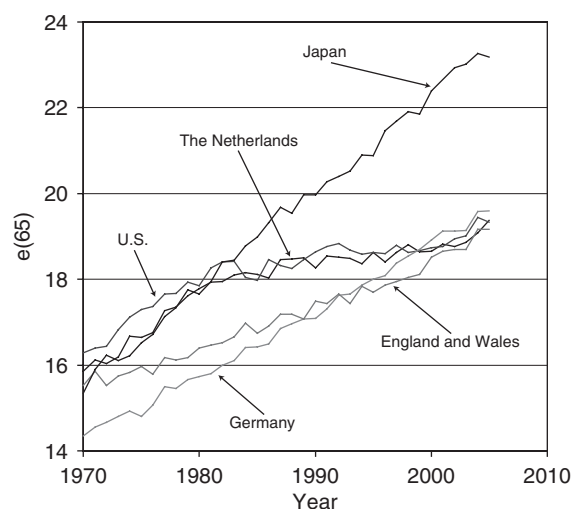


Figure 4: Life expectancy at age 65 for females in England and Wales, Germany, Japan, the Netherlands and the United States (1970–2005).

The number of lives in the December, 2007 Index was initially 46 290. The number of lives in the December, 2008 Index was initially 65 655. A predetermined spread (5 per cent per annum for a 10-year swap and 4 per cent per annum for a 5-year swap) set by GS is paid by the 'fixed payer' to the 'fixed receiver' based on a declining notional amount as determined by the number of deaths which occur each month. In exchange, the 'fixed receiver' pays to the 'fixed payer' an amount determined by multiplying the number of deaths observed during each month divided by the number of remaining lives in the pool by the notional amount. The amounts owed by each party are 'netted out' and a monthly net payment is made by the party owing the larger amount. Similar to the JPM mechanics (which reduces counterparty risk), payments are actually made to or by GS which then pays out to the side entitled to receive the payment. Each month, the notional amount declines based on the size of the surviving pool compared to the size of the surviving pool the month before. An initial payment may be exchanged between the parties upfront to account for variation in mortality expectations (analogous to the payment a party might make to acquire a pool of life settlement policies). GS also offers synthetic/replication life settlement portfolio transactions on

200–1000 equally weighted reference lives. In this case, the investor pays a periodic ‘premium’ amount on remaining reference lives (based on a pre-defined schedule), and receives a fixed ‘death benefit’ payment upon the death of each reference life. The pool of people used in this case is composed of an insured population in the United States, and prospective investors are provided transparency to detailed information on each individual in this pool such as gender, state of residence, smoking status, health conditions and date of birth. Similar investment options are also available from Credit Suisse.

The GS investment is notably different from that of JPM. JPM’s investment is based on national populations for a number of countries known to have reliable and regularly reported vital statistics whereas GS’s investment is based on a subgroup of the population collated by AVS (a life expectancy appraiser) from individuals seeking or, in the past, have sought to sell their insurance policies (that is, life settlements). There are elements of the GS approach that are worth emphasising. First, because it is based on an insured population with an average age of 77 – most of whom are seeking to sell insurance policies with face amounts of \$1 million or higher, the risks of death for this select wealthier segment of the population are considerably lower than that observed at the national level. There are incentives for policy holders to attempt to exaggerate their health risks in order to maximise the amount they hope to receive for their policy, whereas others may be selling their policies *because* they face significant immediate health risks and need the cash.

Men comprise two-thirds of the GS cohort and are on average 1.1 years younger than the females (Figure 5), so any investment must take into account the significantly higher risk of death for men relative to women and their younger age distribution. Furthermore, when GS created a new investment cohort of 65 655 insured lives in December, 2008 from the survivors of the 46 290 person cohort from a year before (with approximately 20 000 people added to the list), the average age of the cohort declined by about 1–2 months. Notice the age shift to the left in

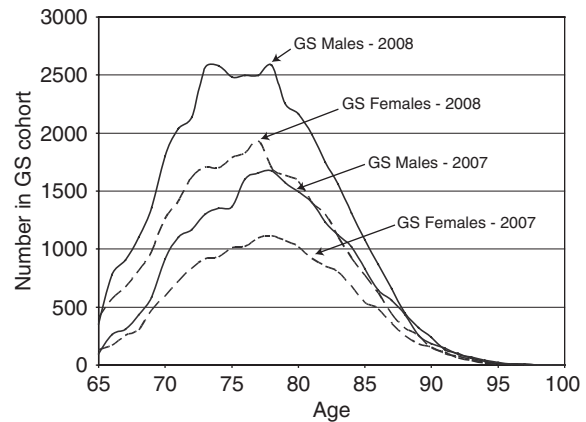


Figure 5: Age distribution of Goldman Sachs 46290 (2007) and 65655 (2008) person cohorts by sex.

the distribution of the GS cohorts between the 46 290 people in 2007 and the 65 655 people in 2008 (Figure 5). One reason for the investment cohort growing younger is that those most likely to die in the first year are those at highest risk (which tend to be at higher ages), and the insured lives added in to replenish and expand the cohort have roughly the same age distribution as the original cohort. Thus, every time a new GS cohort is reconstituted, it is likely to be younger on average than the one that preceded it.

Deaths in the GS cohort are reported on a monthly basis from the Social Security Administration’s death master file, but these reports are generally not complete and it is possible that months could pass before some deaths make their way into the file. Finally, those familiar with mortality statistics recognise that a phenomenon referred to as ‘seasonality of mortality’ could play a significant role in an investment of this kind. For example, note that in the year 2008 when the first GS Index was made available as an investment option, there were a significantly larger number of deaths observed in the month of February relative to all other months (Figure 6). This occurs primarily because of influenza, which kills anywhere from 20 to 80 thousand Americans every year depending on the strain that emerges each winter, and most of these deaths occur in the first 3 months of the year. Savvy investors would

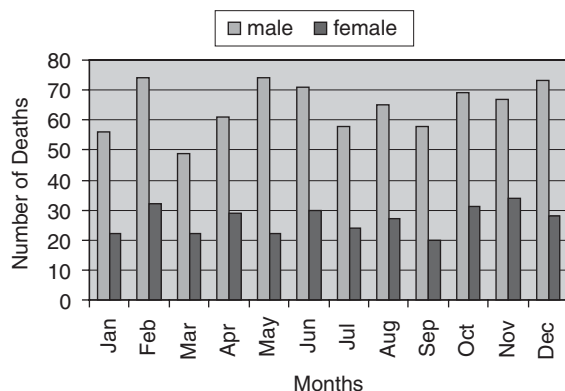


Figure 6: Distribution of deaths in the GS 46290 person cohort in 2008 by month of death.

not only be aware of the seasonality of mortality, but they might consider monitoring infectious disease alerts (or retaining someone to do so on their behalf) to determine which strain of influenza has surfaced. Some strains are twice as lethal as others on a yearly basis, and pandemic strains of influenza appear about three times in every century – sometimes raising the death rate tenfold or more, so knowledge of this kind should become a routine part of any prudent investment strategy.

Other financial organisations are beginning to enter into this longevity market based on national or subgroup populations because they want to be in a position to participate in the market once it takes off. By and large, their indexes are variations of the common themes described above.

Who benefits from investments in longevity/mortality?

When life expectancy changes, especially when it does so beyond expectations, public and private entities become exposed to significant financial risk. If individuals live longer than expected, the gap between planned accumulated assets and actual pension liabilities will grow rapidly. As indicated above, these entities can now hedge against this risk by investing in instruments that are 'long longevity'. By making a 'long longevity' investment, companies such as pension schemes and annuity providers that are inherently short longevity will be able to generate an offsetting

financial return from the very phenomenon (unanticipated increase in life expectancy) responsible for the potential liability in the first place.

Conversely, life insurance companies which are inherently long longevity can invest in instruments that are 'short longevity'. Insurance companies which face the financial risk that their insured populations will not live long enough to pay sufficient premiums to cover earlier-than-anticipated payouts of death benefits will also generate offsetting financial returns from the very phenomenon responsible for the original financial exposure.

Thus, investing in longevity-related financial instruments that payoff for longevity-related events that place such companies at risk, makes perfect sense. However, in order to effectively hedge their exposure, companies on either side of the longevity equation face fundamental challenges: selecting the appropriate instrument in which to invest (*that is*, determining which instrument will most closely mirror the time period(s) of the longevity exposures), and identifying which groups or subgroups used by those offering the investments most closely correlate to the population of pension members or insured populations covered by such companies, and which are most likely to experience unanticipated mortality events that will ultimately make their investment profitable. Although JPM and GS are willing to customise an investment to accommodate the needs of their investors, such customisation is accompanied by added costs and decreased liquidity.

In addition to those who may seek to hedge their respective longevity risks, there are also prospective investors who will choose to speculate by buying or shorting various positions depending on their views of the future course of mortality. Those investors who may embrace the 'Futurists' or 'Optimists' perspectives about longevity might be inclined to invest on the 'long longevity' side whereas those who subscribe to the 'Realists' perspective might invest either long or short longevity if conversant enough in mortality trends to identify the unique cohorts that will experience rising or declining life expectancy.

Why these investments have been slow to take off?

While the mortality indexes created thus far are relatively new to the investment world, standardised swaps, options and structured notes on which the investment vehicles are based are well understood by institutional investors and are regularly being used in other asset classes (for example interest rate swaps, equity and commodity options and so on). Moreover, governmental agencies, pension plans, insurance companies and an entire industry of actuaries are beginning to re-analyze some of the risks associated with longevity and mortality.⁴³

It is no surprise that cautious investors in today's turbulent times are moving slowly. Before proceeding with an investment in this asset class, investors need to develop a level of comfort with the investment opportunities and the mortality data upon which they are based. To promote both familiarity and comfort, all of the financial institutions offering such investments have focused on the creation of their own standardised measures of longevity risk and standardised documentation evidencing the investments.

What exactly does this mean? As the investment banks creating these trading indexes generally are indifferent to the direction of the investment, it is critical that those involved on either side of the transaction understand with perfect clarity: the exact composition of the index; the mortality components of the population upon which the index is based; the factors likely to cause the index to change and the precise monetary consequence of a defined increment of change in the index. Prospective investors also need to fully understand all margin requirements and cash flow probabilities. As a way to enhance this transparency, the firms involved have not only made available to prospective investors all of the data upon which the indexes are based, but in some instances they also provide software that enables investors to manipulate the data used for forecasts in order to examine their own mortality models.^{42,45}

What might trigger accelerated investments in longevity and mortality?

Given the recent turbulence in the global markets and the ensuing bankruptcies and consolidations in the industrial and financial industries, governments in developed countries are taking a closer look at the longevity exposures of insurance companies and pension plans. Legislation has been suggested which will require a better managing of such exposures and a re-analysis of life expectancy projections.

In addition, it stands to reason that once the entities on either side of these investments (who hold nearly \$20 trillion of longevity exposure) realise the benefit from playing off of each other's longevity risk, and better understand the investment instruments and the mortality data upon which they are based, then it appears that the time for this longevity market has arrived. Toss in the opportunity for investors not exposed to longevity risks to speculate in these investment vehicles (and the fact that returns from these investments are not correlated to the stock and financial markets), and it would appear that the ingredients are in place for an explosive growth in this emerging market.

CONCLUSIONS

There is no doubt that the transformation of death in low mortality populations from a volatile event to a much more stable aging-related condition, has set the stage for some degree of confidence in predicting the future course of mortality – especially over the short term. Whether prospective investors can navigate their way through mortality statistics and investment opportunities without the background in understanding either the history or the biology that drives temporal change in mortality and longevity has yet to be determined. What we do know from experience is that actuaries and mathematical demographers involved in mortality forecasting have tended to be one-dimensional – they have consistently struggled with their vision of the future of mortality primarily because they have relied heavily on outdated trends in death statistics, completely ignored the underlying

biological forces that influence and drive death rates, or maintained a biased view that assumes observed improvements in mortality will continue whereas observed declines in health and longevity will be resolved by medical technology and behaviour modification.

The use of more recent data (VBT-2008) by some actuarial firms is a step in the right direction, but it is worth noting that when death is caused by aging-related conditions (as is the case with almost everyone who dies in the indexes now being offered), mortality rates observed today are a product of highly predictable health conditions that existed when people were alive. Scientists with expertise in understanding the linkages between biology and mortality, and the relationship between health conditions among living populations and their subsequent risk of death, may very well be the missing link that is needed to establish confidence in investments in mortality/longevity indexes that are currently outside of the expertise of those now thinking about hedging their risk or investing in this space.

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