

Life Insurance Pricing Competition and Simulation Research

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Abstract

A life insurance pricing competition with the objective of giving underclassmen actuarial science students a brief understanding of one of the roles of actuaries was performed. To accomplish this, a model was developed that considered several factors when determining premiums for annually renewable life insurance products. This model generated market share and business experience such as deaths and lapses based on premiums. These premiums were determined by each team. The teams calculated their own profits according to the experience. Furthermore, teams decided to increase or decrease their premium rates and the magnitude of the change based upon the results of the entire market in the previous rounds. Students worked in teams to discuss factors to consider and speculate how changes would affect the market.

Introduction

Learning involves obtaining and retaining new material, ideas, or abilities. Students learn in various ways, and this is particularly true for “millennial” students (born between 1977 and 1998) who can be characterized by their technical literacy and ability to multi-task in a rapidly evolving environment (Thielfoldt & Scheef, 2004). “Millennials” do not respond well to traditional instruction methods such as lecturing techniques in which educators passively lead students through academic topics (Science and Technology, 2009). In this type of relationship, teachers give students information, students demonstrate their understanding on assignments, and teachers assign a grade to students. This method of teaching is often inflexible and can fail to motivate and/or involve all of the students in the class, especially if generational changes divide teachers and students.

Simulations are an effective way of teaching for technical/engineering-oriented fields as it gives students the opportunity to experiment while dealing with intricate systems. Similarly, virtual environments can help business-related majors understand multi-actor networks, where managers, investors, policymakers, politicians, and other social groups interact and often pursue conflicting interests (Barjis, Sharda, Lee, Gupta, & Verbaeck, 2012). Whereas lecturing instruction customarily focuses on the lower levels of cognitive domain, simulations allow instructors to challenge pupils with more intricate levels of mental thought (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). Simulations can assist individuals as they challenge their assumptions and form new ideas using experiential learning exercises. Research has provided evidence that simulations “help students internalize business thought through the practice of business decision making” (Cadotte, 1995).

A simulation, in the form of a competition, was developed to replicate simplified mechanisms of the life insurance industry to give freshmen and sophomore students a brief glimpse of simplified actuarial work. Students acted as insurance companies and competed against each other for market share and profit. Regulations were set in place to govern the competition as the government would, thus replicating the government's influence in the insurance industry. Upperclassmen managers were appointed to teams of underclassmen in hopes they would lead the underclassmen and teach the basics of determining premium rates.

Competition Description

The competition provided an interactive learning experience where students had the opportunity to volunteer to work in groups of 4-6 with a more experienced upperclassmen leading the team. The competition was meant to simulate the operation of annually renewable term life insurance mechanisms. Students determined annual premium rates after making assumptions and accounting for expenses. The premium rates were entered into an excel model, which generated business experience (e.g. market share, lapses, claims, etc).

Teams were meant to act as the pricing actuaries at a company and with the objective to price a financially viable annually renewable term life insurance product. Several simplistic assumptions were made to facilitate the simulation. All of the people in the market were aged 58 at the start of the competition and aged one year after every round. For example, participants were aged 59 during round two. Hence, each round was considered to be a year. The target market was divided into 6 underwriting classes to include:

- 50,000 people rated as male nonsmoker preferred
- 30,000 people rated as male nonsmoker standard

- 22,000 people rated as male smoker standard
- 54,000 people rated as female nonsmoker preferred
- 32,000 people rated as female nonsmoker standard
- 12,000 people rated as female smoker standard

Each team needed to consider death benefits, fixed expenses, renewal expenses, underwriting expenses, potential lapses, and expected sales when setting premiums for the next year. The expenses that each company incurred are listed as follows:

- the death benefit is \$100,000 payable at the end of year of death
- the initial underwriting expenses for new policies is \$500 per policy incurred at the beginning of the year
- renewal overheads are \$35 per policy
- fixed overheads were \$1,000,000 for each underwriting class
- sales agent's receive an initial commission of 25% of premiums for new policies and 5% in renewal years

For the purpose of this competition, the concept of reserves is ignored as they are insignificant for annually renewable term policies. The risk-free interest rate is 3%. Companies are allowed to increase or decrease their premium rates by a maximum of 15% every year.

There were several metrics for which each company was awarded points based upon. Each company received a 6, 7, or 8 in each of the categories depending on their performance, with 8 being the most desirable. A weighted average of the scores in each category was taken to award each team a final rank. The team with the highest weighted score was the winner of the competition.

Description of Excel Market Share Model

The market share model is designed to distribute policies to various companies based on the premium rates set by the various companies and how they change. The model starts off with 200,000 policy numbers assigned to underwriting classes. These underwriting classes characteristics remain fixed throughout the competition.

Death Determination

The decision of which policyholders experience death is made on the “Policy Experience” worksheet of the excel workbook. The mortality tables used for the model are the 2001 CSO tables for each class. Only the ultimate rates from these tables are used. The table below shows which CSO table corresponded to the underwriting class in this simulation.

<u>2001 CSO Table</u>	<u>Underwriting Class in Excel Model</u>
Super Preferred Select and Ultimate - Female Nonsmoker, ANB	Female Nonsmoker Preferred Class
Super Preferred Select and Ultimate - Male Nonsmoker, ANB	Male Nonsmoker Preferred Class
Preferred Select and Ultimate - Female Nonsmoker, ANB	Female Nonsmoker Standard Class
Preferred Select and Ultimate - Male Nonsmoker, ANB	Male Nonsmoker Standard Class
Residual Standard Select and Ultimate - Female Smoker, ANB	Female Smoker Class
Residual Standard Select and Ultimate - Male Smoker, ANB	Male Smoker Class

To determine which policies experience death, all policies are assigned a “Survival Random Number” between 0 and 1 generated from Excel’s “RAND” function. If this number is less than the mortality rate associated with this assigned underwriting class for the respective year, the model assumes the corresponding policyholder has died in that year. The company that this policy belongs to is liable to pay a death benefit claim. The age is set in the inputs worksheet and the corresponding mortality rate depends on the underwriting class of the policy.

Probability Distribution of Company Selection Determination:

The determination of the company assigned to a policyholder is determined through several steps. A probability distribution calculation is started on the “Calculations” worksheet and policies are assigned a company according to the distribution on the “Policy Experience” worksheet. Each company specifies the premium they want to charge for each underwriting class. In simplified form, the probability of choosing each company given the underwriting class is the reciprocal of the premium divided by the sum of the reciprocals of the premiums from all the companies in the given underwriting class. This equation is shown below.

Let X_i = Premium for Company in an underwriting class;

$$\text{Probability of choosing a company } i \text{ for policies in underwriting class} = \frac{\left(\frac{1}{X_i} \right)}{\left(\sum_{k=1}^n \frac{1}{X_k} \right)}$$

The model breaks this process into several steps. First, the sum of all premiums in underwriting class j is divided by the premium for company i in underwriting class j . This is called Quantity A_i for company i . Then, the percentage of Quantity A_i in terms of the sum of all Quantity A_i 's for all companies in underwriting class j is calculated. This last percentage is the probability that a policy in that underwriting class j chooses that company i . Therefore, the companies with the lowest premium are most likely to have the most new policies. This method is used to calculate the probabilities of choosing each company in all of the underwriting classes. An example is shown below.

$$\frac{\text{Sum of Premiums of all Companies in Underwriting Class } j}{\text{Premium of Company } i \text{ in Underwriting Class } j} = \text{Quantity } A_i \text{ for Underwriting Class } j$$

Probability of choosing company i for policies in underwriting class

$$= \frac{\text{Quantity } A_i}{\text{Sum of all Quantity } A_i \text{'s in underwriting class } j}$$

Company <i>i</i>	Premiums for Underwriting Class <i>j</i>	Quantity <i>A_i</i>	Probability of Choosing Company <i>i</i>
1	\$650.34	2.84769	0.30936
2	\$705.46	2.62553	0.28523
3	\$496.76	3.73185	0.40541

The remaining part of this calculation is continued on the “Policy Experience” worksheet. After the probability distribution of the company chosen is determined, each policy is assigned a “Company Selection Random Number” between 0 and 1. Numbers less than the probability of company 1 will choose company 1. Numbers less than the sum of the probabilities of choosing companies 1 and 2 but more than the probability of choosing company 1 will be assigned to company 2. Numbers less than the sum of the probabilities of choosing companies 1, 2, or 3 but more than the sum of choosing companies 1 or 2 will be assigned to company 3. The pattern will continue for policies assigned to the remaining companies.

All of the policies should be assigned to one of the companies. After the first year, each policy will check if there is a possibility of lapsing according to the “Policy Characteristic” number assigned. If the condition is not breached, the policy will remain with the company it was with in the previous year. If the condition is breached, the policy will choose a company based on a new “Company Selection Random Number”. Note that there is the possibility that it

chooses the same company it was with in the previous year. Hence, there is the possibility that the policy will not lapse even if the condition is breeched.

Lapse Determination

Lapses are determined on the “Policy Experience” and “Calculations” worksheets. Each policy is assigned a characteristic to determine when the policy will lapse. This is done by first assigning a random number between 0 and 1 to each policy. That number is multiplied by 10 and rounded to the closest whole number to determine the policy characteristic. However, to keep the policy characteristics constant throughout for every policy, the policy characteristic numbers are hard coded into the model after the first round.

The following table shows a key for the characteristic number and the approximate percentage of the market with each characteristic. These characteristics are used to determine when policies lapse from company to company.

Policy Characteristic	Characteristic Number	Appx % of Market with Characteristic
Always go for the cheapest premium in the market	0,1	15%
Chance of lapse only if premium increases by more than 10%	2,3	20%
Chance of lapse only if premium increases by more than 5%	4,5	20%
Never lapse	6,7,10	25%
Chance of lapse only if premium increase is 5% higher than that of other companies	8,9	20%

Please Note: Random numbers only have a 5% chance of rounding to 0 and 10 since the original random numbers are limited between 0 and 1.

Policies with these characteristics will not always lapse even if the premium increase suggests it should. It will only have the opportunity to lapse. For example, if a policy with characteristic number 4 experiences a premium increase of more than 5%, that policy will choose

a new company according to the corresponding company selection random number. There is a possibility of choosing the company to which it already belongs. Hence, the policy may not always lapse if the characteristic is triggered, but there is a possibility of the policy lapsing only if the specific condition is breached.

Results

At the start of the competition, there were five teams: Grim Reaper Insurance, Hong Insurance, Meat Tornado Insurance, Company D, and Company E. Teams were allowed to create their own names. If they chose not to, the team was assigned a company letter. Each team consisted of a manager and four underclassmen. The managers all passed the life contingencies 1 course at RMU and had previous actuarial internship experience with an insurance company. The underclassmen were all freshmen or sophomore students who had little or no understanding of life insurance. Therefore, all of the managers had an in-depth understanding of how to determine premium rates for life insurance products. The sophomores had the advantage of understanding time value of money before the competition. As expected, the underclassmen felt extremely overwhelmed at the beginning of the competition.

Over the first couple rounds, managers gave their teams a basic introduction about how life insurance works. They explained concepts of the cost of insurance, pooling risks, time value of money, and defined numerous vocabulary words commonly used by actuaries. The underclassmen had the advantage of being exposed to using excel to calculate profits and premiums when changing input variables. They also developed spreadsheets to calculate profits after business experience was given to them at the end of every round noting lapses, retained policies, deaths, and new policies.

All of the teams faced the issue of not having data with significant credibility to base their lapse assumptions. For the first round, all teams received an example of what the market share model would return if a table of premium rates were set. The teams were able to make the a realistic inference from the data that lower premium rates would lead to higher market share in comparison to other companies in the underwriting class.

Through all rounds, Grim Reaper Insurance maintained the highest premiums and was the most profitable compared to other companies. After a couple rounds, the teams noticed that they experienced higher lapse rates when they increased their premiums by a higher percentage. They were not able to make the connection of how the market share model did this exactly, but they noticed a positive correlation between the two variables. Hence, the teams started to consider this consequence when determining how much to increase their premium rates during the middle of the competition.

After the fourth round, the managers of companies D and E decided they did not have enough time in their schedule to continue participating in the competition. Their team members were given the options to either withdraw from the competition, carry on without their managers, or be redistributed to the three remaining teams in the competition. Of the eight members, three decided to continue with the competition on another team. Therefore, Grim Reaper Insurance, Hong Insurance, and Meat Tornado Insurance all gained one new member after round four. For the purpose of the simulation, companies D and E were declared bankrupt and all the companies were expected to gain more market share in round five. Additionally, the companies were able to strike a contract with underwriters making the underwriting expense only \$100/policy for all new policies in year 5 only. This discount was given to all the companies to enable them to make the new business profitable.

After round 5, all teams decided to increase their premiums to the maximum limit for each round as they did not expect gaining new business would be profitable that late in the competition with only a few rounds remaining. Since all of the remaining companies did this at the end, all of the companies faced a relatively lower percentage of lapses towards the end of the competition.

The biggest reason the teams struggled to be profitable was the high volatility of policies moving between companies. The market share model seemed to be too sensitive when determining lapses which sometimes gave companies lapse rates over 20%. This may or may not be realistic if companies increase their premiums by 15%, but all the companies struggled with finding the happy medium between profit and market share, which is something companies struggle with all the time. This illustrated to the teams a conflict between shareholder interest and policyholder interests.

Suggested Improvements for Future

As the freshmen team members felt overwhelmed at the beginning of the competition, it was a consensus among the participants that this simulation would be most effective with sophomores. Moreover, as this is a learning experience, it is a more effective teaching tool when students can devote more time to the competition. Hence, making it a part of an elective class and teaching some of the concepts rather than solely depending on the managers teaching their team members as they see fit may make the experience better. Attached in the appendix is a good start for a detailed explanation that one of the managers provided to their team.

Furthermore, a lapse table could be integrated into the market share model to replace the policy characteristics used to determine lapses. A random number could be generated and

compared to a lapse rate from a lapse table (similar to how deaths are simulated in this model). Additionally, the lapse rates could be increased by a reasonable factor depending on how much each team increased their premiums. Therefore, the lapse rates may be more realistic for the competition and will still increase as companies increase their premiums.

Appendix

Basics of Life Insurance

Life insurance is something that people buy in order to protect their survivors, generally direct family members, from a financial loss due to their own death. For example, a father would buy life insurance so that if he dies, his wife can have money to support the family since he will no longer be providing income to the family unit. The money the survivors receive is called a **death benefit**. The death benefit can be paid any time after the death of the insured individual, but in our case, it will be paid at the end of year of death. So if somebody dies at any time in, say 2014, the death benefit will be paid on December 31, 2015.

Of course, life insurance companies don't just provide money like this out of charity. The insurance company collects a **premium** that is most often paid in monthly installments. However, in our competition, it will be paid in full at the beginning of the year for simplification purposes. Premiums are the prices that insurance companies charge to protect their consumers against **mortality risk**. Mortality risk is the risk of an individual's death creating a financial loss to that individual's survivors.

Generally speaking, there are many expenses that accompany being able to provide life insurance. A relatively obvious expense is **overhead**. Overhead is, in the simplest way possible, the cost of keeping the company working. It covers expenses like keeping the lights on, paying the employees, advertising, etc... Another expense that insurance companies take on are **commissions**. Commissions are paid to agents who sell the product for the company. For example, Northwestern Mutual is a direct life insurance company. This means that they sell life insurance through their own company, and do not pay commissioned agents. Companies like

State Farm, Allstate, MassMutual, New York Life, Metlife, etc. sell their insurance through agents and need to pay a percentage of premiums to these agents.

Because the only time a death benefit is paid is when an individual covered under insurance dies, it is optimal to have the healthiest customers possible. Companies utilize a practice called **underwriting** to try to get the healthiest customers possible. Basically the customers pay a visit to the doctor, and the doctor will report back to the insurance company with the health standards of the individual. The individual is then placed into a **risk class** that determines what their premiums will be. As you can imagine, healthier customers pay lower rates because they are less likely to die and collect a death benefit.

Finally, the main way that life insurance companies actually gain profits is through **investing** their premiums. Unlike many other types of insurance, there will be at most one payment made, and sometimes, no payment is made at all. The way that insurance companies actually invest their money is relatively complicated, but in this example we are given a flat **interest rate**. So basically, with our 3% interest rate, 100 will grow to 103 in one year and 100 will grow to 106.09 in two years. For any amount of time, T , our principle amount, P , will grow to $P(1.03)^T$. This can be done in reverse, so 103 in a year will only be worth 100. In this case to find the value of money in the future, we just divide the interest rate instead of multiplying it. So going back in time is just $P/(1.03)^T$. This is called the Time Value of Money or TVM.

As explained earlier, the teams want to price our product so that the **expected present value** of the money will be equal to the expected present value of the money that will be paid out. The expected present value, to put it simply, is the (amount of the cash flow \times the probability that the cash flow happens \times time value of money factor).

Below are links to articles that explain the basics of life insurance and time value of money in more detail:

- <https://www.fidelity.com/life-insurance-planning/what-is-life-insurance>
- <http://www.investopedia.com/articles/03/082703.asp>

By Aaron Hartman, Manager of Meat Tornado Insurance

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