On the Importance of Older Age Mortality Rate Estimates

Background

The fundamental currency in life-actuarial science is the mortality table. A mortality table classifies a person and based on their characteristics, predicts the mortality rate. Mortality rates typically vary by attained age and sex. In addition, it is also common to vary mortality rates by policy features[1], policy year, underwriting status and other variables. Mortality tables typically go from some minimum age (some tables start from birth or 0) to an ultimate age. Lately, this ultimate age has been set to 120 (SOA, n.d.). These older ages which I will define as over 100 years old, is the topic of this paper as determining an appropriate ultimate age is challenging. Two clear reasons are mortality improvement and lack of data. Mortality has improved significantly since the beginning of the 20th century which has made some pioneering mortality tables obsolete (initially 100 was the ultimate age (in the 1940s) and 120 eventually became the standard for Commissioner's Standard Ordinary Tables (SOA, n.d.)). As for data insufficiency, insurers generally lack credible data for people over 100 years old. One explanation is that many people do not live to be over 100 years old. This explanation begs the question, do age 100+ mortality rates financially matter to an insurance company? Based on the Individual Annuity Mortality table ("IAM"), it appears that the answer is not really.

It is important to highlight how mortality improvement could undermine this argument. Mortality improvement could reduce all mortality rates and thus lead to a situation where a significant number of people do in fact live into their 100s. For example, if this argument was made back in the 1940s it would not have held water. The argument may have been since 70-89 mortality rates were so high (at that time), then 90–99-year-old mortality does not matter (the ultimate age was 100). However, this would have failed to consider mortality improvement. To bring it back to current times, if mortality improves for ages 85-99 dramatically, then more people will live into their 100s and therefore these old age mortality rates will become more impactful. From this line of thinking, it may be mortality improvement that insurance companies should be concerned with rather than the mortality rates for people over 100-years-old. Mortality improvement is the only way to make these 100+ mortality rates matter financially.

Mortality improvement is not an exact science, it may ebb and flow with external events in both favorable (new medical treatment) and unfavorable (opioids) directions. Further, as evidenced by the 2010s and early 2020s, mortality does not improve in perpetuity (Kochanek et al, 2020). Some posit that there is an ultimate age where all human biology fails and therefore it is impossible to live past this age. Others believe that since this ultimate age has been pushed back further overtime (SOA, n.d.), there is no limit (or the limit is well above the 120 years). This argument is perhaps spurious and best left to scientific researchers since so few people live to be over 110.

This paper provides quantitative examples and highlights the fact that misestimates in the older mortality rates (ages 100+) are not as impactful as misestimates for younger age ranges (younger

[1] Policy features can be predictive. For instance, if person has a richer plan design, they may a wealthier person which may correlate to lower mortality.

is perhaps a misnomer as I am referring to ages 60-89). Actuarial present value will be used as the metric to measure financial impact. In the next section, I will describe the methodology and mathematical principles behind actuarial present value. The actuarial present value is the present value of expected insurance benefits. I will evaluate misestimates in mortality (applied to certain age groups individuals) for 3 life insurance products and assess the actuarial present value under each scenario. The three products tested will be payout annuities, traditional whole life insurance and long-term care ("LTC").

Mathematical Background

The actuarial present value ("APV") is the present value of benefits for an insurance product. The generalized discrete formula is below and assumes constant interest rates.

$$APV(x) = \sum_{k=1}^{w-x} B(k) * v^k * f(k)$$

$Where;\ APV(x) = actuarial\ present\ value\ as\ of\ attained\ age\ x,$

$B(k) = benefit\ paid\ if\ insured\ makes\ claim\ for\ time\ period\ k,$

$v^k = discount\ factor\ to\ account\ for\ time\ value\ of\ money\ ,$

$f(k) = probability\ insured\ makes\ a\ claim\ at\ time\ period\ k$

This is the generalized formula, and the formula can accommodate different life insurance products. f(k) can be thought of as the benefit trigger which will vary by product type. The benefit trigger for a payout annuity is if the person is still alive as of time period k whereas for whole life insurance it is if the person died in time period k. For LTC, it is a little more nuanced as the benefit trigger is, initially, whether the person qualifies for LTC benefits.[2] Further, there is a secondary benefit trigger thereafter that determines if the person is still entitled to LTC benefits after becoming disabled. Below are the more detailed equations for whole life, annuities and LTC in that order.

$$APV^{Life}(x) = \sum_{k=1}^{w-x} B(k) * v^k * {}_{k-1}p_x \ * \ {}_1q_{x+k-1}$$

For life insurance, f(k) turns into the probability that a person dies in time period k. This is equivalent to the probability to that they survived to the beginning of time period k (${}_{k-1}p_x$) multiplied by the mortality rate, which is a conditional probability. For life insurance, APV generally decreases (favorable to the insurance company) when mortality rates decrease.

$$APV^{Annuity}(x) = \sum_{k=1}^{w-x} B(k) * v^k * {}_{k-1}p_x$$

[2] A person typically qualifies for LTC benefits if the insured cannot perform 2 out of the 6 activities of daily living or if they have significant cognitive decline.

For annuities f(k) is the probability of survival.[3] In this case, lower mortality rates (which increase survival probabilities) lead to an increase in the APV. Now, we will turn our attention to LTC, where we need more notation.

$$APV^{LTC}(x) = \sum_{k=1}^{w-x} APV^{Dis}(x+k) * v^k * {}_{k-1}p_x * \left(1 - {}_1q_{x+k-1}\right) * d(x+k-1)$$

$${}_kp_x = {}_kp_x * \left(1 - {}_1q_{x+k-1}\right) * \left(1 - d(x+k-1)\right); where\ {}_kp_x = 1$$

$$d(x)\ is\ the\ incidence\ rate\ for\ a\ person\ aged\ x\ (rate\ that\ they\ go\ on\ claim)$$

$$given\ they\ are\ alive\ at\ the\ beginning\ of\ the\ time\ period.$$

In this case, f(k) is set to the probability of the person becoming disabled (as defined by the LTC policy) in time period k. I set this equal to the probability of remaining active (not on claim and alive) times the probability of going on claim assuming deaths happen first (a simplification). In addition, B(k) also had to be transformed. I assumed that the "benefit paid" by the insurance company is the present value of the disabled annuity for someone who is disabled at age x+k. Like annuities, LTC APV's increase when mortality decreases (more people are alive who can then become disabled and/or people stay on claim for longer).

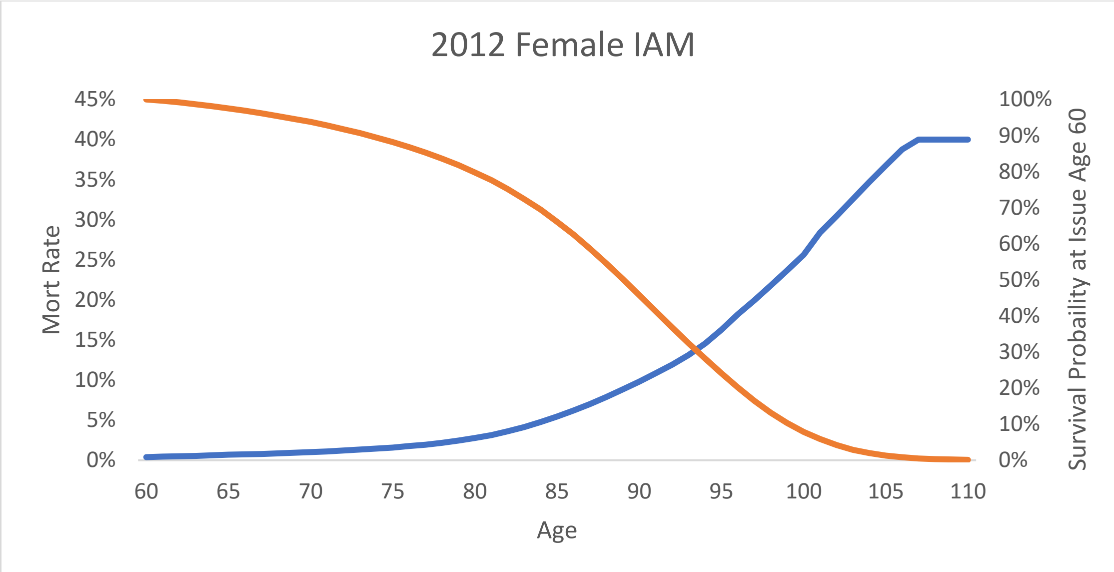
In this analysis, the 2012 female IAM was used as the starting point. Further, it was assumed that everyone was 60 years old at the start of the analysis. To evaluate the impact of mortality, I applied a 10% reduction in mortality to specific age ranges (see Table 1, below). As an example, when applied to the 100+ age range, this test represents mortality being overestimated by 10% for ages 100+. I cited deltas as a percentage change to ease the comparability.

Table 1: Age Ranges

Range #	Age Range
1	60-69
2	70-79
3	80-89
4	90-99
5	100+

Below is the survival curve and mortality rates for a female, 60 years old at the start of the analysis. Note that mortality rates drastically increase with age, which should come as no surprise. Further, only roughly 8% are expected to live to be over 100 years old based on this mortality table. Another aspect is that after age 107, the mortality rates are held level at 40%. I speculate this was a simplification made by the creators of the table and was needed because there is sparse data at ages 100+.

[3] In this paper I have assumed that payments are at the beginning of the year



I must now quickly document some of the assumptions used, see Table 2 below. Of note is that this analysis is limited in that it does not consider any additional decrements besides mortality and incidence (Only LTC considers incidence). Considering other assumptions, would have been spurious as this analysis is purely on mortality rates.

Table 2: Summary of Assumptions

Product	Name	Assumption
Life	Mortality	2012 IAM Female Table
	Payment timing	End of year
Annuity	Mortality	2012 IAM Female Table
	Payment timing	Beginning of year
LTC	Mortality	2012 IAM Female Table
	Incidence	50% x 2012 Female IAM Table
	Policy features	Lifetime benefit period, no EP
	Payment timing	End of year
General	Decrements	Mortality is the only decrement (an exception is LTC)
	Sex	Females

Analysis

Life Insurance

Recall the following equation from above. Note that a 5% annual discount factor was assumed throughout this analysis.

$$APV^{Life}(x) = \sum_{k=1}^{w-x} B(k) * v^k * {}_{k-1}p_x \; * \; {}_1q_{x+k-1}$$

Below are the baseline APV's split out by age group using the raw 2012 IAM female table. Note that for life insurance, only a fraction of the value of benefits is attributed to ages 100+. The largest contributor is the 80-89 age group. This hypothetical life insurance policy only considers death benefits and ignores premiums and cash surrender value. Cash surrender values are typically required by law for some insurance products and the law calculates a predetermined amount the insurer must reward a policyholder who lapses. The cash surrender value has an interesting effect in that it leads to the life insurance being more risk neutral at older ages. It becomes especially more risk neutral to misestimates in the lapse assumption. The cash surrender value typically approaches the reserve value as the policyholder ages and the reserve value approaches the face amount as the policyholder ages. The insurer's loss incurred is equivalent to benefit paid (cash surrender value or death benefit) less the reserve release (used to pay the benefits). Cash surrender values lead to higher premiums as well.[4]

Table 3: Life Baseline Results
Face Amount = 1000

Age Range	APV	APV %
60-69	48.93	16.3%
70-79	67.19	22.4%
80-89	100.69	33.6%
90-99	72.79	24.3%
100+	10.05	3.4%
Total	**299.65**	

As cited above a 10% reduction in mortality was run separately for all developed age groups. The table below presents the results of the table. APVs are aggregated to ease interpretation.

Table 4: Life Sensitivity Results
Face Amount = 1000

Scenario	APV	APV Delta %
Base	299.65	
60-69: Shock	296.50	-1.051%
70-79: Shock	296.33	-1.109%
80-89: Shock	296.36	-1.099%
90-99: Shock	298.14	-0.505%
100+: Shock	299.51	-0.046%

Note that the 10% reduction for the 60-69, 70-79, 80–89-year-old mortality rates (each applied separately), reduce the actuarial present value of benefits by roughly 1.1% (favorable). However,

[4] Since the insurer has to pay more benefits, this is must be priced in

only a 0.5% reduction was incurred for the 90-99 shock and a 0.05% reduction for 100+ shock. This indicates that misestimates of the 100+ ages are not extremely impactful. The interpretation is that a 10% reduction in the mortality rates for 100+ people decreases the APV by ~0.5%. This result is intuitive if we go back to the IAM survival curve. We see that a small percentage of people live to be over 100-years old. Therefore this 10% reduction at ages 100+ gets applied to a miniscule survival rate. In addition, if a company is concerned about too many people dying in their 100s, that is a good problem to have as it means more people are living longer and therefore the death benefits are getting deferred.

Annuities

Recall the equation for payout annuities. You will notice annuities are a classic case of incentives not being aligned between the insurer and the policyholder. In life insurance, both the insurer and the policyholder want the policyholder to live so both "win" when the insured lives a long life. For annuities, the policyholder benefits when they live a long life, but not just spiritually. They also financially benefit since payout annuities often (or at least they do in this example) pay until death of the policyholder. Since the financial payments are paid by the insurer it is in the insurer's best interest for the annuity policyholder to die prematurely[5]. Insurers can counteract this by insuring a mix of life insurance and annuities which naturally hedge one another. If mortality goes up the life insurance will be costlier, but the annuities will be more profitable. The converse being true if mortality goes down.

$$APV^{Annuity}(x) = \sum_{k=1}^{w-x} B(k) * v^k * {}_{k-1}p_x$$

Table 5 below, shows the baseline APV contribution by age group. Surprisingly, this view shows that ages 100+ are even less impactful than life insurance. However, if we go back to the formula, we see that a lot of value will naturally be reaped in the beginning years since benefits are paid every year. In the early years survival probabilities are closer to 100% and the discount rate is closer to 100%.

Table 5: Annuity Baseline Results
Yearly Benefit = 1,000

Age Range	APV	APV %
60-69	7,935	52.9%
70-79	4,427	29.5%
80-89	2,077	13.8%
90-99	534	3.6%
100+	34	0.2%
Total	**15,007**	

[5] Insurance companies are not known for their empathy.

The table below, presents the results for each of the 10% reduction in mortality applied to a different age group. Similar to life insurance the 100+ shock is immaterial relative to the other age groups. 90-99 roughly half as material for the other age groups. We can also note that these are less impactful than for the life product. This may seem surprising, but perhaps it is driven by the fact that much of the value for annuities is hoarded in the initial payments. Further, life insurance is likely more sensitive to assumption changes since life insurance payments are concentrated at older ages where there are higher mortality rates.

Table 6: Annuity Sensitivity Results Yearly Benefit = 1,000		
Scenario	**APV**	**APV Delta %**
Base	15,007	
60-69: Shock	15,070	0.420%
70-79: Shock	15,073	0.443%
80-89: Shock	15,073	0.439%
90-99: Shock	15,037	0.202%
100+: Shock	15,010	0.018%

LTC – Part 1

Recall the equation used to estimate the actuarial present value for LTC below.

$$APV^{LTC}(x) = \sum_{k=1}^{w-x} APV^{Dis}(x+k) * v^k * {}_{k-1}p_x * \left(1 - {}_1q_{x+k-1}\right) * d(x+k-1)$$

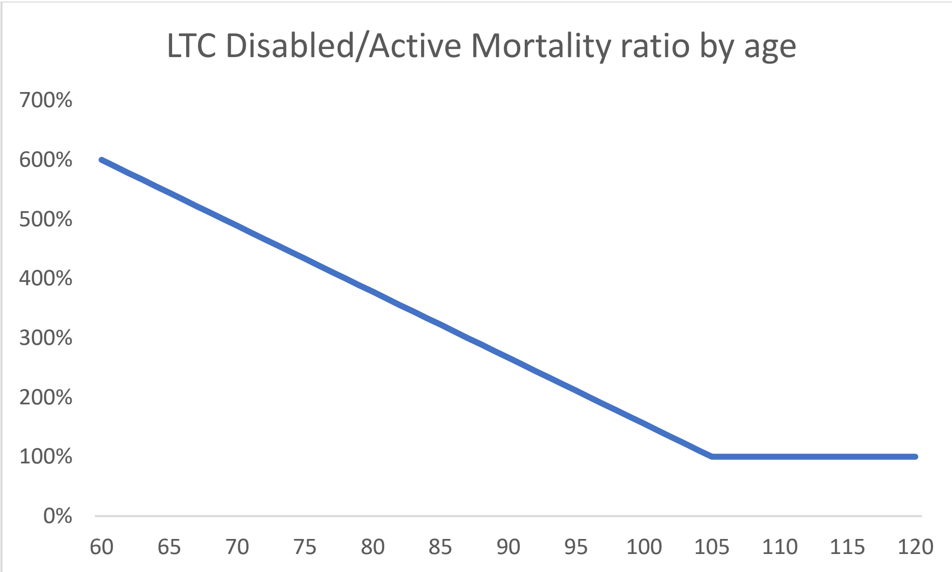
This equation shows that LTC's actuarial present value (APV) is an APV of APVs. The inner actuarial present value fundamentally is an annuity for disabled lives. That is because once a person goes on claim they are paid benefits until they go off claim by either dying, recovering or running out of benefits. However, incurring a claim is similar to life insurance in that the benefit trigger is driven by a discrete event.

Below are the actuarial present values by age contributions based on assuming a yearly benefit of 1,000. The skewness for LTC is in between life insurance and annuities. Life insurance is slightly more skewed to the older ages whereas annuities are more highly skewed to younger ages. Like both annuities and life insurance very little value is concentrated in the ages 100+ because based on the IAM table, very few insureds live into this age group.

Table 7: LTC Baseline Results Yearly Benefit = 1,000		
Age Range	**APV**	**APV %**
60-69	75	15.0%
70-79	186	37.0%
80-89	177	35.2%
90-99	60	12.0%
100+	4	0.8%
Total	**503**	

The first test ran was the standard test of shocking mortality down by 10% for each age group. For LTC, the age group 80-89 appeared to be most sensitive to a 10% shock in active mortality which is in slight contrast to life and annuities where the younger age group, 70-79, was the most sensitive. This is likely driven by the incident event for LTC. Like the previous products the 100+ shock was relatively immaterial, but it was more material than the other two products. The age group 90-99 was very material but less material than the age groups 70-79 and 80-89. A key driver of the relatively higher sensitivity is the disabled mortality rates which are typically higher than active mortality rates. For this paper, I assumed a percentage load on active mortality rates (IAM) as defined by the graph below using made up numbers that linearly grade down to 100%. It is likely that the relative mortality gap decreases with age as the differences in health statuses for an older disabled and older active person is likely lower than for a younger disabled and younger active.

Table 8: LTC Sensitivity Results Yearly Benefit = 1,000		
Scenario	**APV**	**APV Delta %**
Base	503	
60-69: Shock	508	1.054%
70-79: Shock	515	2.475%
80-89: Shock	521	3.635%
90-99: Shock	512	1.927%
100+: Shock	504	0.161%



In addition, to the standard 10% shock I have also tested one more scenario for LTC. In this scenario I set the starting age to 80 instead of 60. This may be more consistent with reality since many LTC carriers have stopped issuing LTC policies and manage these policies as a closed block (Cohen, et al, 2013). I ran the same test as before, a 10% reduction in each age-group's mortality rate. Below are the baseline and the sensitivity results.

Table 9: LTC - Starting Age 80 Results
Yearly Benefit = 1,000

Age Range	APV	APV %
80-89	303	57.8%
90-99	207	39.5%
100+	15	2.8%
Total	**525**	

Table 10: LTC - Starting Age 80 Sensitivities
Yearly Benefit = 1,000

Age Range	APV	APV %
Baseline	525	
80-89: Shock	567	8.049%
90-99: Shock	559	6.467%
100+: Shock	528	0.571%

The 100+ age group contributes a little bit more to the total APV in this scenario than it did previously (at 2.8% vs. 0.8% in baseline). However, this is still not a large percentage contribution. The bulk of the APV comes from the 80-89 age group which makes sense since this age is a prime claiming age and is before mortality rates get too high.

After completing this test, the sensitivity for the 100+ age group is higher than previously. When shocking mortality rates go down 10% for 100+, this leads to a 0.57% increase in APV as opposed to 0.16%. Overall, it does appear that LTC is more sensitive to the 100+ mortality rates relative to other products but the younger age groups are still much more material. It does appear that LTC is extremely sensitive to misestimates on the disabled mortality front given disabled mortality rates are higher. The total APV is again most sensitive to the 80-89 mortality rates where the reduction of 10% leads to an 8% increase in APV which is fairly sizable. 90-99 is more impactful compared to the past iteration at 6.5%. Discounting may drive some of this increased sensitivity. In the baseline case at issue age 60, we were roughly 20 years away from the prime claiming age. However, in this scenario we start out in the prime claiming age.

Conclusion

With the exception of LTC, these quantitative tests on the IAM mortality table all indicate that 100+ mortality should not materially affect insurance products since so few people make it into these ages for these older age mortality rates to matter. While LTC appears more sensitive, the 80-99 age range is dramatically more sensitive than the 100+. It should be noted that the IAM should generally be thought of as a conservative (low) mortality table as it is meant to capture US annuitant mortality. The annuitant population is generally wealthier and in better health than the average American.

My conclusion is that 100+ mortality rates actually hinge on mortality improvement. I do feel comfortable in saying that 100+ mortality rates should not materially impact insurance products in today’s mortality environment. However, I feel less confident in the validity of this claim to remain valid 20 years from now. It is entirely possible that there could be numerous health breakthroughs that extend human longevity such that living to 100 becomes normal.

Based on the above it may be more prudent for actuaries to focus more on drivers of mortality improvement rather the older age rates themselves. This is because there are so few data points in these ages. Therefore, the concern should not be analyzing these un-credible[6] data points but being watchful for scenarios that could lead to people to live into their 100s (which will yield more data points for one to collect). It should be noted that some people consider old age mortality to be those 80 or above. And as seen in this paper, these rates can still materially impact the actuarial present value.

[6] I am using credible in the actuarial sense. Which measures a statistical result can be relied upon. More data points leads to more actuarial credibility.

References

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