Estimating International Adverse Selection in Annuities

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Abstract

It is well known that purchasers of annuities have lower mortality than the general population. Less widely known is the quantitative extent of this adverse selection and how it varies across countries. This paper proposes and applies several methods for comparing alternative mortality tables and illustrates their impact on annuity valuation for men and women in the US and the UK. Our results indicate that the relatively lower mortality among older Americans who purchase annuities is equivalent to using a discount rate that is 50-100 basis points below the UK rate for compulsory annuitants, or 10-20 basis points lower than the UK rate for voluntary annuitants. We then draw on the mortality experience of over half a billion lives to estimate mortality differentials due to varying degrees of adverse selection controlling for country, gender, and an allowance for mortality improvements. Results show that adverse selection associated with the purchase of individual annuities reduces mortality rates by at least 25% in the international context. We also find that the system of mortality tables used to value Japanese annuities is quite distinct from international norms.

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As life expectancies rise and people anticipate spending longer in retirement, it is becoming increasingly important for aging populations to gain access to financial instruments that can help them insure against the risk of outliving their assets. Life annuities are one product that can help in this regard, in that they help shift mortality risk away from individuals and toward the insurer. In exchange for a fixed sum of money, the insurer pays out a regular flow of income for life and thus guarantees that the survivor will not live so long that he runs out of assets. Inevitably, well-functioning funded retirement systems will require properly-functioning annuity markets, as annuities play an essential role in converting asset accumulations into a regular flow of retirement income guaranteed for life. The importance of annuity markets and their role in funded retirement systems have been explored by Brown et al. (2000); Diamond (1999); Doyle and Piggott (1999); Feldstein (1998); Finkelstein and Poterba (2000); James and Vittas (1999); Milevsky (1988); Mitchell et al., (1999); and Warshawsky (1988), among others.

But as actuaries well know, it takes a great deal of statistical information on mortality patterns by age and sex to develop the necessary survival forecasts needed for valuing annuity products. In practice, many developing countries lack a vital statistics collection mechanism, so they have few national mortality statistics specific to their own populations. Consequently policymakers and researchers working throughout Latin America and Asia must often rely on mortality data from other countries in order to value life insurance and annuity products.

In order to properly price such life annuity products, actuaries and financial experts must utilize mortality tables, which are statistical representations of the expected distribution of a population's remaining life span. Devising a mortality table (or life table) is very data intensive, of course, since it relies on collecting the incidence of deaths by age and sex occurring in a given population over a specified time.[1] Using the raw data, experts then compute the estimated probability that a group member aged x will die in the next year of life, either by fitting a hazard rate model to the empirical distribution of deaths in the population, or by applying a smoothing algorithm to the raw maximum likelihood estimates. These smoothed estimates are then used to construct a complete mortality table. For most ages, the results are very small numbers, and hence a large number of lives must be observed in order to obtain reliable estimates of very small probabilities.

Most developed nations today have their own mortality tables: some are freely available[2] and others are more difficult to obtain. While actuaries are aware of the differences, these tables differ across countries in ways that are quite striking to the non-actuary. Comparing OECD countries, for instance, population mortality pattern differences are substantial enough to imply very different consequences for programs intended to maintain living standards for the older population (Hewitt and Schieber, 2000). In this paper, we explore alternative measures of these mortality differences and then go on to examine mortality differences in annuitant pools as well. Based on prior research using US and UK data (Brown et al. 2000; Finkelstein and Poterba 1999) we anticipate that in the larger sample of countries we examine here, annuitants will also

[1] For additional background see Blake (1999), Gerber et al. (1997), and Executive Committee of the Continuous Mortality Investigation, Faculty and Institute of Actuaries (1999).

[2] The Society of Actuaries maintains an excellent database of international mortality tables on its website www.soa.org. Recent European population, insured lives, and annuitant mortality tables may be obtained from MacDonald (1997).

have lighter mortality patterns than the population as a whole. This is anticipated because people who opt to buy an annuity in a voluntary purchase market are likely to be self-selected to live longer than average – partly, it may be argued, because they have private information about their own health status, and partly because they tend to be wealthier than the general population.

In this paper, we show how using different mortality assumptions can influence the assessment of the "money's worth" of annuity products. We focus on mortality patterns for older persons, since this is the population most relevant for retirement system purposes. We first explore key differences between mortality tables for the same groups in the United States and the United Kingdom, since many other countries in the Americas, in Europe, and in Asia use either the US or UK tables to value annuities. After comparing how mortality patterns differ across the developed world for the older population, we estimate an empirical model to quantify the extent of adverse selection among annuitants across our sample of countries. To do this, we collect and employ data on the mortality experience of over half a billion lives to estimate mortality differentials by sex across different countries. This information and our statistical model permits us to quantify the extent of adverse selection in mortality tables specific to annuitants versus the general population, using alternative mortality metrics. We also outline some puzzles that arise in the cross-country data context. The results indicate that the choice of mortality table has a potent effect on annuity money's worth calculations.

I. What Mortality Tables Tell Us

A mortality table represents an estimate of the statistical distribution of the remaining life span that can be expected for members of a given population.[3] A mortality table is typically derived by beginning with data on deaths occurring in the given population over a specific period

[3] For additional background see Gerber et al. (1997), and Faculty and Institute of Actuaries (1999).

of time. The probability, q_x, that a member of this group aged exactly x will die in the next year of life is then estimated by either fitting some sort of hazard rate model to the empirical distribution of deaths in the population, or by applying a smoothing algorithm to the raw maximum likelihood estimates of q_x. As a final step, the smoothed estimates of q_x are used to construct a complete mortality table. For most ages, q_x is extremely small, which implies that a large number of lives must be observed in order to obtain reliable estimates.

A prominent source for mortality data in the United States is the US Social Security Administration (1999). Using these data as input, mortality tables have been constructed by the Society of Actuaries (1999); these have been updated in Mitchell et al. (1999). In the UK, mortality tables are produced by the Continuous Mortality Investigation Executive Committee of the Faculty and Institute of Actuaries (1999), and more recently by the Government Actuaries Department (2000). Because the US and the UK data collection mechanisms for mortality experience are substantial and relatively consistent, it is widely believed that these two countries produce reliable mortality tables. As a consequence, these tables are extensively used in both developed and developing nations as a basis for modeling local mortality. In practice, US mortality tables appear to be commonly used in the Western hemisphere, while UK tables are typically employed in countries that were once British colonies or where British influence was strong.[4]

Mortality tables may differ across segments of the population for various reasons, one of which is adverse selection. This could arise, for example, if purchasers of annuities are more likely to live longer than average. In such a case, the observed mortality pattern for annuitants

[4] See James and Vittas (1999). Often actuarial adjustments are applied to these tables, ostensibly to make them more reflective of local conditions. Lacking good mortality data, however, it is difficult to know what actuarial adjustments might be appropriate.

would be lower than that of the general population, requiring that separate mortality tables be prepared for the annuitants and the general population. How important this adverse selection effect may be in the annuity market is likely to depend on the extent to which annuitization is optional. In the UK, for instance, a portion of retirement benefits is often subject to mandatory annuitization, whereas other benefits may be voluntarily annuitized. As a result, separate UK mortality tables have been generated for voluntary as well as compulsory-purchase annuitants, both of which differ from that of the general population (Finkelstein and Poterba, 1999; Murthi et al, 1999). In the US, retirement benefits paid under the current Social Security system are annuitized, but corporate pensions are increasingly paid as lump sums rather than the conventional annuities of times past (Mitchell 1999). As a consequence of the fact that some retirees purchase annuities while others do not, US mortality tables are published for both annuitant purchasers and for the general population, with the latter having higher mortality than the former (Brown et al., 2000).

Mortality tables also change over time as a result of past and projected future improvements in life expectancies. Over the last several decades, mortality among older people has dropped rapidly in developed countries, and there reason to believe that this will continue in the future (Executive Committee, 1999). Actuaries tend to handle this problem by estimating so-called *period* mortality tables from past data, and then devising separate, forward-looking, *cohort* mortality tables by extrapolating future trends in mortality. Of course, anticipated future declines in mortality built into cohort tables are only estimates based on past trends. Nevertheless these must be incorporated in valuing annuities since future mortality estimates are needed to determine the money's worth of retirement income flows for people alive today, some of whom will survive into the future.

A. Metrics for Comparing Mortality Tables

There is no single generally accepted method that can be used to compare mortality tables across countries. In this section we develop five metrics that can be used for comparing mortality tables: plots of survival frequency distributions, the A/E method, the expected remaining life method, the present value of a life annuity metric, and a measure we call the internal rate of return. We illustrate the different answers these five metrics yield by using them to compare the 1998 US and UK mortality tables for men and women currently age 65.

Plots of survival frequency or age at death distributions

A conventional way to compare mortality tables is to plot expected survival frequencies by age and examine them visually. To compare different mortality tables, this approach would graph the percentage of individuals who attain age x given that they reached age 65. An advantage of the graphical approach is that it affords an illustration of which mortality curve is higher (or lower) at given ages. A major disadvantage of this technique is that it does not offer any measure for "how far apart" two mortality or survival tables might be.

A/E Method

The A/E ("A over E") method is also used by actuaries and demographers to compare mortality patterns of two different populations. It expresses the number of deaths expected in a population with a given age structure using one table ("the benchmark"), and compares these to the expected number of deaths in a population of the same size in a second mortality table. The results are generally presented as a ratio multiplied by 100. For example, a value of 100 implies that the same number of deaths is expected in a given population relative to the benchmark. This measure is mathematically equivalent to a ratio of the weighted average probabilities of death for the two mortality tables, using a specific population structure for the weights.

The specific A/E measure one obtains depends, of course, on the benchmark age distribution of the population used to calculate the number of deaths. In what follows, we will use as the base the US Male period population table. All A/E comparisons are then computed as:

$$\text{A/E} = \frac{\sum_x w_x q_x^*}{\sum_x w_x q_x} \times 100$$

where q_x^* is the probability that an individual of age x dies according to the table in question, and q_x is the probability that an individual of age x dies according to the US Male period population table. The weights, w_x, are set so that w_{65} = 100,000, and $w_x = w_{x-1}(1 - q_{x-1})$.

Expected remaining life method

A different way to compare mortality tables determines a person's expected remaining lifetime (in years) conditional on having attained a given age, in the different tables. For the present analysis we generate these data for people who attain age 65, and the relevant statistic for a given table is calculated as:

$$\text{Expected Remaining Life} = \sum_x (x - 65 + \tfrac{1}{2})\,{}_{x-65}p_{65} \cdot q_x$$

where ${}_{x-65}p_{65}$ is the probability that an individual alive at age 65 lives to at least age x and q_x is the probability that an individual alive at age x dies before reaching age $x+1$, according to the mortality table in question. The same statistic is computed for a benchmark mortality table (the same one used previously) and the two numbers can be compared. When calculating this number we assume that deaths are uniformly distributed over the year of age x.

Present value of a life annuity method

Yet another way to compare two mortality tables is to compute for each table the present value of a life annuity of $1 per year commencing at age 65, paid continuously until an individual's death.[5] This approach is similar in spirit to money's worth calculations for life annuities, in that the result depends on the choice of discount rate.[6] Specifically, the present value of a $1 annuity is a monotonically decreasing function of the discount rate chosen. If the discount rate were assumed to be 0% per year, this statistic is then precisely equivalent to the individual's expected remaining lifetime (the third method described above). As a consequence, the expected remaining life is the maximum possible difference in annuity values between any two mortality tables. Our metric is then developed as:

$$\text{Comparison of PV Life Annuity} = \sum_x \bar{a}^{2\%}_{\overline{x-65+\frac{1}{2}}|}\ {}_{x-65}p_{65} \cdot q_x$$

where ${}_{x-65}p_{65}$ is the probability that an individual alive at age 65 lives to at least age x, q_x is the probability that an individual alive at age x dies before reaching age $x+1$, according to the mortality table in question, and $\bar{a}^{2\%}_{\overline{x-65+\frac{1}{2}}|}$ is the present value at 2 percent p.a. of an annuity certain, paid continuously for x-65+$^1/_2$ years. In the calculations, we again assume that deaths occur uniformly over the year of age x. Note that if $\bar{a}_{\overline{x-65+\frac{1}{2}}|}$ is calculated at 0 percent interest, it equals x-65+$^1/_2$, showing the consistency between this method and the expected remaining life method.

[5] Our formula assumes that the payment is received continuously, beginning at age 65.

[6] For a discussion of money's worth measures in valuing annuities see Mitchell et al. (1999).

Internal Rate of Return (IRR) method

An alternative approach considers the mortality process as akin to a mathematical discount rate. That is, if $1 of today's money were to be divided in five years time between survivors of a group of one million people alive today, each individual survivor's share would grow over time with mortality, just as it would with compound interest. So to compare mortality tables, one could use a first mortality table to solve for the internal rate of return required to equate the present value of a life annuity computed using a second mortality table and some fixed interest rate.

To implement this technique, we require both a benchmark mortality table and an interest rate. In what follows, we calculate the value of a life annuity using first the US Male population period table and an interest rate of 5 percent per year. We then solve for the interest rate required to equate the annuity in present value with some other mortality table. In other words, this approach solves for the *r* in the following equation:

$$\sum_x \bar{a}^{r\%}_{\overline{x+1-65|}} \cdot {}_{x-65}p_{65} \cdot q_x = \sum_x \bar{a}^{5\%}_{\overline{x+1-65|}} \cdot {}_{x-65}p^*_{65} \cdot q^*_{65} = 10.18079$$

where ${}_{x-65}p_{65}$ is the probability that an individual alive at age 65 lives to at least age x according to the mortality table in question; q_x is the probability that an individual alive at age x dies before reaching age $x+1$; $\bar{a}^{r\%}_{\overline{x+1-65|}}$ is the present value at r percent per year of an annuity certain paid continuously for x-65+$^1/_2$ years; and ${}_{x-65}p^*_{65} \cdot q^*_x$ is the probability that an individual alive at age 65 dies aged x according to US Male population period mortality.

B. Comparing Mortality Tables Using Cross-Country Variation

To implement these measures, we use the most recent US mortality information on voluntary annuitants (from Brown et al., 2000), US data on group annuitants (RP2000), and UK data based on voluntary annuity tables with estimated mortality improvements. A first set of comparisons uses survival functions for a cohort of 65-year old male and female annuitants in the UK and the US, respectively, appearing in Figures 1 and 2.

Figures 1 and 2 here

This evidence indicates that pensioner mortality is remarkably similar in the UK and the US for both men and women. Whether these observed small differences are "large enough" to have an influence on money's worth results is unclear from a direct inspection of the figures; below we say more on this comparison.[7] Computed age at death distributions for US and UK *populations* appear in Figure 3, where it is again clear that the two distributions overlap exceedingly closely. A visual inspection immediately reveals that there is no particularly easy graphical way to summarize tiny differences in mortality behavior across tables. Similarly, while US and UK *annuitants* both live longer than the population as a whole, on average, the two countries' distributions overlap very considerably, as depicted in Figure 4.

Figures 3 and 4 here

Our additional comparison measures are reported in Table 1 where findings for annuitants appear in Panel A and population results are given in Panel B. Focusing first on the A/E metrics in columns 1 and 5, we assign a value of 100 to the benchmark US male period population table. Annuitant mortality rates for both the UK and the US are lower than this base group by 10-15 percent, as is evident in Panel A. Nevertheless, there are substantial differences in mortality patterns across countries. For men, the US *voluntary* annuitant mortality pattern is 10 percent lower than for the UK *voluntary* annuitant group, and the US rate *compulsory*

[7] The figures in the appendix compare the unconditional probabilities of death at each age after 65, although, again, beyond noting that the probabilities of death are very similar, it is difficult to estimate the how big an effect these might have on annuity valuations.

annuitant rate is 16 percent lower than the corresponding UK group. For women the gaps are much smaller, with the US *voluntary* annuitant rate only 5 percent below the UK counterpart, and the *voluntary* annuitant rates being almost identical. Population results for A/E values, reported in Panel B, columns 1 and 5, are similar to one another. That is, the US Male population *cohort* mortality is only 93.9 percent of the US Male population *period* mortality (the base table selected here), because of the allowance in the cohort table for future reductions in mortality. Once again, however, the A/E figures indicate that mortality patterns are lighter for both men and women in the US than in the UK.

Table 1 here

Life expectancy remaining, conditional on surviving to age 65, is calculated for the US and UK using the method described above and reported in columns 2 and 6 for men and women, respectively. After age 65, the male US *voluntary* annuitant can anticipate a remaining lifetime of 20.0 years (Panel A), while his UK counterpart may expect to live another 19.2 years, only a 4 percent difference. The UK male *compulsory* annuitant can expect to live another 17.4 years, or 8 percent less than the corresponding US figure. Like-aged female *voluntary* annuitants can anticipate 22 additional years in both the US and the UK, about 20 years for *compulsory* annuitants. The cross-national differences in *annuitant* life expectancies are much larger than those appearing in Panel B for the entire *population*; here the percentage differences are only 2 percent for men and virtually no difference for women.

In columns 3 and 7 we convert these mortality differences into expected present values of a $1 per year life annuity paid continuously from age 65 onwards, assuming a discount rate of 5 percent. Focusing first on annuitants, Panel A indicates that a US man’s *voluntary* annuity would be worth $11.92; the value is $11.66 for the UK *voluntary* male annuitant but only $10.93

for the UK *compulsory* male annuitant.[8] Among women the pattern is similar, but the gaps are smaller: the US female *voluntary* annuitant would receive \$12.96 and her UK counterpart \$12.90. Turning to Panel B, the results are much closer using population mortality tables, with the present values differing by only 60¢ or less. Evidently, the choice of mortality table used to value annuity flows has a rather substantial impact on the resulting annuity value.

Finally we examine comparisons of internal rates of return (IRR) implied by the different mortality tables. The first line of Panel A, Column 4, reports a figure of 6.92 percent associated with the US male *voluntary* annuitant cohort mortality table. This may be compared to a 5 percent assumed return used in valuing a \$1 life annuity for the male US population period mortality table. In other words, the fact that in the US, mortality is less for male voluntary annuitants is equivalent to using a discount rate 192 basis points greater than the rate assumed for the base calculation (i.e. 6.92-5.0=1.92). The IRR results for women appear in column 8, where it appears that the even lower mortality rates for US women *voluntary* annuitants translates into a 282 basis point difference (i.e. 7.82-5.0=2.82). Turning to data derived using population tables, the IRR figures in Panel B are smaller by about 125 basis points for men and 180 basis points for women.

When comparing UK and US mortality tables using the IRR measure, we would anticipate that the higher mortality rates in the UK would produce a relatively lower implied IRR. This proves to be true. Panel A indicates that using UK versus US mortality results in a internal discount rate of 5.92 percent for male UK *compulsory* annuitants and 6.70 percent for male UK *voluntary* annuitants. The values for women are 7.23 percent for UK female

[8] These are calculated assuming an interest rate of 5%. As noted earlier, the life expectancy column could be thought of as the present value of the same annuity calculated at 0% interest.

compulsory annuitants and 7.80 percent for UK female *voluntary* annuitants, both lower than the US results (see the first line of the Panel). In other words, using UK instead of US annuitant mortality tables is mathematically equivalent to discounting at an interest rate 100 basis points higher for male UK compulsory annuitants, but only 22 basis points higher for male UK voluntary annuitants. The corresponding differences for men and women are 59 and 2 basis points, respectively. In Panel B, the IRR's are even lower, at 5.05 percent and 6.74 percent, though it is interesting that the US/UK gap remains larger for men than for women.

The last two columns of Table 1 provide an idea of how sensitive money's worth numbers are to mortality assumptions, where we see that the choice of national mortality table matters less than whether one uses an annuitant versus a population mortality table. One interpretation of these IRR results is that a US insurer would have to earn approximately 100 basis points more on invested assets for men, and 59 basis points more for women, to provide the same payout as the UK compulsory annuity product.[9]

III. Implications for Annuity Markets

In this section we draw out the implications of these data for valuations of annuity market products. Previous studies have noted that mortality tables may differ across different subgroups in the population and also across populations for a wide range of reasons. One possible explanation is that groups of people have differential mortality probabilities, such as the well-known differentials by sex, age and income. In most developed countries, for instance, women outlive men, particularly at older ages. A different reason that mortality patterns differ, one from

[9] This sets aside second-order effects, in that the comparison is strictly being made with US population period male mortality in each case, rather than between the tables in question.

the other, is that life expectancy has increased over time. Hence, if expected future improvements are built into one mortality table used for projections but not into another, the two tables cannot be directly compared. Extrapolations of future improvements are particularly important for the development of forward-looking, *cohort* mortality tables, as distinct from so-called *period* tables that refer to probabilities at a given point in time (Executive Committee, 1999). Finally, there are numerous reasons to expect that mortality patterns will differ by country, many of them due to differential levels of development. For instance, developed nations tend to have higher income levels and better healthcare provision than their poorer counterparts, and these socioeconomic factors would be anticipated to translate into higher life expectancies as compared with their less wealthy neighbors. Of course within the set of developed nations there is also room for mortality table differences due to a wide range of factors including national differences in lifestyle, diet and climate, and perhaps genetics.

A. **Adverse Selection**

For the present analysis, the most interesting factor differentiating mortality tables, and the one we focus on in what follows, is the extent of *adverse selection*. This arises when people who buy life annuities tend to live longer than people who do not buy them (cf Brown et al. 1999). As a consequence of adverse selection, an actuary pricing annuities and related insurance products would tend to use special survival probability distributions that take account of these distinct survival patterns. Ideally, the expert would obtain actual survival data on annuitants to determine how closely this subpopulation resembled (or differed from) the population as a whole. In addition, it would be anticipated that the impact of selection would depend on the extent to which annuity purchase is a voluntary or a mandatory decision. In the UK for example, one component of old-age pension benefits must be annuitized on a compulsory basis while other annuities are voluntary. As a result, experts have devised distinct UK mortality tables (by sex) for voluntary and compulsory-purchase annuitants, both of which differ from the general population table (c.f. Finkelstein and Poterba, 1999). In the US, where private annuity purchase is fully voluntary, actuaries have devised both male and female annuitant mortality tables that differ fairly substantially from the associated population tables. Actuaries have also derived mortality tables suitable for use in US pension plans that offer annuities to member, which in this analysis we have treated as compulsory annuitant tables (SOA, 1999). Several other countries also publish annuitant survival information, which we employ below in our comparative analysis. By contrast, many other countries lack data on annuitant mortality experience, so in these cases experts tend to use adjusted population mortality tables (either with an age "setback" or *ad hoc,* usually multiplicative, adjustment) to proxy for the extent of likely adverse selection in the annuitant pool.[10]

B. The Empirical Framework

In the empirical analysis undertaken, we seek to estimate the size of the self-selection factor. Specifically, we use available population and annuitant mortality data from a range of developed countries, to determine empirically the average degree of adverse selection in annuitant mortality tables. This measure of adverse selection can then be compared to outcomes for specific countries to determine how any given country results deviate from the norm. It is important to realize that the classifications we have introduced between 'population', 'compulsory' and 'voluntary' selection in mortality tables are to some extent arbitrary. We have called selection 'compulsory' if the mortality table relates to annuitants of pension funds and

[10] As an example, insurers in Singapore reportedly use 85% of a dated UK Pensioner's mortality table (a(90)) to value their annuity business.

'voluntary' if it refers to voluntary individual annuitants. Countries may have different voluntary or compulsory selection effects, even within these categories, due to different labor force demographics (including participation rates), compensation packages, tax codes and legislation. We hope to capture most of these effects in the error term of our model - our results are intended to capture a range of 'normal' variation of adverse selection due to all unspecified causes.

The dependent variables in this analysis are, respectively, the A/E, the Expected Remaining Life, and the IR metrics described above. Our statistical model relates these outcomes to the degree of selection associated with annuitants, controlling on other factors. Specifically, the regression equation estimate is as follows:

$$Y_{ijkl} = a + \mathbf{ß'}\mathbf{C}_{\mathbf{i}} + \mathbf{?'}\mathbf{S}_{\mathbf{j}} + dG_k + zT_l + q(S*G) + l(T*G) + e_{ijkl}$$

where Y_{ijkl} refers to the mortality metric in question (A/E, LE, or IRR); $\mathbf{C_i}$ is a vector of indicator variables representing country; $\mathbf{S_j}$ is a vector representing the degree of selection; G_k is a scalar representing gender; and T_l is a scalar representing table type (cohort or period). Remaining noise is summarized in the error term e_{ijkl} assumed to be independent, identically distributed, normal random variables. Our primary null hypothesis is that g $= \mathbf{0}$, which means that the mortality tables display no additional statistically significant adverse selection, after controlling on the country-specific effects as well as table and gender differentials. The alternative hypothesis is that $\mathbf{?} \neq \mathbf{0}$; its magnitude is an indication of the extent of predictable adverse selection in annuitant mortality tables. We also test for statistical significance of interaction terms indicative of differential selection and cohort effects for women than may differ from those for men, or that l and q = 0.

C. Pooled Cross-Country Results

The regression analysis is conducted using information on population and annuitant mortality tables taken from nine countries, namely Australia, Austria, Canada, Chile, Germany, Israel, New Zealand, the United Kingdom, and the US. All told, these data cover over half a billion lives, and are summarized in 60 different life tables.[11] These include population period and cohort, as well as annuitant period and cohort tables, for both men and women.[12] Independent regressors include a set of country-specific indicators with the US as the omitted category. In addition we include (0,1) indicators of whether the table was for male or female (with male being the omitted category), for period or cohort (with period being the omitted category), and whether the table was a population or compulsory or voluntary annuitant table (with population being the omitted group). Estimated coefficients on the population/compulsory annuitant/voluntary annuitant set of variables are what we look to, to evaluate the null hypothesis of key interest.

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[11] The mortality tables from the UK are from the Executive Committee of the Continuous Mortality Investigation of the Institute and Faculty of Actuaries (1999), and the Government Actuaries Department of the UK (1999), for the US from the US Social Security Administration (1999), Mitchell *et. al*. (1999) and SOA (1999), for Australia from Knox (1999), for Canada from Kim and Sharp (1999), for Chile from Callund (1999), for Israel from Spivak (1999), and for Austria, Germany and Switzerland from MacDonald (1997). Many of these sources are summarized in James and Vittas (1999).

[12] Not all countries have data for all types of tables. Specifically, for the USA and Canada we have tables for males, females, population, voluntary annuitants for periods and cohorts, and all combinations of these (a total of 16 tables); for the US we also have the four RP2000 tables for pension annuitants; for the UK we have all these for both voluntary and compulsory annuitants (12 tables); and for Australia we have population tables for periods and cohorts, males and females, but voluntary annuitant tables only for periods, males and females (6 tables). For Israel and Chile we have annuitant and population period tables for males and females (total of 8 tables), for Austria and Germany we have cohort tables for male and female compulsory annuitants but period tables for male and female populations (total of 8 tables) and for Switzerland we have period tables for voluntary and compulsory annuitants, and the population, for males and females (6 tables). In all cases we use the most recent available tables; generally these come from 1997-1999, although the tables from German-speaking Europe tend to be slightly older than this. The UK tables were based on the 1992 experience but have been adjusted to a 2000 experience by applying the recommended mortality improvement factors. In future work we plan on including older tables to determine how they have changed over time. We only examined tables from age 65 onwards, so our results only apply in this range.

The results for this analysis are reported in Table 2, including estimated model coefficients for the three alternative metrics described above. All three models fit well with a high degree of explained variance (adjusted R-square). Focusing on the individual mortality metrics, the "female effect" turns out to be negative for the A/E measure: it is statistically significant, and it is large in magnitude. Specifically, across the sample, mortality rates for women are 34 percent lower as compared to the benchmark US male population. This is comparable to the 33 percent and 26 percent lower relatively mortality experienced for voluntary and compulsory annuitants, versus the population. Only one of the interaction terms is statistically significant, indicating that selection between female voluntary annuitants and the population is one-third lower than among men (33.62-10.63=22.99).

Table 2 here

There is no significant difference between estimated coefficients on the selection variables for voluntary and compulsory selection. This implies that the range of normal variation of compulsory and voluntary selection in different countries overlaps to some extent. Using the A/E metric, the international data series are consistent with an average degree of adverse selection for annuitants versus the general population of at least 25 percent. The cohort effect is much smaller, on the order of 12 percent relative lower mortality.

As an illustration of our model, the predicted A/E metric for Male UK Compulsory Annuitants would be derived as follows:

$$\text{Pred}(AE_{\text{UK Male Comp Ann}}) = \underset{Intercept}{106.44} + \underset{UK}{7.79} - \underset{CompAnn}{25.75} = 88.48$$

This falls just within one standard deviation of the true value of 95.94.

Turning to the other two metrics provided in Table 2, we find that the female effect is again positive and statistically significant for both the LE and the IRR metrics, and the results are on the same order of magnitude. That is, women's remaining life expectancy of 3.4 years versus the baseline of 15 years represents an incremental 22 percent, and the IRR advantage is on the order of 32 percent. The annuitant female advantage with these metrics is similar to that found with the A/E metric, of around 20 percent ((1.41-0.45)/5.002=0.19).

A final point to emphasize regarding Table 2 is the degree of statistical significance associated with many of the country-specific effects, with the exception of Chile and Germany. Austria and Israel have 12-13 percent higher mortality than the benchmark, while Switzerland and Canada have 10 percent lower mortality. All of the country-specific variables are highly significant when the IR metric is used, indicating that this metric is more sensitive than the other two measures.

D. Differential Results for Japan

Next we extend our analysis to compare these cross-national results with specific mortality metrics for Japan. Our focus on to Japan is partly motivated by the fact that this is the country facing the most rapid aging in the near term. Further, the Japanese government has recently announced that it will soon promulgate regulations favoring a new defined contribution, 401(k)-type pension system, wherein retirees will receive a lump sum that could then be annuitized on a voluntary basis.[13] Hence additional information would be invaluable on the extent to which adverse selection might influence the appeal of annuities in Japan.

To understand the sources of mortality data obtained for Japan, we note that such tables are available for the Japanese population since 1891. Subsequent to World War II, population mortality tables were calculated every five years based on the quinquennial national census

[13] For more information on Japanese pension reform, see Takayama (1998), NLI Research (2000) and Ministry of Health and Welfare (1998a).

supplemented by national birth and death records in the two-year period centered on the date of the census. The most recent available national mortality table is known as the JLT 18, based on the 1995 census (Ministry of Health and Welfare, 1998b).

Using this information, we offer in Figure 5 a comparative graphical illustration of the distribution of expected of age at death in the Japanese and US population. These data reveal that at younger ages, before age 78, a greater proportion of US males is expected to die than Japanese males; conversely, a higher proportion of Japanese males is expected to die at older ages. As a result, the average age at death for US males is lower than for Japanese men, consistent with lower Japanese mortality rates. Interestingly, the *modal* age of death is the same in both populations, around 83. Among women, the pattern is similar, although cross-national differences are more marked. Here again, it appears that a higher proportion of Japanese women will die after age 83 than US women, with the opposite being true until that age. Modal age at death is once again the same in both populations – around 89 years old. Given the essential similarity in the results of the US and UK comparison, it is remarkable that Japanese tables are so strikingly different.

Figure 5 here

Japanese experts have also produced three tables used for valuing pension liabilities and annuities. It is important to note that none of these tables appears to be derived from the underlying experience of annuitants – all, in one way or another, rely on the Japanese population mortality tables in their construction. One is a Japanese voluntary annuitant table derived by the Japanese Institute of Actuaries and released in 1996. The actuaries report that this was obtained by first measuring annual age-specific mortality improvements in the Japanese population using population mortality tables published between 1955 and 1980. Next they used these improvement factors to project mortality rates, essentially for a cohort of individuals born in 1945 taking as a base Japanese population mortality in 1980. The use of this table is required for the statutory valuation of individual annuity products of life insurers. A second applies to annuitants in the Tax-Qualified Pension Plan (TQPP) system. The TQPP is one of the two main types of defined benefit corporate pension plan in Japan and covers mainly smaller employers. The TQPP mortality table is specified as 85 percent of the JLT 15 table, which was derived from the mortality of the Japanese population in 1980. Under a collective agreement between Japanese trust banks, life insurers, the national tax administration agency, and the Ministry of Finance, actuaries are required to use this table to value TQPP liabilities. A third annuitant mortality table used in Japan is produced under the direction of the Japanese Ministry of Health and Welfare that must be used for Employee Pension Fund (EPF) valuations. The EPF is the second major type of defined benefit pension plan in Japan, covering mainly large employers. One of the differences between an EPF and a TQPP is that employers can partially contract out of the national Social Security system into an EPF, but not into a TQPP. This EPF table is meant to represent the mortality experience of annuitants in EPF plans through March of 1999, and is apparently derived from the actual mortality experience of members of these plans.

A graphical comparison of the US and the Japanese voluntary annuitant table is provided in Figure 6. Apparently large differences are evident across the two countries in the distributions of ages at death for men and women, but in an unexpected direction. The Japanese voluntary annuitant table indicates far higher expected mortality than for US *annuitants*, particularly for men, despite the fact that Japanese *population* mortality rates are lower than in the US.

Figure 6 here

To test whether these patterns are statistically distinguishable, Table 3 extends the empirical model described above by adding the Japanese mortality data, a Japan effect indicator, and three new variables specific to Japan. One is an indicator of whether the mortality table refers to Japanese annuitants, the second represents the EPF annuitant pool, and the third represents the TQPP annuitant table. We test the hypothesis that the coefficients on these additional variables are zero – in other words, that the patterns of mortality differences between the different Japanese tables are statistically indistinguishable from those our model would predict.

Table 3 here

The results indicate that there is higher mortality than the model would predict in both the voluntary annuitant and TQPP tables. The magnitudes of these unexpected differences are quantitatively substantial: TQPP and voluntary annuitants in Japan would be seen to face a 29-35 percent higher mortality and live 3 to 4 years less than what our model predicts based on international norms. In fact, the excess mortality assumed in the TQPP tables results in these tables being heavier than Japanese population tables, implying negative adverse selection. We confirm that Japanese mortality is low relative to the US since the Japan indicator variable is statistically significant for all measures. Also the Japanese *pension* indicator variables are highly significantly different from zero in most cases.[14] All other coefficients in the baseline model are robust to the inclusion of additional data and variables.

A further illustration of the excess mortality contained in these tables appears in Figure 7, which provides confidence intervals for the predicted values of the A/E metric for Japanese

[14] An F-test that the set of three Japanese annuitant coefficients is jointly equal to zero is rejected at the 5% level.

compulsory and voluntary male and female annuitants, together with the actual values of this metric. The vertical axis represents the A/E mortality measure, and the four types of non-population mortality tables considered for Japan (compulsory selection, represented by TQPP and EPF mortality tables, and the voluntary annuitant table, for males and females). The vertical bars represent confidence intervals for predicted levels of the A/E metric, while the points show where we calculated these tables actually lie.[15] As the hypothesis tests imply, the TQPP and voluntary annuitant mortality patterns are well outside the confidence intervals for both males and females, while the EPF tables are very close to the lower limit of the confidence interval. The fact that the two compulsory annuitant tables behave so differently from each other underscores the point that Japanese annuitant tables embody mortality patterns that are unusual in an international context.

Figure 7 here

We emphasize that these results do not necessarily imply that liability estimates and contribution rates are incorrect for TQPP, EPF and individual annuity business in Japan. This is because actuaries use many different assumptions to value annuities, and it is not uncommon to alter one or more other assumptions to compensate for a mortality assumption believed to be inaccurate. However, as Thornton and Wilson (1992) point out in the context of UK pension liabilities, using offsetting assumptions can lead to inaccurately estimated reserves, distort sensitivity estimates, and complicate analyses of insurer surplus/strain. In general, such practice is best avoided.

[15] This exercise assumes the null hypothesis that the coefficients on the Japanese annuitant variables in Table 2 are zero.

IV. Conclusions and Extensions

This study has illustrated how mortality tables differ in rather substantial ways across countries and populations within countries, and what difference these patterns might have on annuity markets. Specifically we offer new evidence on the expected value and variation of the effect of adverse selection on mortality in international annuities markets, for both compulsory and voluntary annuities. The amount of adverse selection is a key consideration in the policy debate as to how to create efficient annuities markets needed to ensure properly-functioning privatized social security systems.

Our results are of interest because the choice of a mortality table rather importantly influences annuity valuation. We find that mortality rates of voluntary annuitants are similar in the US and the UK and that annuitant mortality is much lighter than population rates. We then compute money's worth values of life annuities using these various mortality tables using the US male population period mortality table as a benchmark. Compared to this group, annuity valuations would differ by 10 to 15 percent if instead one used US or UK annuitant cohort mortality tables. This is a rather substantial variation, in light of the fact that life annuities relative to premiums are worth on the order of 90-95 percent in both the US and the UK (Brown et al, 2000; Finkelstein and Poterba, 1999).

Clearly, deciding which mortality table to use has a potent effect in valuing these products. This is important to acknowledge, since many developed nations and most developing countries lack adequate mortality data for use in pricing retiree annuities. When a country lacks mortality data, an insurer may use the US or UK tables but may require a higher margin to reserve against greater uncertainty. Consequently, annuities could likely be worth less in a country where mortality data are difficult to come by. Alternatively, if US or UK mortality tables were used without such reserves, unexpected mortality developments could quickly undermine the survival of the insurance sector.

We believe that annuities are likely to become more important internationally as countries replace traditional pay-go social security systems with privately funded social security systems. Estimating the likely extent of adverse selection in annuities markets, especially in countries where sufficient data on annuitants does not exist, is vital to ensure that this process runs smoothly.

Our central finding is that adverse selection associated with the purchase of individual annuities reduces mortality by least 25%. We also find that there is no significant difference between the effects of voluntary and compulsory selection on mortality, which warrants further research. We do not believe that this result implies that *in an individual country*, there is no significant difference between compulsory and voluntary selection. Rather, we interpret it to mean that the ranges of variation of what might be called “compulsory” and “voluntary” selection in different countries overlap. This, we believe, highlights the important point that the extent of adverse selection is highly dependent on the legal and economic environment.

We also find that the system of mortality tables used to value Japanese annuities does not fit well into international norms. Specifically, the Japanese voluntary annuitant and TQPP tables embody higher mortality than would be predicted, while the Japanese EPF mortality tables are close to the bottom of the expected range. This, we believe, warrants further investigation, especially as, according to our understanding, none of the Japanese tables we investigated, except the population tables, is derived from the actual experience of Japanese annuitants. We expect that further research will highlight the financial significance of these deviations.

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Table 1: Comparing Mortality Patterns Across Countries: Cohort Results for the US and the UK

A. <u>Annuitants</u> conditional on attaining age 65

		Male				Female			
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
		A/E (%)	Life exp (yrs)	PV Ann ($)	IRR (%)	A/E (%)	Life exp (yrs)	PV Ann ($)	IRR(%)
US	V†	61.2	20.0	11.92	6.92%	44.6	22.7	12.96	7.82%
	C‡	69.0	18.9	11.53	6.55%	55.3	20.9	12.24	7.20%
UK	V†	68.0	19.2	11.66	6.70%	47.0	22.2	12.90	7.80%
	C‡	82.3	17.4	10.93	5.92%	55.9	20.8	12.25	7.23%
$\%(US^V - UK^V)/US^V$		(11.11)	4.14	2.12	22.1*	(5.36)	1.85	0.51	1.7*
$\%(US^C - UK^C)/US^C$		(19.28)	7.94	5.20	63.2*	(1.08)	0.48	(0.00)	(3.2)

B. <u>Population</u> conditional on attaining age 65

	Male				Female			
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
	A/E (%)	Life exp (yrs)	PV Ann ($)	IRR (%)	A/E (%)	Life exp (yrs)	PV Ann ($)	IRR(%)
US	93.9	16.2	10.4	5.24%	62.9	19.7	11.8	6.79%
UK	98.3	15.9	10.2	5.05%	65.8	19.4	11.7	6.74%
%(US-UK)/US	(4.43)	2.32	1.41	18.3*	(4.40)	1.48	0.56	4.6*

† This line refers to the mortality of voluntary annuitants.
‡ This line refers to the mortality of compulsory annuitants. Individuals are compelled to annuitize a certain fraction of pension benefits in the UK. In the US, data are of pensioners in retirement plans from SOA(1999).
* This difference is shown as a raw basis point difference between US and UK 'voluntary' figures.

Columns 1, 4, 5 and 8 rely on the US male population period mortality as the reference category; see text. Columns 4 and 8 assume a 5% return for base annuity; see text. Authors' calculations use mortality tables appropriate for UK from Executive Committee (1999) and GAD (2000), and US mortality tables from SSA (1999) and SOA (1999).

Table 2: Regression Analysis of International Voluntary and Compulsory Annuitant Factors

	A/E Metric		**LE Metric**		**100*IRR Metric**	
	Coefficient	*Std Error*	*Coefficient*	*Std Error*	*Coefficient*	*Std Error*
Female	-33.62**	3.61	3.39**	0.47	1.580**	0.118
Vol. Annuitant	-32.52**	3.62	3.29**	0.47	1.419**	0.118
Compuls. Annuitant	-25.75**	4.16	2.41**	0.54	1.048**	0.136
Cohort	-12.07**	3.41	1.20**	0.44	0.385**	0.111
UK	7.79**	3.45	-0.82*	0.45	-0.296**	0.113
Canada	-9.93**	3.98	1.37**	0.52	0.406**	0.130
Chile	7.57	5.12	-0.97	0.67	-0.559**	0.167
Australia	-8.95**	4.36	1.10*	0.57	0.356**	0.143
Israel	11.68**	5.12	-1.26*	0.67	-0.729**	0.167
Austria	13.94**	4.96	-1.17*	0.64	0.907**	0.162
Germany	6.49	4.98	-0.66	0.65	0.965**	0.163
Switzerland	-9.10**	4.42	1.98**	0.57	1.448**	0.144
FemalexVol. Ann	10.63**	5.05	-0.09	0.66	-0.452**	0.165
FemalexComp. Ann	6.05	5.64	0.19	0.73	-0.405**	0.184
FemalexCohort	2.81	4.56	0.05	0.59	-0.067**	0.149
Intercept	106.44**	3.57	15.15**	0.46	5.002**	0.117
Adjusted R-Square	0.86		0.84		0.94	
N. of Obs.	60		60		60	

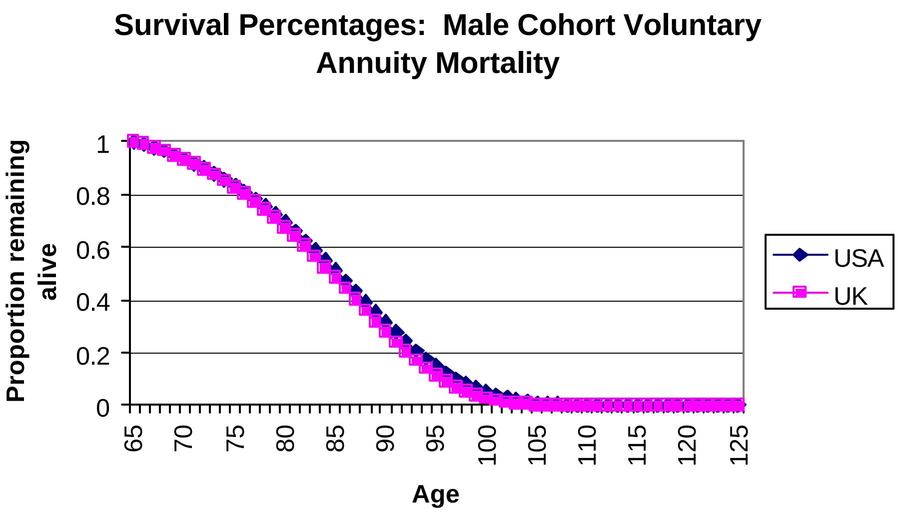
Notes:
** $p\text{-value} \leq 0.05$; * $p\text{-value} \leq 0.1$. The reference category throughout is US male population period mortality table.
Source: Authors' calculations, see text.

Table 3: Extended Analysis of International Voluntary and Compulsory Annuitant Factors

	A/E Metric		**LE Metric**		**100*IRR Metric**	
	Coefficient	*Std Error*	*Coefficient*	*Std Error*	*Coefficient*	*Std Error*
Female	-34.03**	3.31	3.51**	0.43	1.617**	0.110
Vol. Annuitant	-32.63**	3.43	3.35**	0.45	1.433**	0.114
Compuls. Annuitant	-26.16**	3.85	2.41**	0.50	1.038**	0.128
Cohort	-12.02**	3.22	1.26**	0.42	0.404**	0.107
Japan EPF	-12.39	8.68	2.53**	1.14	0.613**	0.288
Japan TQPP	35.23**	8.68	-3.93**	1.14	-1.435**	0.288
Japan Vol. Annuitant	28.80**	8.83	-3.49**	1.16	-1.035**	0.293
UK	7.79**	3.33	-0.83*	0.56	-0.296**	0.111
Canada	-9.93**	3.84	1.38**	0.59	0.406**	0.127
Chile	7.57	4.93	-0.97	0.74	-0.559**	0.164
Australia	-8.95**	4.21	1.10*	0.64	0.356**	0.140
Israel	11.68**	4.93	-1.26*	0.74	-0.729**	0.164
Austria	13.94**	4.78	--1.17*	0.73	0.907**	0.159
Germany	6.49	4.80	-0.66	0.77	0.965**	0.159
Switzerland	-9.10**	4.26	1.98**	0.69	1.448**	0.141
Japan	-13.91**	6.49	1.89**	0.96	0.721**	0.215
FemalexVol. Ann	10.84**	4.70	-0.21	0.62	-0.479**	0.156
FemalexComp. Ann	6.87	4.93	0.19	0.65	-0.385**	0.164
FemalexCohort	2.69	4.19	-0.07	0.55	-0.104	0.139
Intercept	106.64**	3.40	15.10**	0.44	4.983**	0.113
Adjusted R-Square	0.87		0.86		0.94	
N. of Obs.	68		68		68	

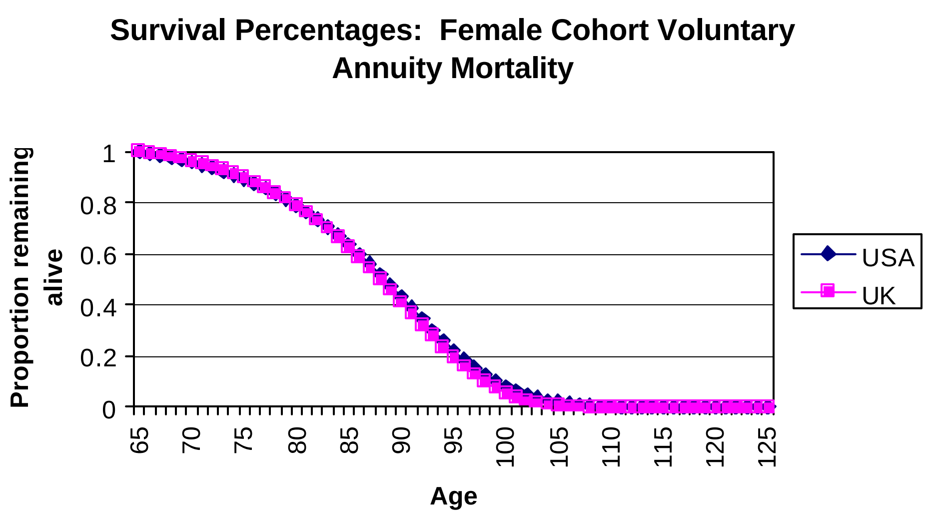
Notes:
** $p\text{-value} \leq 0.05$; * $p\text{-value} \leq 0.1$. The reference category throughout is US male population period mortality table.
Source: Authors' calculations, see text.

Figure 1: Survival from age 65: US/UK cohort mortality for male annuitants conditional on reaching age 65.



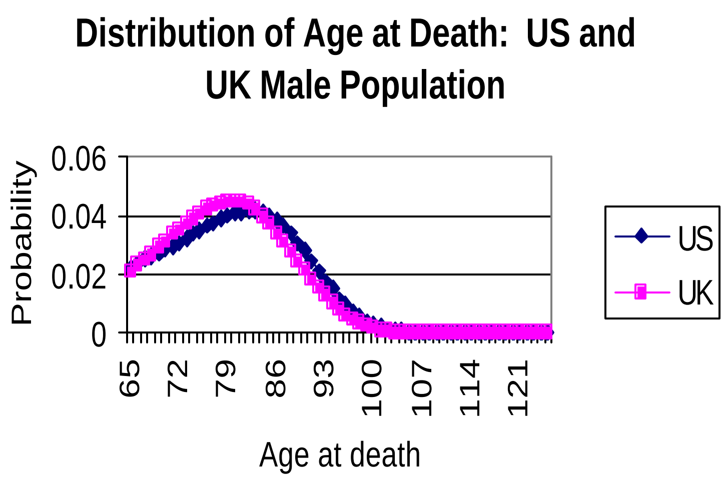
Source: Authors' calculations based on mortality tables from Executive Committee (1999) and Mitchell *et al*. (1999).

Figure 2: Survival from age 65: US/UK cohort mortality for female annuitants conditional on reaching age 65.



Source: Authors' calculations based on mortality tables from Executive Committee (1999) and Mitchell *et al*. (1999).

Figure 3: Distribution of Age at Death, US and UK Population
Source: Authors' computations.



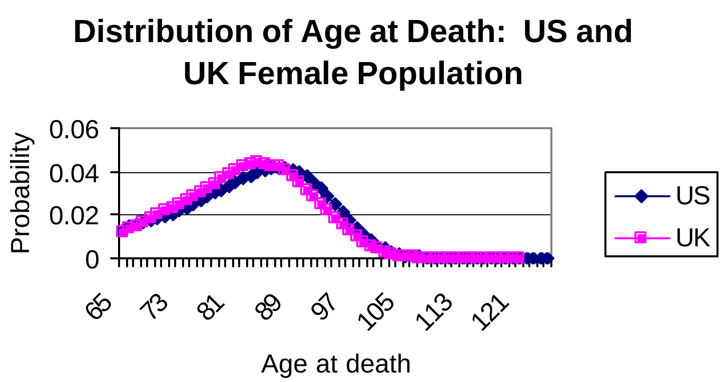
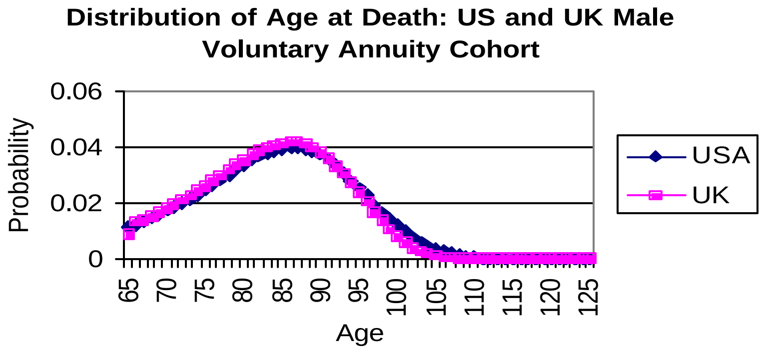


Figure 4: Distribution of Age at Death, US and UK Annuitant Population
Source: Authors' computations.



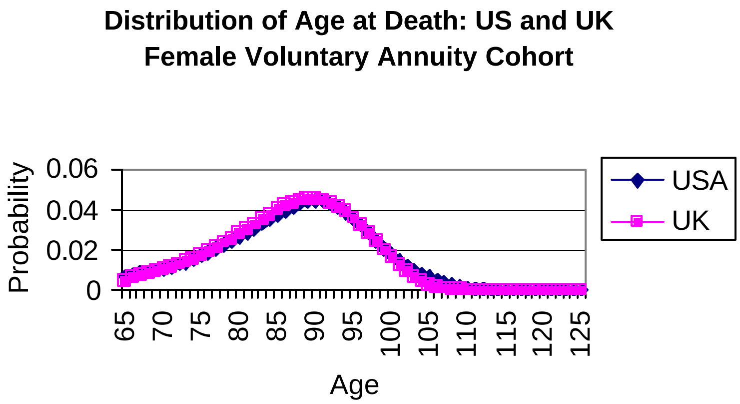
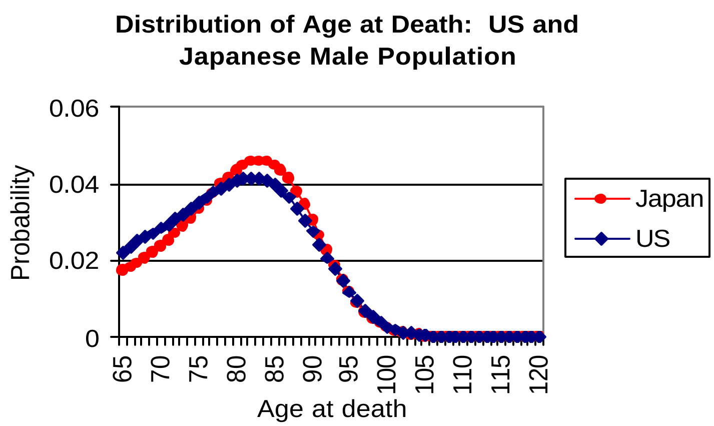


Figure 5: Distribution of Age at Death, US and Japan Population
Source: Authors' computations.



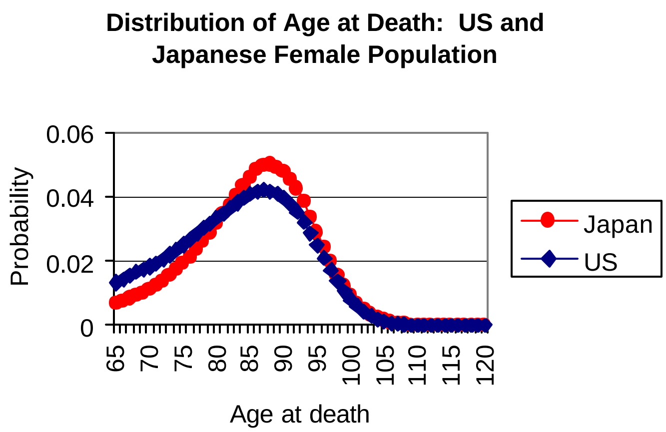
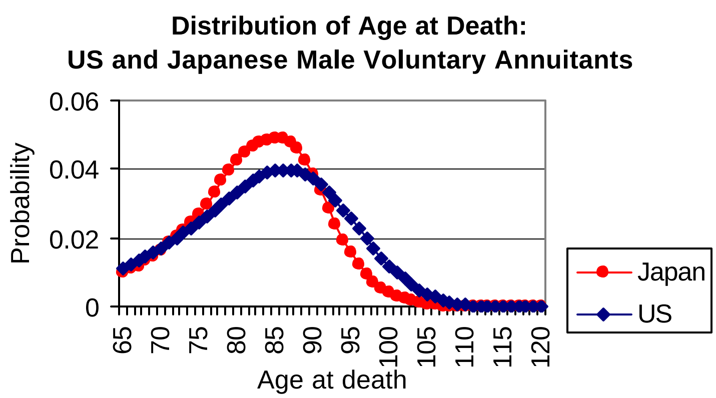


Figure 6: Distribution of Age at Death, US and Japan Annuitant Population
Source: Authors' computations.



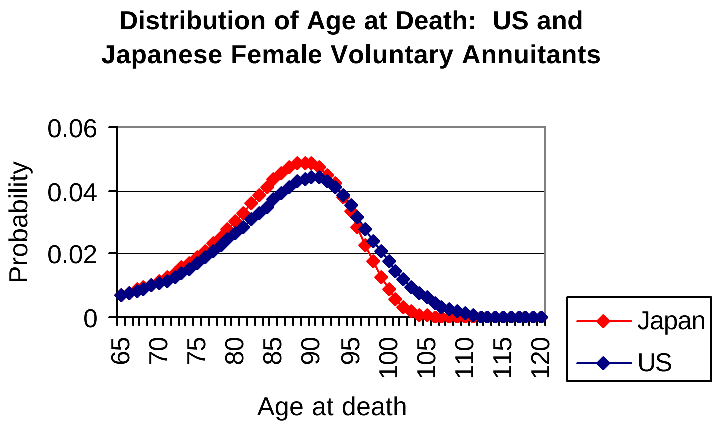


Figure 7: Japan Actual Annuitant Tables vs 95% Confidence Intervals From International Data, A/E Metric
Source: Authors' computations.