Black Swans in Actuarial Science

Introduction

A fundamental job duty for actuaries is developing future projections for insurance products and assessing the ability of the insurance company to remain solvent. This projection job is made possible by actuarial models. I will define actuarial models as a tool (or tools) that estimates the future income statement and balance sheet contributions for a given insurance product. As computing power advanced, so did actuarial models. Actuarial models can be split into two broad classes. The two classes are deterministic and stochastic models. The former assumes the underlying assumptions are fixed and the actuary determines the assumptions based on historical data. Some examples of assumptions include economic assumptions (such as interest rates), policyholder behavior (such as lapses) and decrements (such as mortality). For deterministic models, the assumptions are commonly calibrated to be "moderately adverse." This means that the projected future is worse than what the actuary believes will actually happen. Moderately adverse assumptions will make the reserves higher (or more conservative) which helps achieve the goal of avoiding insolvencies. Stochastic models, the latter, assumes that the assumptions are random variables that will fluctuate within each of the many scenarios developed by the stochastic model. Thus, stochastic model runs several (perhaps 1,000) scenarios with random assumption paths. Actuaries may set reserves on the assets required to stay solvent in x% of stochastic scenarios (e.g., x = 99%). The catch with all modeling is no one can predict the future, and often times stressful scenarios (aka "Black Swans") wind up falling outside the tail of the bell curve (Taleb, 2007).

I take issue with stochastic models due to their complexity and their potential to give a false sense of security. While these models have been made possible by computing innovations, one really doesn't conceptually know what is happening in each scenario considering there may be a thousand or more stochastic scenarios run. To understand the 1% of the 1,000 scenarios that fail (example above), you would need to understand 10 different stochastic scenarios. One deterministic scenario is challenging enough to understand. Even if one did have the mental capacity to do so, I question if they would be making accurate predictions of realistic worse case scenarios. Further, the 1% of scenarios that fail the solvency test, may not really reflect the unknown unknown that could (perhaps will is the better word) happen in the future (Taleb, 2007). Nassim Nicholas Taleb cites various financial collapses in his book, aptly named Black Swan, that fit the definition random and unknowable (at the time) but there can be Black Swans in the Actuarial world too. For example, Long Term Care lapse rates being much lower than expected (combined with interest rates declining and claim terminations being lower than expected) for Long Term Care is an example of an Actuarial Black Swan. It may now be obvious that LTC policyholders valued their policies more than expected, however, it is easy to critique the past from the mantle of hindsight. It wasn't obvious back then especially when considering the challenge of projecting human behavior forward (Taleb, 2007).

Now it is easy to criticize rather than offer solutions. I offer the following idea; for solvency testing actuaries should spend more time trying to determine ways that they could become insolvent. This is as opposed to assuming insolvency is averted in various scenarios which are chosen by the actuary. Solvency is not a given. In a 2000 book, Secrets & Lies, by Bruce Schneier, the author makes the case that a similar phenomenon applied to cryptography. Computer security companies were claiming their systems were un-hackable. This claim was of course supported by their own in-house tests (Schneier, 2000). However, in computer security, there is always a back door and the author argues the computer scientist should be spending more time deliberately attempting to break into the system (Schneier, 2000). Back to actuarial science, Black Swans do not care about one's rules outlined in their enterprise risk management program and the future is unknowable. As such, it would be more prudent to prepare for disasters rather than assuming Black Swans are impossible because they are too far outside of the model's prediction interval (Taleb, 2007).

Black Swans

In Taleb's book, Black Swan, Taleb describes Black Swans as random, unknowable, extreme events. Some financial Black Swans cited are the Dot Com bubble, the Russian debt crisis (and Long-Term Capital Management's collapse) and Black Monday (Taleb, 2007). The 2008 financial crash was not cited as Taleb's book coincidentally came out in 2007. Further, you can look at history for Black Swans such as Pearl Harbor, 9/11, Franz Ferdinand's assassination to name a few. In a mathematical sense, Black Swans fall out outside the reasonable limits implied by the normal bell (or any distribution) curve which Taleb despises (Taleb, 2007). The problem is that these Black Swans seem to happen more often than they "should."[1] Before discussing the implications, it is also important to note Black Swans are not always adverse. There are random, unknowable, extreme, good events as well. For example, if you purchased an out of the money short term put option (that pays only if the stock market declines by say 15%) the week before black Monday, you would have reaped significant financial returns from a Black Swan event.

To highlight Taleb's disdain for modern statistical applications in finance, Taleb tells a story about two men, Fat Tony and Dr. John. Fat Tony is an industrious man who relies on his street smarts. Conversely, Dr. John is a mathematician and, coincidentally an actuary bound by the "laws" of statistics. In his thought experiment, Taleb asks both men if a coin that is unweighted is flipped 99 times and lands heads each time, what is the probability the next coin flip is tails. Dr. John states "50%" without hesitation (Taleb, 2007). Fat Tony on the other hand, states "no more than 1%". He supports this argument by claiming that the coin is surely weighted towards heads (Taleb, 2007). The brilliance of Fat Tony is he is thinking outside the rules that were given to him. Seeing a 50%, raised to the 99^{th} power, event is far less likely than being lied to about the fairness of a coin. Probability textbooks may say otherwise but, they do not consider that Taleb (or any unruly individual) could have been lying (Taleb, 2007).

Now what does all this mean? Black Swans throw a massive wrench into solvency testing. The scenarios developed, by nature, cannot predict the unknown unknowns because they rely on historical data. Further, the normal distribution seems to poorly reflect the range of possible

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[1] Or perhaps it is the models do not really reflect the whole range of possibilities in the real world but rather a hypothetical mathematical world with elegant equations used to fit realty (Taleb, 2007). This is paraphrasing a central accusation by Taleb.

adverse outcomes. Taleb states that mortality is generally not as susceptible to Black Swans, as there is biology bringing mortality rates into line (Taleb, 2007). A comparison made by Taleb (2007), is wealth. Wealth is highly concentrated (e.g., compare Jeff Bezos to the average millionaire, note that I am comparing millionaires not even average worker) and would not be correctly modeled by the normal distributions. However, life expectancy seems to vary little compared to a unit such as wealth. Human behavior which is an implicit assumption in actuarial models does vary significantly. For example, lapse rates are the policyholder's decision. In Long Term Care insurance, actuaries assumed that lapse rates would be much higher than they actually were (Eaton & Morton, 2022). This became a huge problem since people held on to their policies for longer and therefore insurers had to pay out more LTC benefits than initially expected. As such, the lower lapse rates (and decline in interest rates and reduction in claim termination rates) became Long Term Care's Black Swan. To quantify, the ultimate lapse rate for Long Term Care was assumed to be around 5% but wound up being around 1% as experience emerged (Eaton & Morton, 2022).

The Current State of Actuarial Solvency Testing

Solvency testing is typically done by running various stresses and determining if the insurance company will be able to maintain adequate assets through the projection period to fulfill its obligations. The scenarios may be deterministic or stochastic. Deterministic scenarios (at least in the US) may be specific stresses targeted on various key assumptions (e.g. reduction in lapse rates for Long Term Care, elevated mortality in Life Insurance). These stresses may be calibrated based on standard deviations (thus implicitly using a normal curve (Taleb, 2007)). The issue here is that not all insurance assumptions are normal distribution appropriate. For example, interest rates can move quickly and have recently moved up which can be adverse (if you are a deferred annuity insurer).

As for stochastic modeling, I will push back harder[2]. As I stated in the introduction, stochastic modeling overcomplicates the modeling process and gives a false sense of security. Many of the assumptions are assumed to follow some sort of distribution, a.k.a. following a random walk. The question is what if the assumptions deviate outside of the tail? Further, what if the historical data does not reflect future events? These issues could become especially problematic with human behavior assumptions. Human behavior is naturally subjective and seems questionable to model (such as an indexed annuity shock lapse modeled based on interest rates). Further, can you realistically determine if the model adequately projects the future if you don't understand each of the scenarios determined by an assumption from a random number generator? As noted in the footnote, there doesn't appear to be tons of stochastic modeling used in the US, yet[3]. It appears the Europeans have been much keener on bringing this technique to insurance with Solvency II (Curry, 2018).

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[2] I am generally supportive of the US cash flow testing process. I think that it is consistent as the goal of cash flow testing which is to show that the liability are sufficient under moderately adverse circumstances. In my opinion, Black Swans are more prevalent for regulatory Capital (assets held above liabilities). Another, way to interpret my argument is I would prefer that the stochastic testing which has been accepted by Europeans does not infect the American insurance system. I can live with European condescension for not having complicated stochastic models.

[3] There are some examples that come to mind such as certain regulatory capital components (for variable annuities)

Acknowledging Insolvency

My problem with actuarial solvency testing (more so stochastic modeling than cash flow testing) is that we are testing for solvency rather than trying to develop scenarios that make the insurance companies insolvent. I dislike this approach since I find it delusional to think that it is impossible for an insurance company to go under. For instance, there could be a global financial collapse that wipes out all assets. I am not stating this is likely but it is not impossible. The statement that "we are solvent under 99% of scenarios" is probably not a realistic probability, especially if Black Swans are not captured in the tail.

I propose that insurance companies focus more so on trying to break their models to identify areas where they are exposed to large deviations, a Schneier-Cryptography inspired approach (Schneier, 2000). For instance, extremely adverse mortality may be extremely unlikely (unless there is a nuclear war and in that case insurance wouldn't matter). But adverse deviations in the economy and human behavior are more prone to Black Swans since there is no hard-scientific laws (like biology) governing these aspects (Taleb, 2007). By being more cognizant of where we fail, insurance companies can identify areas where they are at risk from unknown unknowns. Further, it may be prudent for the insurance company to de-risk in areas that are more prone to Black Swans through product design and strategy.

Taleb contends that some Black Swans are created by the very models that fail to predict Black Swans (Taleb, 2007). I do think he has a point. For instance, Copula models were used to price collateralized debt obligations (and other traunched assets) in the early 2000s (Salmon, 2009). However, most of the assumptions were more-so fancy mathematics than adequately reflecting the future and elevated, interlinked (Copula models assumed all mortgages were independent of one another), mortgage defaults underlying these complicated assets were not in the range of possibility[4]. The interconnectedness of the Global Financial System exacerbated this problem. In a more insurance sense, by developing complicated products allowing policyholder behavior to become more prevalent, insurers are exposing themselves to too much risk. While simplifying the insurance market and reducing policyholder option may seem controversial, what is less controversial is that an insurance company's main job is to stay solvent. As such simplifying the insurance marketplace is exactly what I am suggesting.

Let us start with product design. Insurance companies' products now contain a range of riders which may be impacted by policyholder behavior and the economy. An example would a guaranteed minimum accumulation benefits for variable annuities. If the account value falls below a certain level for annuities, the rider guarantees that the annuitant is entitled to the rider's specified minimum. As such these can be seen as a put option and this rider (and other riders) may use options pricing theories to develop premiums. However, as seen by Long Term Capital Management, option pricing theory can be used to cripple the financial system[5] (Lowenstein, 2002). Further some riders may not be modeled at all since they are complex and there may be

[4] Of course, there are other contributing factors such as lax lending standards and regulatory rating agency negligence. But both these factors were reality and a good model reflects reality.

[5] Not saying these riders can do the same, just think the risk to insurers seems a little forced given 2008 financial crisis

limited data to principally model these riders. Further, these riders may not even benefit policyholders since insurers may charge a metaphorical arm and a leg for taking on unknown risk. If the insurance company goes insolvent, that will not be in the policyholder's best interest either. I am not against all riders, for example long term care riders that are accompanied with life insurance conceptually makes sense since the LTC benefits and life insurance benefits are natural hedges (higher mortality leads to less LTC benefits). I am mainly suggesting that insurers should focus on products that can be actuarially priced and do not add unnecessary complexity.

In addition, if there are cases where human behavior is inevitable, actuaries should seek product designs that make the products human behavior neutral. As I have repeated, lapse rates for LTC were lower than anticipated which caused the industry great harm (Eaton & Morton, 2022). My proposal (given with the benefit of hindsight) would have been mandatory cash values as seen in life insurance. Upon lapsing the insurance company would have to pay a cash value. Now you might think this would just lead to more benefits being paid out, which is true. However, this would have increased the premiums to compensate. LTC policyholders may not like higher premiums but at least they can rest assured that they will receive cash back if they choose to lapse[6]. By developing human behavior neutral product designs, insurance products can be less prone to behavioral prediction errors.

Lastly, an elephant in the room is interest rate risk. This is a meta problem given the US' financialized system where one bank failure can put the economy on the brink. There are potential insurance industry options to limit interest rate risk. Some examples are renewable terms where the premium each year increases due to aging and experience (similar to health insurance), interest rate hedging, and removing interest rate guarantees. Renewable terms would lead to little pre-funding thus little reserve build-up and little interest rate risk. However, this is problematic since retired people typically have the highest insurance needs and therefore it would unreasonable to charge them an escalating premium scale without pre-funding for certain products such as life insurance. It is unreasonable since elderly income is typically low. Interest rate hedging largely makes sense for products that require large reserve buildup (e.g., individual life insurance). Lastly, I believe interest rate guarantees may be imprudent since insurance companies are "insurance" risk takers not interest rate speculators. Interest behaves strangely and deferred annuities with high interest rate guarantees, written in the 1990s may have realized losses. Insurance is risky but insurance companies should not be risky since their job is to stay solvent. I believe that considering Blacks Swans when conducting solvency testing and product design can help achieve this goal.

[6] One could counter with the sunk cost fallacy but, people do not behave like the economic models would insist.

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