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 U.S. and the U.K. 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 U.K. rate for compulsory annuitants or 10–20 basis points lower than the U.K. 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.‡

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 because 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.

Yet, 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, Eastern Europe, Africa, 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 data intensive, of course, because it

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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 small numbers, and hence a large number of lives must be observed in order to obtain reliable estimates of small probabilities.

Most developed nations today have their own mortality tables; some are freely available,[2] and others are more difficult to obtain. Though actuaries are aware of the international differences in such tables, they differ across countries in ways that are quite striking to the non-actuary. For instance, population mortality pattern differences are substantial enough across the Organization for Economic Co-operation and Development (OECD) countries to imply very different consequences for programs intended to maintain living standards for the older population (Hewitt and Schieber 2000).

In the present paper, we explore alternative measures of these population mortality differences, then we examine mortality differences in annuitant pools. As suggested by prior research using U.S. and U.K. data (Brown et al. 2000; Finkelstein and Poterba 1999), we anticipate that in the large set of countries we examine here, annuitants will also have lighter mortality patterns than the population as a whole 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.

We further illustrate how using different mortality assumptions can influence how one might assess the "money's worth" of annuity products. We focus on mortality patterns for older persons because this is the population most relevant for retirement system purposes. Key differences between mortality tables for the same groups in the United States and the United Kingdom are worthy of examination because many other countries in the Americas, in Europe, and in Asia use either the U.S. or U.K. tables to value annuities. Next we estimate an empirical model to quantify the extent of adverse selection among annuitants across our sample of countries by employing 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 permit us to quantify the extent of adverse selection and income effects in mortality tables specific to annuitants versus the general population, using alternative mortality metrics. We conclude with a brief discussion of some puzzles that arise in the cross-country context. Our 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 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

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[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).

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

United States is the U.S. Social Security Administration (1999). Using these data as input, mortality tables have been constructed by the Society of Actuaries (1999) and updated by Mitchell et al. (1999). In the U.K., 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 U.S. and the U.K. 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, U.S. mortality tables appear to be commonly used in the Western Hemisphere, while U.K. 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, which 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 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 U.K., for instance, a portion of retirement benefits is often subject to mandatory annuitization, whereas other benefits may be voluntarily annuitized. As a result, separate U.K. 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 U.S., 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, U.S. 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 is 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 because 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 propose five metrics to 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 U.S. and U.K. 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

[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. Uncertainty about mortality data may also cause insurance companies to raise prices, with adverse consequences for the annuities market in general.

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 U.S. 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 U.S. 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

The next approach compares mortality tables to determine 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

Expected Remaining Life

$$= \sum_x \left(x - 65 + \tfrac{1}{2}\right) {}_{x-65}p_{65} \cdot q_x,$$

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

Comparison of PV Life Annuity

$$= \sum_x \bar{a}^{5\%}_{\overline{x-65+1/2}|}\; {}_{x-65}p_{65} \cdot q_x,$$

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 $\bar{a}^{5\%}_{\overline{x-65+1/2}|}$ is the present value at 5% per annum of an annuity certain, paid continuously for $x - 65 + \frac{1}{2}$ years. In the calculations, we again assume that deaths

[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).

occur uniformly over the year of age x. Note that if $\bar{a}_{\overline{x-65+1/2}|}$ is calculated at 0% interest, it equals $x - 65 + \frac{1}{2}$, implying a connection between this method and the expected remaining life method.

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 U.S. male population period table and an interest rate of 5% 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 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% per year of an annuity certain paid continuously for $x - 65 + \frac{1}{2}$, and ${}_{2-65}p^*_{65} \cdot q^*_x$ is the probability that an individual alive at age 65 dies aged x according to U.S. male population period mortality.

B. Comparing Mortality Tables Using Cross-Country Variation

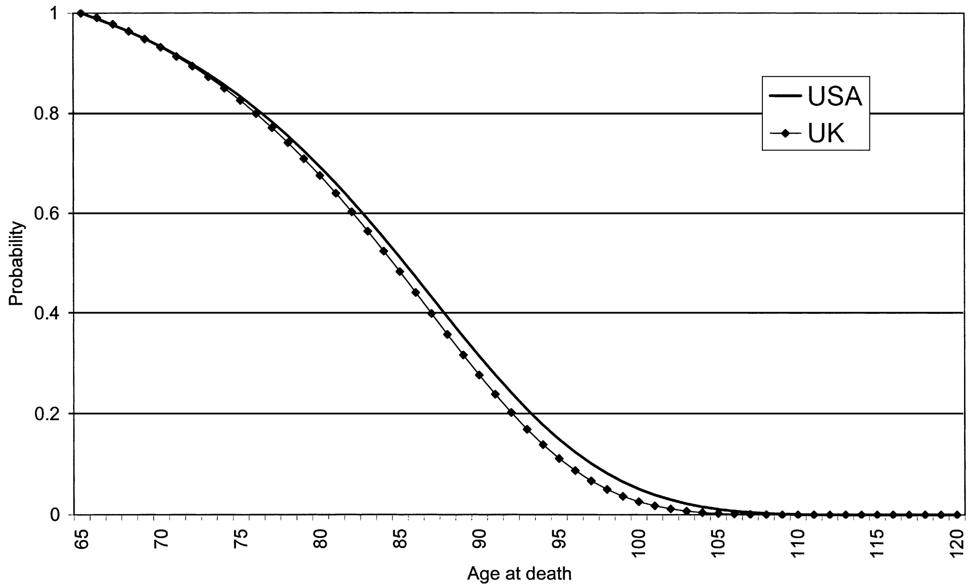
To implement these measures, we use the most recent U.S. mortality information on voluntary annuitants (Brown et al. 2000), U.S. data on group annuitants (SOA 2000), and U.K. data based on voluntary annuity tables with estimated mortality improvements (Executive Committee 1999). A first set of comparisons uses survival functions for a cohort of 65-year-old male voluntary annuitants in the U.K. and the U.S. appearing in Figure 1. This evidence indicates that pensioner mortality is remarkably similar in the U.K. and the U.S. 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 U.S. and U.K. annuitants appear in Figure 2, 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.

The additional comparison measures are reported in Table 1; 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 U.S. male period population table. Annuitant mortality rates for both the U.K. and the U.S. are lower than this base group by 20–40% for males, and 45–55% for females, as is evident in panel A. Nevertheless, there are substantial differences in mortality patterns across countries. For men, the U.S. *voluntary* annuitant mortality pattern is 11% lower than for the U.K. *voluntary* annuitant group, and the U.S. rate *compulsory* annuitant rate is 19% lower than the corresponding U.K. group. For women, the gaps are much smaller, with the U.S. *voluntary* annuitant rate only 5% below the U.K. counterpart, and the *voluntary* annuitant rates are almost identical. Population results for A/E values, reported in panel B, columns 1 and 5, are similar to one another. That is, the U.S. male population *cohort* mortality is only 93.9% of the U.S. 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

[7] We have also compared 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 how big an effect these might have on annuity valuations.

Figure 1
Survival from Age 65: U.S./U.K. Cohort Mortality for Male Voluntary Annuitants Conditional on Reaching Age 65



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

patterns are lighter for both men and women in the U.S. than in the U.K.

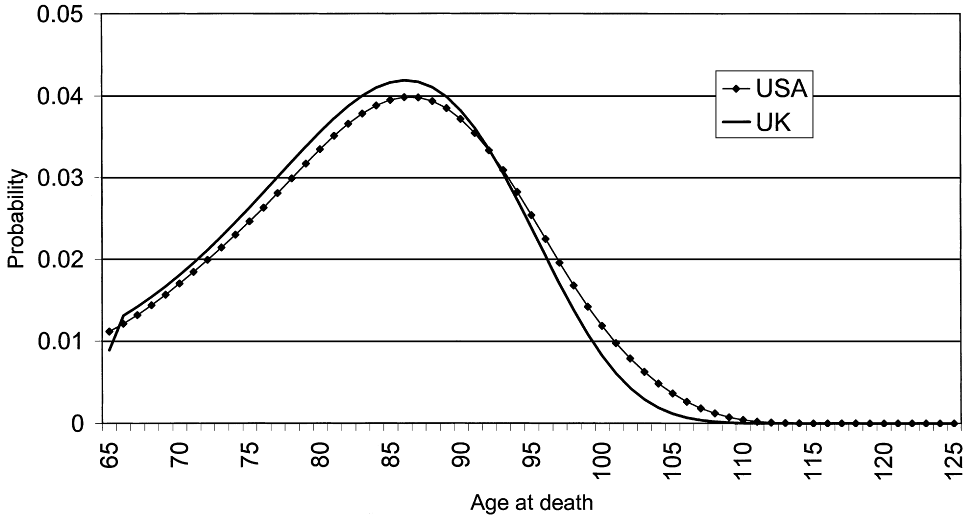
Remaining life expectancy, conditional on surviving to age 65, is calculated for the U.S. and U.K. using the method described above and reported in columns 2 and 6 of Table 1 for men and women, respectively. After age 65, the male U.S. *voluntary* annuitant can anticipate a remaining lifetime of 20.0 years (panel A), while his U.K. counterpart may expect to live another 19.2 years, only a 4% difference. The U.K. male *compulsory* annuitant can expect to live another 17.4 years, or 8% less than the corresponding U.S. figure. Like-aged female *voluntary* annuitants can anticipate 22 additional years in both the U.S. and the U.K. and about 21 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% for men and virtually none for women.

Columns 3 and 7 of Table 1 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%. Focusing first on annuitants, panel A indicates that a U.S. man's *voluntary* annuity would be worth $11.92; the value is $11.66 for the U.K. *voluntary* male annuitant but only $10.93 for the U.K. *compulsory* male annuitant.[8] Among women the pattern is similar, but the gaps are smaller: the U.S. female *voluntary* annuitant would receive $12.96 and her U.K. counterpart $12.90. Turning to panel B, the results are much closer using population mortality tables, with the present values differing by only 20¢ or less. Evidently, the choice of mortality table used to value annuity flows has a rather substantial impact on the resulting annuity value.

Finally, Table 1 provides a comparison 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% associated with the U.S. male *voluntary* annuitant cohort mortality table. This may be compared to a 5% assumed

[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.

Figure 2
Distribution of Age at Death, U.S. and U.K. Male Cohort Voluntary Annuitant Population



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

return used in valuing a $1 life annuity for the male U.S. population period mortality table. In other words, the fact that in the U.S., 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, in column 8, show that the even lower

Table 1
Comparing Mortality Patterns across Countries: Cohort Results for the U.S. and the U.K.

	A. Annuitants Conditional on Attaining Age 65							
	Male				Female			
	1 A/E	2 Life Exp (yrs)	3 PV Ann	4 IRR	5 A/E	6 Life Exp (yrs)	7 PV Ann	8 IRR
U.S. V[†]	61.2%	20.0	$11.92	6.92%	44.6%	22.7	$12.96	7.82%
C[‡]	69.0	18.9	11.53	6.55	55.3	20.9	12.24	7.20
U.K. V[†]	68.0	19.2	11.66	6.70	47.0	22.2	12.90	7.80
C[‡]	82.3	17.4	10.93	5.92	55.9	20.8	12.25	7.23
% ($U.S.^V$–$U.K.^V$)/$U.S.^V$	(11.11)	4.14	2.12	22.1*	(5.36)	1.85	0.51	1.7*
% ($U.S.^C$–$U.K.^C$)/$U.S.^C$	(19.28)	7.94	5.20	63.2*	(1.08)	0.48	(0.00)	(3.2)
	B. Population Conditional on Attaining Age 65							
U.S.	93.9	16.2	10.37	5.24%	62.9	19.7	11.79	6.79%
U.K.	98.3	15.9	10.22	5.05	65.8	19.4	11.72	6.74
% (U.S.–U.K.)/U.S.	(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 U.K. In the U.S., data are of pensioners in retirement plans from SOA (1999).
* This difference is shown as a raw basis point difference between U.S. and U.K. "voluntary" figures.

Columns 1, 4, 5 and 8 rely on the U.S. male population period mortality as the reference category; see text. Columns 3, 4, 7 and 8 assume a 5% return for base annuity; see text. Authors' calculations use mortality table appropriate for U.K. from Executive Committee (1999) and G.A.D. (1999), and U.S. mortality tables from SSA (1999) and SOA (1999).

mortality rates for U.S. 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 U.K. and U.S. mortality tables using the IRR measure, we would anticipate that the higher mortality rates in the U.K. would produce a relatively lower implied IRR. This proves to be true. Panel A of Table 1 indicates that using U.K. versus U.S. mortality results in a internal discount rate of 5.92% for male U.K. *compulsory* annuitants and 6.70% for male U.K. *voluntary* annuitants. The values for women are 7.23% for U.K. female *compulsory* annuitants and 7.80% for U.K. female *voluntary* annuitants, both very similar to the U.S. results (see the first two lines of the panel). In other words, using U.K. compulsory instead of U.S. compulsory annuitant mortality tables is equivalent to discounting at an interest rate 63 basis points lower for male U.K. compulsory annuitants, but only 22 basis points lower for male U.K. voluntary annuitants. The corresponding differences for women are much smaller, at 2 and −3 basis points, respectively. In panel B, the IRRs are even lower, at 5.05% and 6.74%, though it is interesting that the U.S./U.K. 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 U.S. insurer would have to earn approximately 63 basis points more on invested assets for men, and 3 basis points more for women, to provide the same payout as the compulsory annuity product.[9]

II. 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 for a wide range of reasons. One possible explanation is that groups of people have distinct mortality probabilities, such as those associated with well-known differentials by sex, age, and income. In developed countries, for instance, women tend to outlive men, particularly at older ages. A different explanation is that life expectancy has increased over time. Hence, if expected future improvements are built into one mortality table used for projections but not 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 across countries, many of them attributable to differential levels of development. For instance, developed nations tend to have higher income levels and better health-care provision than their poorer counterparts, which are socioeconomic factors anticipated to translate into higher life expectancies as compared with their less wealthy neighbors. Of course, within the subset of developed nations, there are also mortality differences across populations, probably due to a wide range of factors including national differences in lifestyle, diet, and climate.

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 U.K., for example, one compo-

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

nent of old-age pension benefits must be annuitized on a compulsory basis while other annuities are voluntary. As a result, experts have devised distinct U.K. mortality tables (by sex) for voluntary and compulsory-purchase annuitants, both of which differ from the general population table (cf. Finkelstein and Poterba 1999). In the U.S., 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 U.S. pension plans that offer annuities to members, 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's results deviate from the norm. It is important to realize that the classifications we have introduced among "population," "compulsory," and "voluntary" selection in mortality tables are to some extent arbitrary. We define selection as "compulsory" if the mortality table relates to annuitants of pension plans and "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.[11] We hope to capture most of these effects in the error term of our model: the results are therefore 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 IRR 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 we estimate is as follows:

$$Y_{ijkl} = \alpha + \boldsymbol{\beta}'\mathbf{C}_i + \boldsymbol{\gamma}'\mathbf{S}_j + \delta G_k + \zeta T_l + \theta(S * G) + \lambda(T * G) + \epsilon_{ijkl}$$

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 ε_{ijkl}, modeled as independent, identically distributed random variables.[12]

Our primary null hypothesis is that $\gamma = 0$, which means that the mortality tables display no additional statistically significant adverse selection, after controlling on the country-specific ef-

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

[11] Mortality tables are not *directly* affected by the factors listed here because the tables used are based on the experience of actual purchasers of annuities. However, since purchasing behavior is affected by regulation and other factors, these may have an impact on the sample composition. One example is unisex annuities in some countries. If annuities are priced on a unisex basis, more females will find them to be better value, which implies that adverse selection will be lower for females than for males. Another example may be options given to individuals at retirement. If individuals can cash out of a plan instead of buying an annuity, this may induce further adverse selection.

[12] We also explored results in which table type is treated as a random effect with non-zero mean and variance σ_T^2 to allow for the possibility that cohort mortality tables may be based on period mortality tables. The null hypothesis that $\sigma_T^2 = 0$ is rejected using a likelihood ratio test, but coefficient estimates are virtually unchanged, so the results reported in the text reflect the simpler error structure; additional details are available from the authors upon request. We also estimated standard errors robust to heteroskedasticity and found these to be less than OLS standard errors; the text reports the more conservative OLS results.

fects as well as table and gender differentials. The alternative hypothesis is that $\gamma \neq 0$; 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 that may differ from those for men, or that λ and $\theta = 0$.

C. Pooled Cross-Country Results

The regression analysis is conducted using information on population and annuitant mortality tables taken from nine countries: Australia, Austria, Canada, Chile, Germany, Israel, New Zealand, the United Kingdom, and the U.S. All told, these data cover over half a billion lives drawn from 60 different life tables,[13] which include population period and cohort, as well as annuitant period and cohort tables for both men and women.[14] Table 2 summarizes the A/E metric for the data set, as well as the key variables used in the analysis. Independent regressors include a set of country-specific indicators (the U.S. is the omitted category). In addition we include (0,1) indicators of whether the table was for male or female (male is the omitted category), for period or cohort (period is the omitted category), and whether the table was a population or compulsory or voluntary annuitant table (population is 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.

Results of this analysis appear in Table 3, 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^2). Focusing on specific mortality metrics, we find that the "female effect" turns out to be negative for the A/E measure—it is

Table 2
Data Summary Statistics

	A. Sample Statistics of A/E Metric			
	A/E Metric			
	Mean	Std Dev	Min	Max
All	72.43	22.87	27.68	120.70
Female	58.61	16.06	27.68	104.57
Vol. Annuitant	66.92	18.19	27.68	95.94
Compuls. Annuitant	57.34	14.47	32.40	89.85
Cohort	64.24	17.54	32.40	98.25
U.K.	75.45	20.18	46.99	115.61
Canada	60.76	18.88	32.40	91.69
Chile	83.61	21.19	59.76	109.50
Australia	68.06	19.96	43.29	97.69
Israel	89.95	27.54	55.96	118.59
Austria	86.88	26.68	55.25	119.92
Germany	77.19	30.31	44.54	117.26
Switzerland	63.89	33.16	27.68	120.70

	B. Composition of Data Sample
	Proportion of Sample
Female	0.500
Vol. Annuitant	0.233
Compuls. Annuitant	0.333
Cohort	0.367
U.S.	0.200
U.K.	0.200
Canada	0.133
Chile	0.067
Australia	0.100
Israel	0.067
Austria	0.067
Germany	0.067
Switzerland	0.100

Source: Authors' calculations; see text. For description and sources of mortality table data, see footnotes 13 and 14 of text.

[13] The mortality tables from the U.K. 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 U.K. (1999); for the U.S. from the U.S. 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).

[14] Not all countries have data for all types of tables. Specifically, for the U.S. 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 U.S. we also have the four RP2000 tables for pension annuitants; for the U.K. 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 1997–99, although the tables from German-speaking Europe tend to be slightly older than this. The U.K. 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.

statistically significant and large in magnitude. The estimate implies that in this data set, mortality rates for women are 34% lower than the benchmark U.S. male population rates, which is comparable to the 33% and 26% 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).

There is no significant difference between estimated coefficients on the voluntary versus compulsory selection variables. 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%. The cohort effect is much smaller, on the order of 12% relative lower mortality. As an illustration of our model, the predicted A/E metric for male U.K. compulsory annuitants may 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 3, we note that the female effect is now 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% ((1.41 − 0.45)/5.002 = 0.19).

A final point to emphasize regarding Table 3 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% higher mortality than the benchmark, while Switzerland and Canada have 10% lower mortality. All of the country-specific variables are highly significant when the IRR 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 met-

Table 3

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
U.K.	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
Female × Vol. Ann.	10.63**	5.05	−0.09	0.66	−0.452**	0.165
Female × Comp. Ann.	6.05	5.64	0.19	0.73	−0.405**	0.184
Female × Cohort	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^2	0.86		0.84		0.94	
Number of Obs.	60		60		60	

Notes: ** p-value ≤ 0.05; *p-value ≤ 0.1. The reference category throughout is U.S. male population period mortality table.
Source: Authors' calculations; see text. IRR columns rely on U.S. male period population mortality and a base interest rate of 5%; see text. For description and sources of mortality table data, see footnotes 13 and 14 of text.

rics for Japan. Our focus on 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.[15] 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 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 3 a comparative graphical illustration of the distribution of expected age at death in the Japanese and U.S. populations. These data reveal that at younger ages, before age 78, a greater proportion of U.S. males is expected to die than of 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 U.S. 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. Given the essential similarity in the results of the U.S. and U.K. comparison, it is remarkable that Japanese tables are so strikingly different.

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 im-

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

Figure 3
Distribution of Age at Death, U.S. and Japanese Male Population

Source: Authors' computations based on population mortality tables from SSA (1999) and Mitchell et al. (1999) for the U.S., and for Japan from the Ministry of Health and Welfare (1998).

provements 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 table applies to annuitants in the Tax-Qualified Pension Plan (TQPP) system. The TQPP is one of the two main types of corporate pension plans in Japan and covers mainly smaller employers. The TQPP mortality table is specified as 85% of the JLT 15 table, which was derived from the mortality of the Japanese population in 1980. Under a collective agreement among 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 plan members.

A graphical comparison of the U.S. and the Japanese voluntary annuitant table is provided in Figure 4. Apparently large differences are evident across the two countries in the distributions of ages at death for men, but in an unexpected direction. The Japanese voluntary annuitant table indicates far higher expected mortality than for U.S. *annuitants,* particularly for men, despite the fact that Japanese *population* mortality rates are lower than in the U.S.

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.

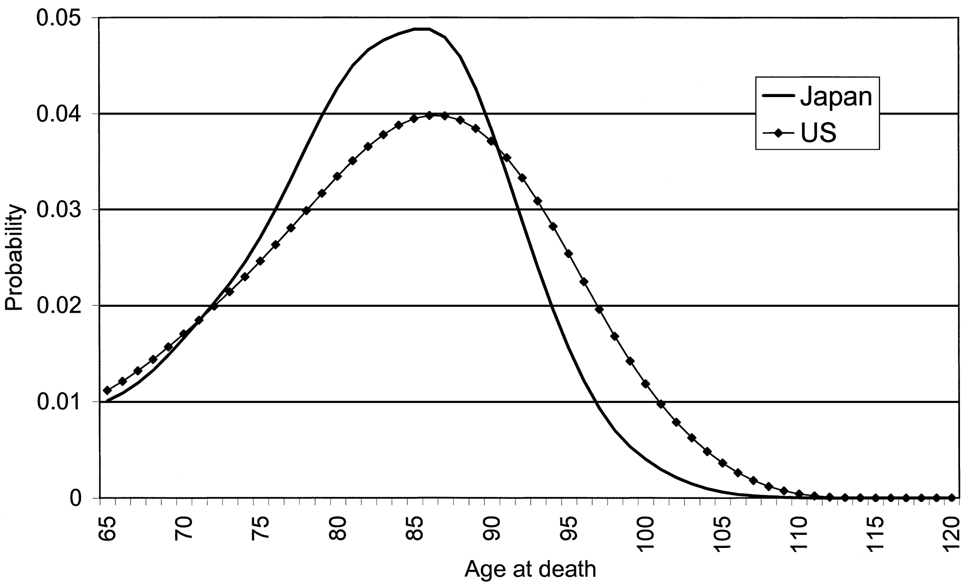
The results indicate that there is higher mortality than the model would predict in both the voluntary annuitant and TQPP tables. The magnitudes of these unexpected differences are quantitatively substantial; TQPP and voluntary annuitants in Japan would be seen to face a 29–35% higher mortality and live 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 U.S. because 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.[16] 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 5, which provides confidence intervals for the predicted values of the A/E metric for Japanese 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.[17] As the hypothesis tests imply, the TQPP and voluntary annuitant mortality patterns are well outside the confidence intervals for both males

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

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

Figure 4
Distribution of Age at Death, U.S. and Japanese Male Voluntary Annuitants



Source: Authors' computations.

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.

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. Because actuaries use many different assumptions to value annuities, 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 U.K. 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.

III. 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 U.S. and the U.K. 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 and the U.S. male population period mortality table as a benchmark. Compared to this group, annuity valuations would differ by 10–15% if instead one used U.S. or U.K. 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% in both the U.S. and the

Table 4

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
U.K.	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
Female × Vol. Ann.	10.84**	4.70	−0.21	0.62	−0.479**	0.156
Female × Comp. Ann.	6.87	4.93	0.19	0.65	−0.385**	0.164
Female × Cohort	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^2	0.87		0.86		0.94	
Number of Obs.	68		68		68	

Notes: ** p-value ≤ 0.05; *p-value ≤ 0.1. The reference category throughout is U.S. male population period mortality table.
Source: Authors' calculations; see text. IRR columns rely on U.S. male period population mortality and a base interest rate of 5%; see text. For description and sources of mortality table data, see footnotes 13 and 14 of text.

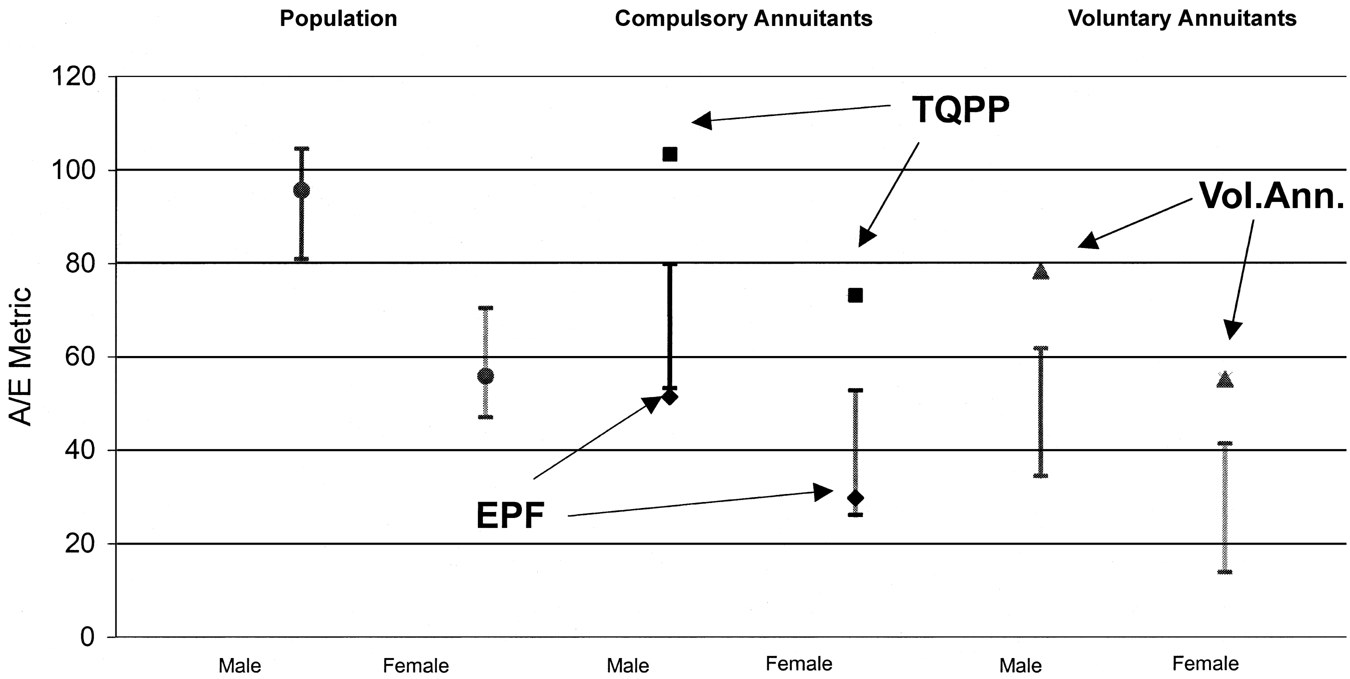
U.K. (Brown et al. 2000; Finkelstein and Poterba 1999).

Deciding which mortality table to use evidently has a potent effect in valuing these products. This is important to acknowledge because 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 U.S. or U.K. 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 U.S. or U.K. 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 do 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.

Of late, some analysts have sought to measure the effect of adverse selection due to private information on the mortality of a wide rang of insurance purchasers (cf. Finkelstein and Poterba 2001; Cawley and Philipson 1997). Using aggregate data, of course, it is difficult to differentiate between income effects and adverse selection due to asymmetric information, without making further assumptions. In the present paper, we as-

Figure 5
Japan Actual Annuitant Tables vs. 95% Confidence Intervals from International Data, A/E Metric



Source: Authors' computations.

sume that the distribution of income is the same for both compulsory and voluntary annuitants, permitting us to use aggregate data to test for adverse selection by comparing the mortality of compulsory and voluntary annuitants. A companion paper makes an alternative assumption, namely that the income of life insurance purchasers and annuitants is equal, so mortality differentials may be used to test for adverse selection (McCarthy and Mitchell 2002). Further pinpointing of the magnitudes of adverse selection would benefit greatly from individual-level data.

Our final conclusion is 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 additional research can explore the financial significance of these deviations.

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