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Assessing the Impact of Mortality Assumptions on Annuity Valuation: Cross-Country Evidence

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Disciplines

Economics

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Evaluating the money's worth of annuities requires one to employ an assumed mortality table. In practice, of course, there are many measures of mortality probabilities including cohort, period, annuity and population mortality tables that differ by age and sex. Each of these tends to differ across countries, as well, making it difficult to compare the working of annuity markets internationally. This paper proposes several methods for comparing alternative mortality tables and illustrates their impact on annuity valuation for men and women in the US, the UK, and Australia. 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. Australian mortality rates are notably lighter than those in both the UK and US.

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Assessing the Impact of Mortality Assumptions on Annuity Valuation

David McCarthy and Olivia S. Mitchell

Retirement specialists recognize that well-functioning funded retirement systems require well-functioning annuity markets.[1] This is because annuities play an essential role in converting asset accumulations into a regular flow of retirement income guaranteed for life. But as actuaries 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. As a result, policymakers and researchers working in Latin America and Asia must often rely on mortality data from other countries in order to value life insurance and annuity products.

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. Next we evaluate comparable results for Australia, where available. The results indicate that the choice of mortality table has a potent effect on annuity money's worth calculations.

I. What a Mortality Table Is

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.[2] A mortality table is generally derived by first collecting data on deaths occurring in this 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 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 by Johansen (1996) and subsequently 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.[3]

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 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., forthcoming).

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.

II. Metrics for Comparing Mortality Tables

In this section we examine several methods that can be used for comparing mortality tables. Five approaches are examined: 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, and where possible, compare these findings with results for Australia.

Plots of survival frequency distributions

The traditional 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 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.[4] 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.[5] 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.

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, both a benchmark mortality table and an interest rate are required. In what follows, we first calculate the value of a life annuity using 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.

III. Comparing the Measures Using Mortality Tables Across Countries

To implement these measures we rely on the most recent US mortality information, made available in early 2000 for mortality results collected as late as 1998; UK data are based on voluntary annuity tables with estimated mortality improvements for a cohort aged 65 in 1998. In addition we provide some results for Australia using population tables; [6] it appears that no cohort mortality table for annuitants has been derived in Australia.

The first set of comparisons uses survival functions ~~survival functions~~ and results appear in Figures 1 and 2. Data are provided for a cohort of 65-year old male and female annuitants in the UK and the US, respectively. The results show that pensioner mortality is remarkably similar in the UK and the US for both men and women. Whether these small observed differences are "large enough" to have an influence on money's worth results is unclear from an inspection of the Figures. 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 effect of these differences on money's worth calculations.

Figures 1 and 2 here

Our other comparison measures are reported in summary form in Table 1 for men and women. Findings for annuitants appear in Panel A and population results in Panel B (additional computations are reported in the Appendix). Turning first to the A/E metrics in columns 1 and 5, we assign a value of 100 to the benchmark US male population (using the period mortality rates). Annuitant mortality rates for both the UK and the US are lower than this base group, as is evident in Panel A. Nevertheless, there are substantial differences in mortality patterns across countries. For men, the US annuitant mortality pattern is 34 percent lower than for the UK *compulsory* annuitant group, but only 11 percent lower than the UK *voluntary* annuitant group. Among women, the *compulsory* annuitant rate in the UK is 25 percent lower and 5 percent lower for the *voluntary* annuitant sample. Population results for A/E values in columns 1 and 5 are much more 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. Also of interest is the finding that Australian mortality is lighter yet, being only 85.2 percent of the base table.

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 US male annuitant can anticipate a remaining lifetime of 20.0 years (Panel A), while the UK male *compulsory* annuitant may expect to live only for 17.4 years, which is a 13 percent difference. The UK male *voluntary* annuitant can expect to live another 19.2 years, only 4 percent less than the corresponding US figure. Like-aged female US annuitants can anticipate 22.7 additional years with their UK counterparts at 20.8 years, for an 8 percent difference. These 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 2.2 percent and 1.4 percent for men and women, respectively. Australian men can expect to live 6.2 percent longer from age 65 than their American counterparts; Australian women 6.1 percent longer than US women from the same age.

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.[7] Focusing first on annuitants, Panel A indicates that a US male's annuity would be worth $11.92; the value is $11.66 for the UK *voluntary* male annuitant and $10.93 for the UK *compulsory* male annuitant.[8] For women the pattern is similar, but the US annuitant would receive $12.96 and her UK *voluntary* counterpart $12.90, implying a much smaller total difference. A compulsory female UK annuitant would expect to receive payments worth $12.25. 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 turn to comparisons of internal rates of return (IRR) generated from different mortality tables. The first line of Panel A, Column 4, reports a figure of 6.92 percent associated with the US male 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 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 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 compulsory annuitants and 6.70 percent for male voluntary annuitants. The values for women are 7.23 percent for female compulsory annuitants and 7.80 percent for female voluntary annuitants, both lower than the US results in the first line of the Panel. That is, 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] The results also indicate that mortality rates in the Australian population are lighter than both the US and the UK, a conclusion that holds using all four of the metrics.[10]

IV. Conclusions and Discussion

This study illustrates how mortality tables can differ in rather substantial ways across countries and populations within countries. Our results are of interest because the choice of a mortality table influences annuity valuation rather importantly. 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 5-10 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, forthcoming; 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.

Table 1: Comparing Mortality Patterns Across Countries:
Results for the US, UK, and Australia ††

A. Annuitants 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	61.2	20.0	11.92	6.92%	44.6	22.7	12.96	7.82%
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-UK^V)/US	(11.11)	4.14	2.12	22.1*	(5.36)	1.85	0.51	1.7*

B. Population 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(%)
Aus	85.2	17.2	10.8	5.80%	55.4	20.9	12.4	7.34%
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^V)/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.
* This difference is shown as a raw basis point difference between US and UK 'voluntary' figures.
†† Cohort tables for Australian annuitants not currently available.

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

Appendix Table 1: Mortality Table Comparison Using the A/E Metric

Male

		Annuitant		Population	
		Cohort	Period	Cohort	Period
Aus		na	62.90	85.24	97.69
US		61.21	65.26	93.90	100.00
UK	V†	68.00	79.35	98.25	115.61
	C‡	82.27	95.94		
%(US-UK^V)/US		(11.11)	(21.58)	(4.64)	(15.61)

Female

		Annuitant		Population	
		Cohort	Period	Cohort	Period
Aus		na	43.29	55.40	63.86
US		44.60	47.79	62.92	67.09
UK	V†	46.99	54.94	65.82	77.04
	C‡	55.92	65.25		
%(US-UK^V)/US		(5.36)	(14.95)	(4.60)	(14.83)

† 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.
Authors' calculations use mortality tables appropriate for Australia from Knox (1999), UK mortality tables from Executive Committee (1999) and GAD (2000), and US mortality tables from SSA (1999) and SOA (1999).

Appendix Table 2: Mortality Table Comparison Using the Expected Remaining Lifespan Metric

Male

		Annuitant		Population	
		Cohort	Period	Cohort	Period
Aus		-	19.64	17.20	16.11
US		19.98	19.44	16.23	15.76
UK	V†	19.15	17.98	15.86	14.70
	C‡	17.45	16.29		
%(US-UK^V)/US		4.14	7.51	2.27	6.70

Female

		Annuitant		Population	
		Cohort	Period	Cohort	Period
Aus		-	22.98	20.90	19.81
US		22.66	22.11	19.67	19.19
UK	V†	22.25	21.07	19.38	18.15
	C‡	20.77	19.54		
%(US-UK^V)/US		1.85	4.67	1.46	5.45

† 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.
Authors' calculations use mortality tables appropriate for Australia from Knox (1999), UK mortality tables from Executive Committee (1999) and GAD (2000), and US mortality tables from SSA (1999) and SOA (1999).

Appendix Table 3: Mortality Table Comparison Using Present Value of $1 Life Annuity Metric

A. Discount rate of 2%

Male

		Annuitant		Population	
		Cohort	Period	Cohort	Period
US		15.91	15.57	13.34	13.02
UK	V†	15.41	14.64	13.09	12.30
	C‡	14.22	13.45		
%(US-UK^V)/US		3.16	5.95	1.88	5.55

Female

		Annuitant		Population	
		Cohort	Period	Cohort	Period
US		17.71	17.38	15.70	15.41
UK	V†	17.50	16.76	15.54	14.73
	C‡	16.46	15.67		
%(US-UK^V)/US		1.18	3.57	1.04	4.39

B. Discount rate of 5%

Male

		Annuitant		Population	
		Cohort	Period	Cohort	Period
Aus		-	11.71	10.83	10.39
US		11.92	11.73	10.37	10.18
UK	V†	11.66	11.24	10.22	9.75
	C‡	10.93	10.49		
%(US-UK^V)/US		2.12	4.22	1.39	4.19

Female

		Annuitant		Population	
		Cohort	Period	Cohort	Period
Aus		-	13.01	12.36	11.99
US		12.96	12.81	11.79	11.64
UK	V†	12.90	12.51	11.72	11.28
	C‡	12.25	11.83		
%(US-UK^V)/US		0.51	2.35	0.56	3.15

† 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.
Authors' calculations use mortality tables appropriate for Australia from Knox (1999), UK mortality tables from Executive Committee (1999) and GAD (2000) and US mortality tables from SSA (1999) and SOA (1999).

Appendix Table 4: Mortality Table Comparison Represented as Basis Point Equivalents

Male

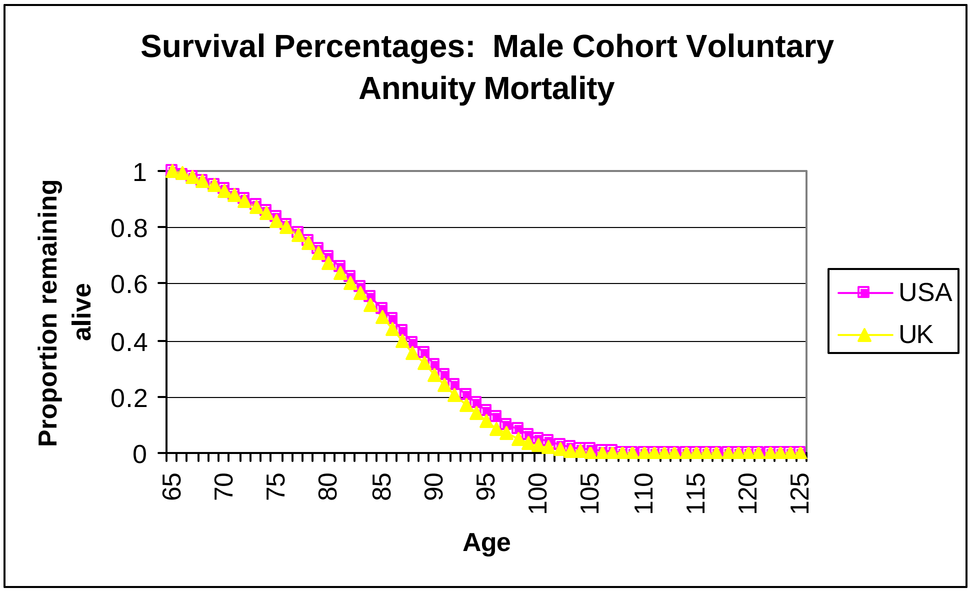
		Annuitant		Population	
		Cohort	Period	Cohort	Period
Aus		-	6.70%	5.80%	5.27%
US		6.92%	6.75%	5.24%	5.00%
UK	V†	6.70%	6.27%	5.05%	4.41%
	C‡	5.92%	5.40%		
US-UK^{V} (b.p.)		22.1	47.9	18.3	59.3

Female

		Annuitant		Population	
		Cohort	Period	Cohort	Period
Aus		-	7.84%	7.34%	7.03%
US		7.82%	7.72%	6.79%	6.66%
UK	V†	7.80%	7.51%	6.74%	6.31%
	C‡	7.23%	6.87%		
US-UK^{V} (b.p.)		1.7	21.1	4.6	35.6

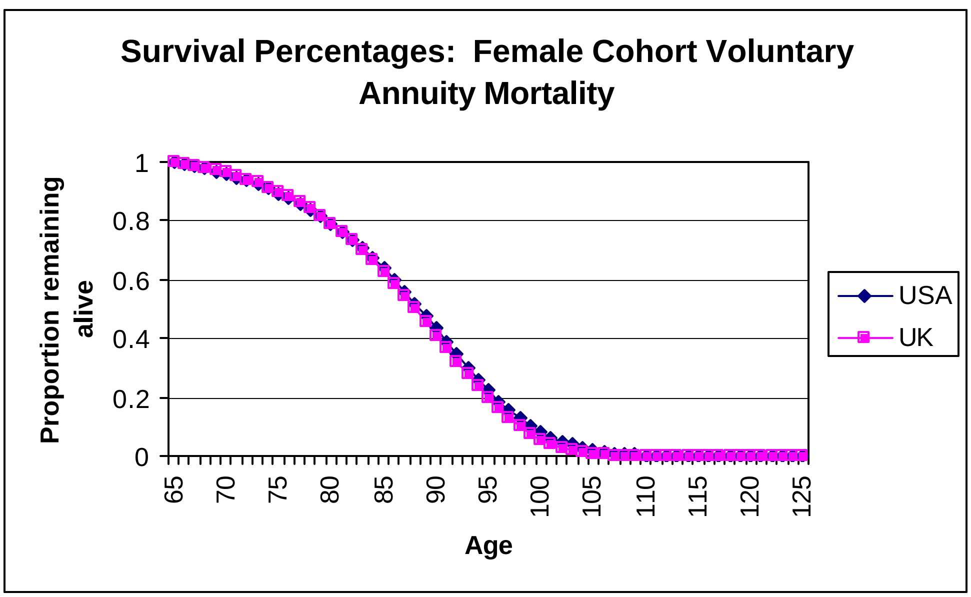
† This line refers to the mortality of voluntary annuitants.
‡ This line refers to the mortality of compulsory annuitants. Individuals are compelled to annuitize a certain fraction of pension benefits in the UK.
Authors' calculations use mortality tables appropriate for Australia from Knox (1999), UK mortality tables from Executive Committee (1999) and GAD (2000), and US mortality tables from SSA (1999) and SOA (1999).

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



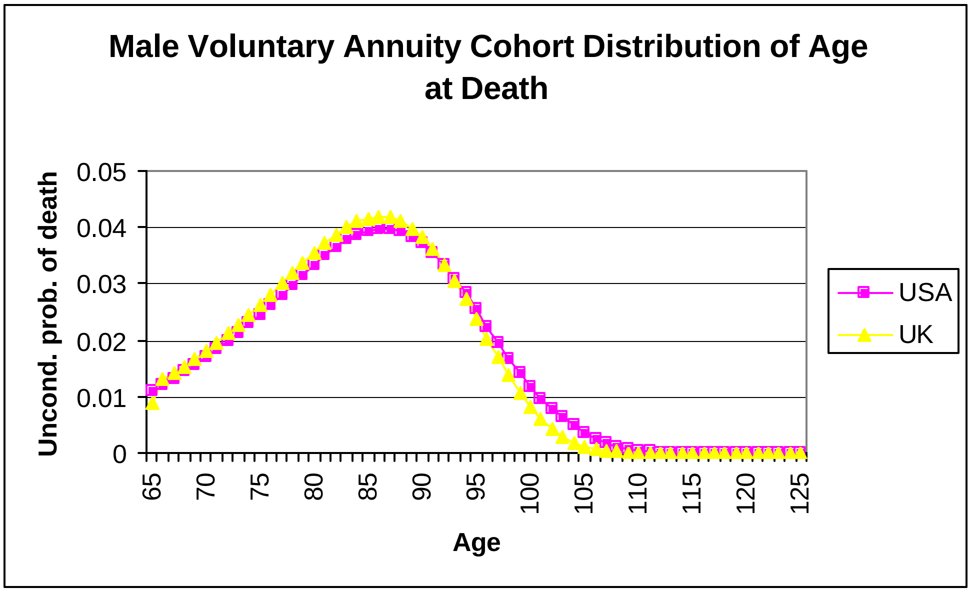
Source: Authors' calculations based on mortality tables from Executive Committee (1999) and Mitchell *et al.*(1999).

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



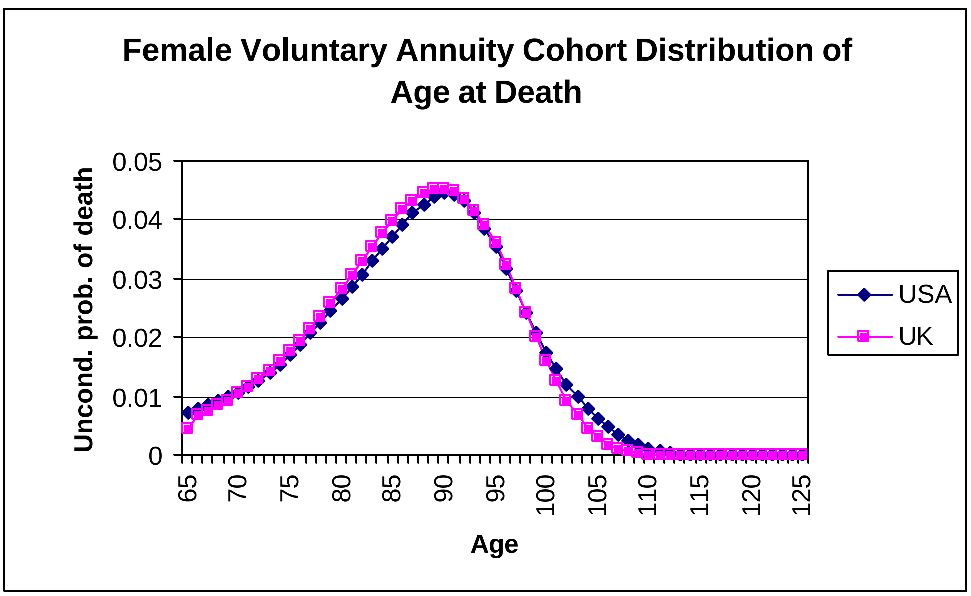
Source: Authors' calculations based on mortality tables from Executive Committee (1999) and Mitchell *et al.* (1999).

Appendix figure 1: Distribution of age at death 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).

Appendix figure 2: Distribution of age at death 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).

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Endnotes:

[1] The importance of annuity markets and their role in funded retirement systems have been explored by Brown et al. (forthcoming); 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.

[2] For additional background see Bowers et al. (1986), and Faculty and Institute of Actuaries (1999).

[3] 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.

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

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

[6] These are derived with data kindly supplied by David Knox (1999).

[7] Table 1 reports results for a discount rate of 5%; in the Appendix we also offer alternative computations using a 2% discount rate.

[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.

[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.

[10] Further results for Australia appear in the Appendix.