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Session 60PD
Demographics and Longevity into the Next Century

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Summary: These topics lie at the core of actuarial science and influence all aspects of the worldwide actuarial profession.

The speakers give their projections on demographic trends and longevity prospects going into the next century in important countries. They analyze the factors influencing the expected trends and comment on what these trends will mean for the financial services industries and the actuarial profession around the world.

Mr. James C. Hickman: I need to do little to motivate this session, but I nonetheless would like to start with two quotations. The first is from Kenneth Boulding, the famous Quaker economist. Boulding once said, "The two things I fear most are a nuclear exchange and life expectancy suddenly jumping to 150." He feared them because both events would destroy the institutions that he had lived with. The probability of both are, I hope, remote, although the probability of one has recently sunk and the probability of the other slightly increased. This increase will be one of the issues that come before us today.

The second quotation is from Peter Drucker, a Viennese, now past 90, who has been the guru of management during much of the last 50 years. In response to the question as to what are the coming challenges for the world, he said, "The first is to adjust our society, especially in the developed countries, to the greatest change the 20th century has wrought, which is the change in demographics."

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Note: The charts referred to in the text are not online. Please contact Linda Blatchford at lblatchford@soa.org or at 847-706-3564 for hard copies.

To develop these topics we have a panel of three experts. Dr. Charles Hertz is the editor of the *Statistical Bulletin*. I urge those of you who would like to keep up to date on demography to read the *Statistical Bulletin*. It has kept me, at least partially, up to date on demographic and social trends during the past 50 years.

Our second speaker will be Tuljapurkar—I always call him Tulja—who is president of Mountain View Research, a San Francisco Bay company that engages sin demographic research. Tulja grew up as a physicist but made the transition to demography. I want to say thank you to Tulja for his participation in our 1997 symposium on Social Security mortality. I call your attention to, what I hope is in your library, the October 1998 issue of the *North American Actuarial Journal* that reports on that symposium. The principal contributor to that excellent program was Tulja.

To our final speaker I also owe a debt of gratitude. David Holland is president of Munich American Reinsurance, and past president of our Society. That's a big job! And I thank you, Dave, for taking it on.

Dr. Charles G. Hertz: I'm going to begin by talking about the current status and trends as we see them. Then I will discuss a whole host of factors that might influence those trends, in terms of demographic and longevity changes, and then end with a few projections.

Life expectancy in the U.S. The thing to point out here is that virtually in every year over the last ten years, there has been a very palpable increase in longevity for men, and an almost imperceptible increase in longevity for women. There are a million reasons for this, none of which we need to go into now. You know them as well as I do. We will only talk about some of the influencing factors.

I thought it would be interesting to talk about, since this is an international meeting, some comparisons with some selected developed nations. The U.S. is at 76.4. This isn't broken down by sex; Japan is right up there with 3.5 years longer. There's a considerable difference among various nations. And again, what are the factors for influencing these results? The factors are genetics, for sure—diet, lifestyle, and environment—all the things that we have read and discussed during the last half century. With those trends, let's talk for a minute about what caps longevity. What are the major causes of death? In the U.S., in 1996 expressed as deaths in thousands, cardiovascular disease and cancer are the big killers for both men and women. Those two, by a huge margin, exceeded the next four causes combined, which are accidents, chronic obstructive pulmonary disease, pneumonia, influenza, and diabetes.

Since cardiovascular disease and cancer are the two big killers, I thought we should discuss each one of those in a little bit more detail. First, the U.S. has a very interesting trend for cardiovascular disease, again expressed in deaths per thousand. Cardiovascular mortality in men is dropping. In women, it isn't. It's staying the same or maybe even going up a little bit. The suggestion here, I think, is that this trend for women will reverse, and will start improving. You know some of the factors that lead to cardiovascular death; obviously one is diet. There has

been a major change in diets for both genders. Another factor is smoking. Men started ceasing smoking long before women did in this country. But women are catching up now and I think it will be reflected in the next decade or two. I think the use of hormone replacement treatment for women at menopause, which is protective against some cardiovascular disease, will improve that trend considerably.

Let's discuss relative cardiovascular disease among nations. I've taken the liberty using the U.S. as an index of 1. But look at some of these countries: Northern Ireland and Scotland. Ireland is way up there at 1.5 times the U.S. mortality. The diets there are notoriously high in fats. Conversely in Japan, which is way down at 0.16, the diet is very, very low in fats. I'm not blaming all this on fats; there are clearly a lot of other factors. France and Switzerland, whose diets are not known for being low in fat calories have fairly low mortalities in cardiovascular disease.

Cancer mortality—the result that is most noteworthy about cancer from 1930 to the present, is that deaths in men because of lung cancer reached a plateau about 10–15 years ago, and is now very definitely decreasing. Conversely, lung cancer in women has been climbing and climbing and climbing. It is still well below lung cancer in men, but it continues to climb. What isn't known to very many people is that it passed breast cancer as a leading cancer cause of death in women about 10 years ago. Lung cancer in women is a very serious concern. Again, men stopped smoking a number of years before women stopped smoking, but smoking habits for women have gone down considerably in the last few years. I think that we'll see that trend also begin to diminish over the next few years. Colon rectal cancer is decreasing, possibly because of improvements in diet, education about nutrition, and an increase in roughage in diets.

Now, again using the U.S. as an index of 1, looking at death from all cancers in comparative countries, I was able to break it down by gender. There are some very interesting facts. France is very, very high in cancer mortality, while countries such as Iceland, Norway, and Sweden are very low. But there are some facts that really tantalize me. One of them is the difference between men and women. France is very high for cancer mortality in men and relatively low for women. The thing that is interesting is the men in France who are dying of cancer are dying of cancer because of smoking. But very interestingly, they are not dying of lung cancer. They are dying of cancer of the oral pharynx, the esophagus, and the stomach. I don't understand this. How can that possibly be?

Men in this country die of lung cancer when they smoke. Men in France die of other kinds of cancer. Well, it was pointed out by the late Ernst Bender that one of the reasons for that is what he calls *la droop*. What is *la droop*? *La droop* is a method of smoking in which French men droop their cigarettes out of the corner of their mouths. The other thing about cancer deaths in France, besides *la droop*, is the kind of cigarette smoked, which is *Gauloise*, the most popular cigarette in France. If any of you ever smoked a *Gauloise,* you wonder why any one is alive in France. They are really harsh and horrible cigarettes. But the other thing that I just recently learned is two of the favored drinks in France are *Armagnac* and *Calvidos*, which are very high in nitrocymenes, which are carcinogenic.

What are some of the factors that will influence longevity over the next century? They fall into three categories. The first category is patterns of disease. Some diseases occur in cycles. The one that occurs to everybody is influenza. It is certainly seasonal, and in terms of pandemics it is probably cyclic. The problem is the cycles aren't very regular. Public health authorities are absolutely convinced that we are destined to have another huge worldwide pandemic of influenza. The concern in their minds isn't "if," but "when."

New diseases. In the last 30 years alone we've seen HIV, Ebola virus, hepatitis C virus, and a whole host of others which haven't amounted to very much. But these diseases are constantly coming up as new diseases and we will definitely see more of these. Some of these have had major impacts on longevity statistics, certainly HIV has. My colleagues will show you some mind-boggling numbers about that. Other diseases, as I said, haven't been quite as serious from a population standpoint.

Emerging diseases. The emerging diseases that I'm most concerned about are antibiotic-treatment-therapy-resistant organisms. We've been splashing in antibiotics like water for the last 50 years and our little microbial friends are very smart. They've learned how to develop resistance to those antibiotics and that's not getting any better. They're developing resistance faster than our laboratories and drug companies can develop new antibiotics. What have we seen? We've seen the emergence now of treatment of resistant tuberculosis and resistant malaria. In this country we all know about treatment of resistant staph lecocyx, pneumococyx, and E coli. These are very frightening. Some diseases like tuberculosis and malaria have enormous p9ortential for doing tremendous damage on a worldwide basis. We're going to come back to that a little bit later when we talk about progress. But, re-emerging diseases is a serious emergency.

Then, re-emerging diseases are those diseases that we thought we had under control because of public health measures, but now they're beginning to re-emerge in certain parts of the world. Tuberculosis is one of those, especially with the advent of HIV disease in immune-depressed people. What's worse is that the re-emerging tuberculoses is not only tuberculosis, but it's treatment-resistant tuberculosis. Malaria is also re-emerging in many parts of the world. Cholera is once again coming back to haunt us. And I'm not even going to talk about the use of certain bacteria and other agents as a form of terrorism. My colleagues who are much less optimistic than I am, will touch on that further.

Environmental factors. Without question, over the last several hundred years public health advances have accounted for more change in population longevity than any medical advances have covered. Safe drinking water, treatment of sewerage, and food handling have been the biggies. But we really can't be very complacent about that. In the western hemisphere today, in Central America, Brazil, and in some of the southern parts of South America, still one-third of the population does not have access to safe drinking water in 1999 or 2000. In some of the third-world countries across the ocean, I suspect the figures are much worse than that. The other thing about public health factors is that if you subscribe to global warming or not, you have to subscribe to the incursion of humankind into

previously uninhabited rain forests. Some of the stuff that's happening there is extremely hospitable to the development of malaria, yellow fever, and other vector-transmitted diseases. These are major public health problems.

Nutrition and fitness are big problems. In this country and in most of the developed countries there's been some real progress in terms of public health education. People are aware of the impact of nutrition and exercise, and some people actually do it. This has resulted in some very good news and some very bad news. The good news is that people, in general, are eating more nutritious diets. However, cholesterol levels are very interesting. Thirty years ago the average cholesterol in the U.S. was 235. The average cholesterol today is 209. In the population of people who apply for life insurance at high levels at $250,00 or more, at least in our own testing laboratory, the average cholesterol is 190. That's interesting stuff. That's the good news.

The bad news is obesity. Obesity in the U.S. and most of the developing nations is increasing fairly frighteningly. In the U.S. today about 17-20% of our youth are well above the recommended body mass index. That's a little bit scary. Tobacco is, of course, a real bugaboo. In the U.S. today 27% of men and 25% of women still smoke. That figure is decreasing among all groups of men and women with one exception. And the exception is young women, especially Caucasian women of high school and immediate post-high school age. The instance of smoking in that group is increasing. Virginia Slims targets 18- and 19-year-olds with glamorous billboards and print advertisements. I think this is highly irresponsible. To me, it's borderline despicable.

Finally, let's discuss the concept of the shrinking planet and urbanization. We all know now that intercontinental travel is made much easier, diseases can be transmitted much more quickly. In JFK Airport in New York last time we counted, every day there are 31 incoming flights from third-world countries. Well, try to imagine yourself as a public health officer trying to do any surveillance on that kind of impact. It's absolutely impossible. And then, of course, with urbanization and all the things that urbanization brings with it, crowding, poverty, and drug use—really add to the dimensions of the problem of the spread of disease. In less than 20 years, in the western hemisphere the rural population has dropped from 31% to 24%. The shift is a very, very real one.

The third and final category of influencing factors is medical progress. Since cardiovascular disease is the major killer of people, there have been enormous advances both in terms of prevention and treatment in cardiology. Prevention lifestyle changes, as I mentioned, have had a very real impact. Risk identification. Everybody in this room is aware of his or her cholesterol. Some of us even try to do something about it. There are some new markers being developed such as lipoprotein A and homocysteine. And as these markers are developed and ways of dealing with markers are invented, there will be real progress here. I think the development of lipid-lowering drugs has an enormous potential in all populations for decreasing cardiovascular mortality. In terms of treatment, imaging techniques are vastly increasing. We can now really see what's going on in those coronary arteries. Revascularization, like bypass surgery or rotor-rooting, angioplasty, and

things like that, are becoming almost commonplace. They are easier to do; they are effective and even less expensive than they use to be. The problem with revascularization techniques is that those vessels have a habit of restenosing, of closing up once again. The area where we can expect to see progress is in slowing down that restenosis; there has been considerable progress. In one area there is some progress in re-engineering, doing something about the cells in the lining of the vessels that will preclude that kind of restenosis. So that looks good. In the care of newborns, it seems that if you have a fairly small impact on infant longevity, that can result in a significant population impact. There has been enormous progress here, too. The U.S. does not have a great track record in terms of deaths per 1,000 live births, that's the usual metric. I'd say that the U.S. has lagged behind many of the other developed countries. But in the U.S. in the 30 years from 1966 until now, there's a difference. In 1966 there were 23.7 deaths per 1,000 live births. This year there will be 7 deaths per 1,000 live births. That's tremendous progress. That's the good news. The bad news is that other countries are doing much better than that. I'm optimistic enough to think that the U.S. will continue to improve at that rate as well.

Vaccines have a potential of making an enormous impact on longevity. I mentioned earlier that the public health people are convinced we're going to have an influenza pandemic. The problem with influenza is we don't know what strain will attack. We keep hearing that it's going to be chicken strain, or pigeon strain, or whatever.

The most exciting progress is in genetics. The progress in genetics, in terms of vaccines, is to identify the genome of the virus—for example, the influenza virus— and to identify that part of the genome in all strains that is universal. Then you can develop a vaccine against that hunk of the genome. That's very, very doable in theory and people who are better scientists than I tell me that will certainly happen. With HIV you notice that there's an enormous amount of energy and resources put into developing a vaccine. Progress has been disappointing to date. There is no vaccine that works. But, again, at a theoretical level there's no reason why there shouldn't be progress, and I'm convinced that in the next decade there will be. If a vaccine were developed against malaria and an effective one against hepatitis C on a global level, that would make enormous differences. There are a number of centers working on those two vaccines.

Finally, genetics. Genetics probably has the potential for doing more in terms of the practice of medicine than anything that, not only we, but our ancestors have seen. But it's not all as clear as people would make out to be. We all read in the paper every day that they've identified a new gene that's associated with a specific disease. Then the next day one of the high-tech companies will come out with a test for that new gene for a specific disease. The fact of the matter is that very few diseases are caused by anomalies of a single gene. The vast majority of diseases are caused by multiple genetic anomalies plus environmental factors. Now there are a few diseases that are caused by one gene anomaly, but those of us in the insurance industry get all sick and nervous when we hear about genetic testing because we know that everybody is going to run out and get tested for A, B, C, and D disease and then, without telling us, they will apply for insurance. There's some truth in that, but I don't think we should all go out and drink hemlock today. I

don't think it's that clear because, as I said, the association between a single gene and most diseases is most unclear.

There are some exceptions. There is a not uncommon disease called familial polypus, the development of precancerous lesions in the intestinal tract. That is associated with a single gene and if one knows that he or she has that gene that person should get annual colonoscopies. The colonoscopist can snip off those little polyps and that person should have an absolutely normal life expectancy. A very small percentage of breast cancers are due to a single gene. Women who have that gene certainly should have very frequent mammography, and there are even some proponents of prophylactic mastectomy.

In terms of treatment, genetics hold an awful lot of promise. We talked earlier about antibiotic-resistant organisms. There is all the promise in the world of going in and genetically altering the organisms—not the human body, but the organisms themselves—and make them once again responsive to the therapeutic treatment. With tumors and cancers there's a lot of work, some of which is very successful already, of introducing genetically engineered viruses into the cancer and the viruses infect and destroy the cancer. There is a whole host of very fascinating things and these will have real impact.

One of the very interesting ones is genetically engineering animals so that their organs will be more compatible with transplantation to human beings. Instead of pig spleens, which you can't transplant because they'll be rejected, engineer pigs so that they make nice spleens that are compatible with being transplanted into human beings. That's pretty exciting if you want a pig spleen.

Finally, let's do a little bit of projecting. The U.S. resident population today is about 270 million. But, in 2050 the population will be about 394 million. There will be a lot of people in all age categories. These are five-year intervals, incidentally. But look at the very top where there are enormous number of, not only women but men, who are 85 years and older. The life expectancy for men is climbing faster than the life expectancy for women, and it looks as if maybe by 2030 or 2050 male longevity will exceed female longevity. That's a frightening thought, isn't it?

I want to leave you with this thought. There are a myriad of factors that will influence longevity and demography into the next century. In reflecting on this, though, it's clear to me that almost all these factors are under the control of mankind. Mankind has a lot to do with every factor that we've looked at with very few exceptions. The only question I would leave us all with is, is mankind smart enough, or motivated enough, to change all these influencing factors and make them positive factors instead of negative factors?

Mr. Shripad Tuljapurkar: That was a great lead in. I don't have very many answers, but I do have some ideas about particular things that might illuminate what's likely to happen and then a series of questions for which we don't have good answers. The first point, that mortality change is complex, has been nicely illustrated by the previous talk. The second point, which is relatively new, is that in the rich industrialized countries of the world, mortality change has an amazingly

regular characteristic over long periods of time. And, based on that, one could, and I will, make forecasts of mortality change. There are questions that this type of forecasting does not answer and there are great uncertainties associated with it, so much of my talk I will spend talking about what uncertainty is in terms of how it influences forecasts and why one should worry about it. Then I will touch briefly on global trends and the differences between global trends and what you see in the rich industrialized nations. Then I will close with the implications of mortality uncertainty and other kinds of demographic uncertainty for population forecasts.

We know that the details of mortality change are messy. Year-to-year decline is irregular. There are these persistent and puzzling differentials in mortality between the rich and the poor, between the more educated and the less educated. We don't really have a good handle on the structure that drives these differentials. The cause of death structure, as the previous talk has nicely illustrated, is difficult to understand and to predict. There is a poor understanding of the relationships among the driving forces. Therefore, we try to advance on a broad front.

One point that was not brought up is that mortality decline, which we've come to accept as sort of a feature of the passage of time, is startling reversible. For example, if you look at the former Soviet Union and some of the countries in Eastern Europe, where mortality was declining, not quite as fast as in the West, but nonetheless at a noticeable rate, that mortality decline has turned around. In the last decade and a half in the Soviet Union, mortality has actually increased dramatically. That increase seems to have slowed down and may be coming back down again, but there was just an enormous increase in mortality, especially among men in the middle working ages, from about age 30 to 50. And again, we don't really understand why that happened. There are lots of people working on this question, but we don't have a good understanding of it. I think it would be extremely useful if we look at that situation more carefully, because it helps us try to figure out what the dynamics of change really are.

Although there is all this complexity, there does appear to be one trend in the aggregate, meaning that we look only at mortality by age and sex over the long term. We look at changes over a period of at least four decades or so. In the highly industrialized nations there appears to be a simple and possibly general pattern of decline. What do I mean by that? To illustrate, I'll talk about the G7 countries. They're always, or often in the news. Take mortality data for those countries from 1950-1994. Although mortality change is a multi-dimensional process, we find that we can describe an enormous percentage of the variance in time of mortality rates using just one temporal factor.

What do I mean by that? The data that you start with is central death rates by age and time. You take the logs of those and you have a bunch of numbers. You can decompose those numbers into a series which has an age and time factor. And you get a complete decomposition. That's exact. These numbers, the S, the R, and so on, are called singular values. When you do this, if that first number is much, much larger than all the subsequent coefficients, then that first term is effectively a descriptor of the change in the entire mortality process. And if that happens, then

we say that the dominant temporal pattern is given by just that one time factor, and that by the time factor a percentage of variance is explained.

For the G7 countries that first factor explains over 92% of the variance in every country, actually over 96% in all except Italy. Chart 1 shows the different countries and the time factor. What is remarkable about this analysis, from our point of view, is that these factors show a surprisingly linear decline over the span of 50 years. This was most unexpected to us, and if you look at this in somewhat more detail, this impression of linearity does not go away. And given that we have such a pattern, one can use that as a basis for making projections of mortality. The thing to bear in mind is that we don't want to forget about all these other little factors which contribute to the uncertainty around the dominant pattern.

Given that we have this stable pattern of mortality change, we can make forecasts using it, providing that we incorporate uncertainty. Here's an example. Chart 2 is a two-sex forecast, meaning males and females together. It's a forecast of the life expectancy at birth for Canada starting around 1995 and going forward. The lines with dashes are the official Canadian forecasts from the Canadian pension plan. The solid lines represent forecasts using this trend that we discovered along with uncertainty, and these lines are probability projection intervals. We assert that there is, based on history, only a 5% probability that the expectation of life will be below the 50% line. Our 50% line is substantially higher than the medium projection of the pension plan. The same sort of forecast for Japan is dramatically different. The Japanese National Institute of Population & Social Security Research, which generates official projections for the Japanese government, actually produces only one mortality forecast. It's startling that it is conservative, given that Japan has had the fastest rate of mortality decline in the G7, which does not show any signs of slowing down imminently.

The stochastic forecasts are way up there. When we talk about changes in the expectation of life, almost all the data you see will show a certain slowing down as we go out into the future. That is not surprising because we have already knocked mortality at early ages down to very low levels. Most of what we're changing now is mortality at later and later ages. The leverage of that on the expectation of life is less than the leverage of a change in, say, mortality at age 5 or 10. The flip side of that is that when we talk about a one-year increase in the expectation of life from now forward, most of that additional year gained will be lived at high ages; it will be lived in retirement. If we make a forecast that differs from an official forecast by six years, then virtually 90% of that additional six years will be years spent in retirement. From the standpoint of retirement planning and health care, the implications of a one-year, two-year, or five-year change are quite substantial.

That is an example of the pattern that is surprising, but it's robust. We can use it. and I believe it is something that actually has a lot to do with the insurance industry, because you're sort of riding this downward trend and it's a useful thing to have as a benchmark for risk assessment purposes. There are many questions that remain. There is the uncertainty that I talked about, which is actually quite important. We don't understand its dynamics very well. There is a question of whether the trends that we observed over the last five decades will persist over the

next five. That's unclear, but on the other hand, we don't have much more to go on. There is no obvious discontinuity that we can point to which says the trend is going to change. If we wanted to analyze the question of the persistence of trend, we would need to understand better why we have it in the first place, and we don't. There is growing evidence that old age mortality is declining rapidly. The trends that I have described are based on the usual data on death rates, which means that with the exception of Japan, we don't have a good idea about mortality at ages over 85. The reason for that is quite straightforward; if you have somebody who is 90 years old now and alive, he or she was born at the turn of the century at a time when record keeping was poor. Therefore, if he or she says, "I was born on the first of 1901," you don't know whether that's because he or she thought 1901 was a particularly good year and a better year to be born in than, say, 1903 and so on.

There are lots of uncertainties about mortality at old age. However, in the Scandinavian countries for almost a couple of centuries now we have had remarkably accurate record keeping, and so there we have a pretty good idea of who was born when, and consequently of death rates at old ages. In those countries death rates at ages 90, 95, 100, and now 105 are declining every year at rates that appear to be comparable with the rate of decline at ages 75, 80, and 85 in other places. If that is true, then we are seeing a remarkable expansion, as it were, of the tail end of life. And that would, if anything, make the forecasts I showed you conservative. The problem of disaggregation, which the previous speaker talked about at some length, remains extremely troublesome from the standpoint of projection. It's also extremely important from the standpoint of policy—both the sorts of policies you issue and the sorts of policies the government tries to make. It comes down to the question of, if you wanted to spend, say, $5 million to improve mortality conditions, should you spend it on education? We know that better educated people have lower mortality rates. Does education have an absolute affect or relative affect? Does it diminish over time? These are questions that we don't really understand well.

There is variation of the trend that I showed you between countries. In Chart 1 most of the lines were fairly close together except for one. That one country was Japan. Japan is a country that we ought to try to understand better with respect to mortality because we would like to know what happens there. Is the fact that mortality in Japan has declined so rapidly just a consequence of catching up? Is it that after the 1950s the Japanese imported all the know-how about how to reduce mortality change and put it into place and, therefore, they just caught up real quick? And now they're going to slow down? We don't really know the answers to these things.

Once we leave the rich industrialized countries things start to become a lot less regular. If we look at China and India, which together are about one-third of the world population now, China has had very rapid mortality decline in the last two decades. India has had much slower mortality decline, but it has taken place at a fairly regular pace over the last five decades. The data problems that I mentioned to you about old-age mortality show up again when you try to look at other countries. In China we don't really know what happened before 1965. They had three basic censuses that were available before the 1980 census, but they were not

particularly reliable. Same sort of situation holds in the former Soviet Union. When they took censuses there, they were told what the results ought to look like. And the results looked like they were supposed to. Now demographers have gone back and done a lot of detective work and dug out primary sources and used a number of demographic techniques. Now we have a pretty clear idea that in China mortality was actually fairly high until the late 1960s. Some enormous bulges, like the great leap forward, produced an enormous jump in mortality in China. But now it's declining. In Eastern Europe there a lot of problems with respect to mortality, although the countries between the former Soviet Union and Western Europe appear to be turning around. Their mortality appears to be falling now.

Sub-Sahara Africa is in a sense the worst place for mortality conditions on the planet. There are countries where mortality really hasn't budged much from the turn of the century. And, of course, AIDS looms over Sub-Sahara Africa and certain other countries in southeast Asia, but certainly in Sub-Sahara Africa there is potentially enormous impact from AIDS. The International Division of the U.S. Census Bureau has made forecasts of the expectation of life at birth in the year 2010 for a bunch of countries in Sub-Sahara Africa. The impact is enormous, so life expectancy is about 32. Without it we'd be up at about 68. There are countries where 25% of the young male population, adult male population, is infected. It is not clear how these countries will deal with it; it's not clear how anybody will deal with it. There is enormous uncertainty associated with this type of forecasting, but I won't get into that much.

Let's get back to U.S. demographic futures. The uncertainty that I'm talking about here is actually dynamic uncertainty; it's uncertainty about what happens over time to mortality. Most of you are used to dealing with risk in very sophisticated ways, but the sort of risk that you deal with typically is conditioned on some type of future. What I'm talking about is the risk associated with the future that you're conditioning on. And in projecting mortality and projecting the expectation of life, there is an uncertainty of about one year per decade that builds up in these projections. This is sort of cumulative. Fertility uncertainty is enormous. We really don't know what fertility does or why. There's been a lot of work on this question, but the rate at which the conditions of life expectations, attitudes, and so on, among women appear to be changing with regard to the question of how many children they actually have. It is very difficult to keep up with. As a result, when we try to make forecasts of fertility, they are very uncertain. This is 0.5 of a child per woman in a society where women on the average are having 1.5 children. An enormous uncertainty! It's conceivable that all the women might have less than one child. It's conceivable that they all might have close to 2. This means that if we look at the sequence of births over time, we really have a pretty poor idea of what's going to happen. Initially, when we looked at this type of uncertainty, people were very skeptical. They said, "Well, nobody is going to have such a small number of children." Well, in Italy they're down to less than 1.2 children per woman over her entire reproductive life. At that rate Italy is going to disappear, literally. If, in Italy, fertility turned around and went back to replacement, in 30 years the Italian population would be 27% lower than it is today. That's a nontrivial amount. And I'm talking there about a case where fertility recovers. There's absolutely no sign that this is happening. If it stays the same, the decline

in the Italian population will be about 50%. Now these are not trivial numbers. And even people who are advocates of the view that population is the source of all evil have to consider the social, economic, and other implications of such enormous population declines. That is a lot of uncertainty about fertility. When you put these two together and try to make population forecasts, the result is you get great population uncertainty, and because of the fact that these uncertainties accumulate, the uncertainty about the future increases as we go further out.

Chart 3 is a population pyramid for the U.S. from 1990 to 1995. If we go forward 10 years and draw a population pyramid, the dark and light bars in Chart 4 represent a bracket which contains 95% of the forecast. You see that there is some modest uncertainty at the bottom end because of births. At the top end there is also a little bit of uncertainty, but it's barely visible in this example. If we go out another 20 years, (Chart 5), then we see that mortality uncertainty starts to make itself felt. Fertility uncertainty starts to climb into this pyramid. If we go out to 2045, as shown in Chart 6, we have much greater uncertainty at both ends, but this is the dominant uncertainty.

What are the implications of uncertainty? Uncertainty translates into risk. For insurers, there is the question about your ability to discriminate among individuals in terms of their risk levels. Differences in mortality of the sort that I'm talking about at the level of age and sex will affect your ability to discriminate among individuals on the basis of age and sex. If mortality keeps declining, then the use of age and sex, for instance, as discriminants starts to change. You have to start to worry. If 45-year-olds have the same mortality as 40-year-olds and 35-year-olds, and so on, then age is no longer a very good discriminant. Although we tend to use a lot of factors to discriminate among people on the basis of mortality, in virtually every analysis the first factor, the leading factor, has always been age. Age is the first thing that you look to. The ability of that factor to discriminate between risks is declining over time and increasingly over age. Then there's the question of whether you can write trends in risk levels and the extent to which the regularity of the trend in the rate of decline interacts with the uncertainty around that trend in the short run.

For policy makers, this uncertainty is again important—policy risk in the context of policy about Medicare, retirement, social security, or pensions. We can think of policy risk, or one major component of policy risk, as being the probability of success—the probability that in fact the policy will do what you think it will do. Most of our policies are contingent on some view of the future. The point about the pictures that I have shown you is that the future is uncertain, and consequently policy makers always make assumptions about the set of futures they're going to deal with. And when they do that they are gambling. This type of analysis gives you one handle on the type of risks that are associated with certain types of policies.

Then, of course, we can think about utility from the standpoint of, say, the policy maker or the individual citizen. That utility is also a function of this risk. These sorts of analyses may help us to try and explore some aspect of this risk.

Mr. David M. Holland: I'd like to talk about a glimpse into the 21st century. I'm doing it from the perspective of a life insurance actuary, not as a demographer. My best claim to fame is that I have subscribed to the *Statistical Bulletin* for many, many years and studied and followed trends of mortality. When you think about making presentations, prognoses, and looking into the 21st century, it's a somewhat humbling experience. One of the things I wondered about were some of the projections that other people have made and how well they had turned out; maybe it would give me some comfort in terms of how my projections might turn out. Thomas Edison said the phonograph is not of any commercial value. Grover Cleveland (you would expect a President of the U.S. to be very astute) said that sensible and responsible women do not want to vote. Thomas Watson, the founder of IBM, said that there was a world market for about five computers. This is from about 1943. And then there's Ken Olson, the president of Digital Equipment, who said that there's no reason for any individual to have a computer in their home. I think given this experience, I feel a little more confident in making some comments.

I don't know how many of you celebrated October 12, 1999, but that was Y6B day. We've been worried about Y2K, but supposedly as of October 12, 1999, the world population hit 6 billion. That was dynamic. It took us until the year 1804 to get the first billion people in the world. Another billion occurred 123 years later. These events have been occurring with greater frequency. Recently it's been about 12-14 years, although we expect to see this trend slow down somewhat. The current projections come with ranges in estimates. A nice, conservative mid-range from the Census Bureau says that by 2050 the world population is expected to be on the order of 9 billion people—a 50% increase. As Tulja was saying, we expect to see some rather striking differences in terms of how events will progress. If you look at Europe in terms of the change that we have here, you see that over the next 50 years we're actually expecting a decline in population. From Italy, Spain, Germany, and all the countries that are really part of the developed nations right now, we see at least according to current levels of births, that by the year 2050 these populations will be declining. Oceana will be about the same; in North America, we have a little increase over a period of time; out in the rest of the world the largest is, of course, Asia. Close behind is Africa, which has significant projected growth rates. Right now we're growing about 1.3% per annum. By the year 2050 what will be the leading nations in terms of population? India is projected to be number one, I believe, followed by China, Pakistan, Indonesia, Nigeria, the U.S., Brazil, Bangladesh, Mexico, and the Philippines. We will see quite a different shift in the world and the way population is distributed, and that will bring about its own set of problems in dealing with resources.

Look at population pyramids. Chart 7 is from the United Nations. It's very similar to the ones that we have. Right now we have a base of about 300 million males and 300 million females, at least in terms of zero to four for the pyramid. We see that it really does look like a nice Mexican pyramid. If you look at the mid-lines projection, Tulja showed us some of the variation, what we see is that the base is still 300 million males to 300 million females but we see the pyramid moving up, just like a sound wave or maybe like a tsunami following an earthquake. Once the motion is set into action we'll see these things fill out.

I think it's important to note what the shape of the pyramid is going to be from ages 50 and up ranges in the year 2050. Everyone who is going to be in this 50 and up has either been born or will be born within the next 2 or 3 months. In terms of the variation, in terms of base, in this part of the pyramid will have numbers that seem to be realistic and we can start as our working assumption (Chart 8). Also, you see over time, at least with expectation of life of females being larger than males, the way the pyramid will develop. The prognosis is that the pyramid, maybe it's a flower pot now, will become a little more to the right side. You see that for males, at least at population age 0, there are 95 females for every 100 males. If we go up to age 100, there are 386 females for every 100 males. There may be something to look forward to yet, in terms of the way the world will develop. The previous charts were the population for the total world. For developed countries we see that the flower pot is maybe even becoming a flower emerging in different ways. The developed countries have a very narrow base. What we're likely to see, at least according to some projections, is in the future that we will have more elders than we have juveniles, and that has significant implications.

From an insurance point of view and looking at some historical insurance patterns, one thing that we see in terms of the products that are sold in the insurance market is that the annuity market has been catching up with, and is now at the same level as, the premium for ordinary life insurance. In fact, if you look at the development of first-year premium, you'll see that right now annuity income is much more significant than life insurance income. In thinking about that, I will go back to the bank robber, Willie Sutton, who was also somewhat of a philosopher, and whose well-know statement when asked why he robbed banks was, "because that's where the money is." I'd like to set the stage for where the issues are and where some of the products are likely to develop and what we have.

Let's look at the demographics of life insurance. I've taken our company's portfolio, which is in the $70 billion range. It seems to be a reasonable portfolio. I asked, "At what age do people buy life insurance?" As you can see in Chart 9, there's a predominant portion here in ages 35-40, and if you look at ages 30-50 in a very concentrated way, that's the market that is served by life insurance, at least according to recent sales. If we look at annuities we see a different distribution. It's not the 30-50 distribution, in fact, 30 is about 1%. We see the bulk of the business is more in ages 50-70; maybe even going out to ages 50-80. I think, as the demographics of the underlying population will change, we may see changes in the products that we market.

A new and emerging product, which is a little more than 10 years old, is long-term-care insurance. That also has a demographic trend. We couldn't really find any purchasers under age 50. The concentration of long-term care as it is right now is 65, 69, and 70, so we find this particular product in the older age group. I expect that's because there's a very limited proportion of the population that is currently covered by long-term care, but we may see this occur in somewhat younger ages.

Another factor I'd like to put in the recipe for us to think about is consumer expenditures. Chart 10 shows consumer expenditures in 1997. Again, the reference is to consumer units. It's not an individual or a family, but it's very similar to a family; it may be a one- to four-person consumer unit. What we see is there's a pattern of spending that goes from age 25 up to a peak at age 45-54; after that it declines. Now there are probably logical, rational explanations. You may find that when someone becomes maybe 35, 36, or close to 40, the expenditure for potato chips in the household starts to decline. And that may be because the teenagers have grown up and they've gone off to college. Similar to the time when veterinary expense declines because the children have gone off and the dog dies and you don't have to worry about things like that. We see trends in housing where there's a lot more rent or home ownership in the U.S. There are certain things that we can assume or at least think about when we look at the difference in consumer expenditures by age.

But what I'd like to focus on here is the 45-54 group because as we see increasing expenditures, we see, I think, favorable economic situations. On eof the most striking phenomena that we've seen is the baby boom, which occurred in 1946-64. Chart 11 shows growths from 1909 through 1994. I split the baby boom into two sections. The first section from 1946-53 was when the number of births was less than 4 million. If you look at the period 1954-64, births for that particular period were about 4 million per year—a very high level. I think, as we see, the digestion of this wave over time will correct a lot of our trends.

Probably this is the most significant chart in terms of the short run. Sometimes I think of this as Joseph's prediction where in interpreting Pharaoh's dream, he talked about the fat years and the lean years. I think for the next 10 years things look fairly reasonable and we should be preparing. I think after 10 years we will be hitting the lean period. In Chart 12 three age groups are graphed in terms of population projections from the U.S. Census Bureau. The first is ages 30-49, the next group is 50-69, and the final group is 70-89. Surprisingly, or maybe not surprisingly, most of the groups look reasonably linear; there's not a lot of bend or change. 30-50 age group is relatively flat and will be declining.

I picked 1996 as a starting point because that's when the first of the baby boom turned 50. Now, if you're in a business that concentrates on selling products to people aged 30-50, as we saw in life insurance, what we see is that there is not going to be a demographic boost in terms of the products that you sell. Life insurance sales have been relatively stagnant in recent years just as the population growth from the 30- to 50-year-olds has been relatively stagnant. If we look at the older age group, 70-89, we may see the change in long-term care; yes, the numbers will go up from 21 million or so up to 25-26 million people, but it's not dramatic. Obviously, what's dramatic on this chart is what's going to be happening to people ages 50-69. These are the people who are driving spending. If you remember I was talking about ages 45-54 as being the peak spending years for people within the U.S. Age 45 would start the peak spending; for the baby boomers 46 years later would be 1991. If you go to age 54, that cohort would be dropping off peak spending in the year 2000. What we're going to see in the year 2000 is the other baby boomers coming on board; not the 46 wave, but by the time

you get to the 1954 wave they will be coming on board 45 years later in 1999. We're going to see these people, who are in the increasing section of the population, being at peak spending years. I hope they are going to address personal responsibility with respect to saving, and I think that's one of the things that's helping to drive the development of the annuity business that we see now. This is the age group that is more likely to be the target age group for annuity purchases.

In looking at the U.S. population going further, putting the fat years and the lean years together in Chart 13, we see that was linear in the previous chart is going to change quite a bit. What was also linear and what was also flat will be taking off. It's no great surprise to us, I'm sure, that the younger age group will continue to decline. Maybe we'll have an echo and some increase, but not a lot of variation compared to what's happening to the people in the 50-69 age group where it will continue to increase to about the years 2015-2020. We see that after a very slow period of growth up to 2010, people in the 70-89 age group will be increasing. I've also shown the projections of people aged 90 and over who will also be increasing, not as dramatically as going again from 21-22 million to 50 million and over, but still the growth from two million to nine million will be significant.

One of the statistics, and one that you're probably very familiar with, is to look at the ratio of the older-aged people to the younger-aged people. There are many ways to calculate this particular ratio. Since I was using the breakdowns that I have, I have shown the number at age 70 and above as a percentage of the number age 30-69. I see retirement years being pushed out already, so the 70 years olds and up will be employed, while the 30-69 will be the core working group. For the next 10 years that number will be stable at around 18%. What happens is when we get out to the year 2040, we see that the ratio has nearly doubled, 35% is the ratio of people aged 70 to the number of people aged 30-69. At the SOA meeting two years ago in Palm Desert, Jim Hickman, the keynote speaker, reminded us of Adam Smith's comments in *The Wealth of Nations* in 1776. Maybe Jim, during questions, would elaborate on this, but quoting Adam Smith, "With this proportion must every nation be regulated by two different circumstances. First by the skills, dexterity, and judgment with which it's labor is generally applied; and secondly by the proportion between the number of those who are employed in useful labor and that of those who are not so employed." I think, as we look at the work force versus the retired population, and as we see improvements in mortality increasing longevity and what's at stake, we will see that when this ratio stays relatively constant, we expect the times or the environment that we have to be relatively constant. But as it increases it will put more of a strain on the wealth of nations. That's the likely scenario that I see in terms of looking forward.

I have to say that there are things that could be paradigm shifts that could change the nature of the world dramatically. A world war is something we don't like to think about, but World War I was the war to end all wars. We hope that nothing like that will happen again, but it could change. Economic catastrophy could occur. It depends on how the very narrow intricate relations that we have between countries could change things. We saw the Asian meltdown last year in terms of what the effects are. Looking at our statistics, it appears that things will be robust,

with increasing numbers of people in the peak-spending years. It looks very favorable for our economy. But as people buy variable annuities and variable insurance, sometimes buying variable doesn't always mean increasing number of people.

We've talked about epidemics. Dr. Hertz mentioned Ebola, new viruses, and AIDS in Zimbabwe where the life expectancy has been reduced from about age 65 to about 40. These facts have been factored into the United Nations population projections that we used, but because in these areas the fertility rate is so high we still expect significant growth in population by Asia. This is true also in Africa, even though these people do have a relatively high of HIV infection. I think about 25% of Botswana's population has been affected.

Some other paradigm shifts that we would see, again from an insurance point of view, are changes in the structure of the financial insurance industry. We are going through a wave of mergers and acquisitions and changes in tax and inheritance laws that could change the economic outlook for the life insurance actuary. In fact, Congress is talking about major changes to the inheritance tax.

You will see technological changes, we will have virtual companies, Internet distribution. And to me one of the most amazing and significant areas will be the human genome project, as it will change practice of medicine over the next 20-50 years. Things that are being done now and things that could be done could have a tremendous impact on the increase of life expectancy. That will also have implications that are not always favorable. As we see increase in the life expectancy we will see changes in how we will provide for ourselves, our parents, and our children.

We're going back to predictive statements. As we think of the president of Warner Brothers who said, "Who wants to hear actors talk?" I think, again, we can say that these are just projections or ideas as to how things might develop, but things could change quite a bit over time.

Mr. Ethan E. Kra: We just finished a major mortality study in the retirement systems area and found that once you get to the very oldest ages, granted we had limited data, that the mortality rate was almost like approaching an upper limit, around 40% a year. Once you get into the very oldest stages it no longer followed the paradigm of approaching 1.0, it was approaching about 0.4, 0.5, beyond anything we could measure. Have you seen similar items in other studies or other analyses? Second, we saw very different mortality experience within different socio-economic groups, and we measured that by blue collar versus white collar. Where at certain ages the differentiation in mortality was a factor of 3 to 2, and to the extent that the socioeconomic nature of the country changes over time, to what extent will that affect mortality experience?

Mr. Tuljapurkar: Saturation of mortality is something that has been seen in some of the Scandinavian countries and there's a collective data base at Germany's Max Planck Institute of Demography. They have a number of data bases that show that. And interesting results are showing up in animal studies.

Dr. Hertz: What I didn't mention earlier was smoking. I said that 25-27% of adults in the U.S. smoke. Of that same group, who apply for $250,000 or more of insurance, in our laboratories at least, only 16% smoke. There really is a difference among socio-economic groups.

Mr. Holland: The old omega really doesn't have an upper bound; it just keeps on going. We have to cut it off. In 1997 **Jean Calment** passed away at age 122; she had the life-span record in terms of the *Guinness Book of World Records*. We are seeing populations moving up into the older ages. Part of it is improved health. You've talked a lot in terms of the difference between white collar and blue collar. I'm sure there's a lot of factors there that relate to the access to medical care and things that will happen in this phase of life. But I think you're right to say that we are moving things forward.

Jim, did you see anything in the follow up to the Social Security mortality symposium? Have you done some Delphi questions as to an upper bound in terms of age?

Mr. Hickman: They answered the questions, but, I don't recall an answer to the upper bound issue.

Mr. Robert J. Johansen: I have a couple of comments. I'm chairperson of the Life Insurance Research Committee. We have completed a Project Oversight Group, which will look at the subject and shape of the mortality curve at ages over 100. We have, I'd say, a cracker-jack group. It will be sponsoring an international symposium probably in late spring 2000. I'd also like to say on the question of making forecasts, look at scale G, which was fairly new in early 1980s and when we completed the annuity 2000 table we had to modify the female mortality improvement rates drastically. Nothing lasts forever, especially anything that's projected.

I might also add that there is a new mortality study for the purpose of justifying the 1994 MGDB valuation table. That study has been, or at least the tabulations have been, completed. They're now on my desk and I think there will be some surprises there. As far as I know it's the first annuity mortality study of annuities during or prior to annuitization.