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**DETERMINING THE MOST SUITABLE METHOD OF IBNR RESERVE
ESTIMATION IN THE EVENT OF VARYING DEVELOPMENT
PATTERNS**

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DECLARATION

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the Research Project contains no material previously published or written by another person except where due reference is made in the Research Project itself.

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List of abbreviations

AURR – Additional Unexpired Risk Reserve

BCL – Basic Chain Ladder method

BF – Bornhuetter Ferguson method

GEP – Gross Earned Premium

GWP – Gross Written Premium

IBNR – Incurred But Not Reported

IRA – Insurance Regulatory Authority

Mack – Mack model

NEP – Net Earned Premium

NWP – Net Written Premium

ODP – Over-dispersed Poisson distribution method.

UPR – Unexpired Premium Reserve

ABSTRACT

In general insurance reserving, it is assumed in many cases that the losses in each accident year develop the same way. This makes the chain ladder method in general a good method to estimate general insurance claims liabilities.

But what if the runoff patterns in each accident year were different? Which method is best to use to calculate general insurance reserves in such a case? This research paper seeks to answer the question of which method is best suited to estimate general insurance reserves when the runoff pattern in each accident year is different. Claims data was simulated using various constraints that restricted the claims to various distributions. Future claims development was also simulated. The claims reserve estimates using various methods of reserve estimation were then calculated. The results were then obtained as to which method is best suited to calculate claims reserves for a general insurer in different scenarios of varying development patterns. The results of this paper will hopefully provide a new insight of how to calculate claims reserves for a general insurer in the event that development patterns differ in each accident year.

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Chapter 1: Introduction

1.1. Background of the study

Reserving is a very important role for an actuarial expert in the general insurance industry. It involves setting aside funds that will be used to pay out future claims. A reserve that is too small is risky since the company will not have enough money to meet its claims liabilities in the future. A reserve that is too high is also unfavourable as it affects the company's ability to undertake in profitable ventures for its growth as well as limits the dividends to be paid to shareholders.

With regard to reserving in Kenya, an insurer usually discloses two types of liabilities:

1. Premium Liabilities: These are Unearned Premium Reserve (UPR) and Additional Unexpired Risk Reserve (AURR).
2. Claims Liabilities: These relate to claims which the insurer will pay in the future. They are claims outstanding and Incurred But Not Reported (IBNR) claims.

Here, we will be dealing with claims liabilities and in particular IBNR reserves. This is because the claims outstanding reserves of a company are already known in advance. IBNR reserves however, need to be estimated as they are not known in advance. These reserves relate to losses that have already happened but have not been reported to the insurer and therefore have not yet been paid. There are various methods to calculate IBNR. These include: basic chain ladder (where it is assumed that the claims in each accident year develop the same way), the Bornhuetter Fergusson method, the inflation-adjusted chain ladder method, the average cost-per-claim method among others.

In practice, the IBNR reserves of a company are calculated on a per-class basis e.g. motor IBNR is calculated separately from fire and engineering, and then added together to get the total IBNR. This is so because the claims of different classes have different characteristics e.g. Fire Insurance usually has larger claims as compared to most other classes of business. In this paper, instead of looking at IBNR estimation based on classes of business, we will look at it based on the run-off pattern of the claims over time. This could be later generalized to get the best method of IBNR estimation based on the different classes of business of a company by linking the classes of business to particular run-off patterns.

1.2. Problem Statement

The purpose of this study is to compare the various methods of IBNR estimation so as to find the best method when the claims development patterns are assumed to change between different accident years.

The assumption of uniform development patterns over all accident years may have serious negative implications for an insurer's IBNR estimation if it's not accurate. The use of basic chain-ladder in many of these cases may lead to underestimation or overestimation of the IBNR. The magnitude of such underestimations or overestimations may run into tens of millions or even hundreds of millions of Kenyan Shillings depending on the size of an insurance company.

Small amounts paid or incurred as claims in later development years may lead to very small development factors for these later development years. This could lead to a very low reserve being calculated for earlier accident years since we assume that these accident years are almost fully run-off. This phenomenon of underestimating development factors may occur in long-tailed classes of business, for example marine insurance. This is because these classes experience a significant amount of claims reported in later development years.

On the other hand, IBNR may also be overestimated because of assuming uniform development of claims in each accident years. One instance of this may be when the company changes its claims payment policy and decides to pay more claims in earlier development years as compared to previous accident years. The development patterns will therefore have a significantly larger tail in earlier accident years leading to an overestimation of IBNR if the company is using claims paid data to estimate its ultimate claims.

1.3. Research Questions

1. To what extent do various IBNR estimation methods underestimate the variability of losses when the development patterns are not the same in each accident year?
2. How do various IBNR estimation methods compare with each other when calculating reserves in a situation where the development patterns are not the same in each accident year?
3. What are the best conditions for the suitability each method considered to calculate IBNR assuming changing development patterns in each accident year?

1.4. Research Objectives

1. To determine the extent to which various IBNR estimation methods underestimate the variability of losses when the development patterns are not the same in each accident year.
2. To determine the comparison between various IBNR estimation methods when calculating reserves in a situation where the development patterns are not the same in each accident year.
3. To evaluate the best conditions for the suitability each method considered to calculate IBNR assuming changing development patterns in each accident year.

1.5. Justification of the study

On the 31st of March every year, general insurance companies in Kenya are required to disclose their reports for the previous financial year ended 31st December. These reports include the annual report and valuation report among others. Various stakeholders such as the public, investors, the government, among others use the information in these reports for their own purposes, for example, an investor may use this information to decide on whether to buy the shares of a certain listed insurance company.

In the insurer's balance sheet, the IBNR constitutes a significant portion of the liability. IBNR reserves represent an important cog in the insurance accounting machinery (Bornhuetter & Fergusson, 1972). This means that an accurate estimation of the IBNR is advantageous for the insurance company while an inaccurate valuation of IBNR can have negative implications on the same insurer. Therefore, the assumptions underlining the calculation of the IBNR reserves need to be carefully selected as they greatly affect the calculations of the outstanding claims reserves.

One of the assumptions that significantly affect the IBNR value is the assumption of a constant development pattern in every accident year. While this assumption is feasible when the IBNR is being calculated per-class of business where there are homogeneous claims in each class of business, it may not be feasible in some cases. One example of such a case is where there is a presence of unusually large claims that distort the calculation. Another example is where an insurer has many small classes of business and combines these classes in the calculation of IBNR. In the latter case, the advantage of homogeneity within the risks will no longer be present and therefore the development pattern of the claims is likely to change between successive accident years.

The assumption of a constant development pattern in each accident year where this is not the case may lead to the wrongful calculation of claims liabilities. Claims liability forms a significant proportion of insurance total liability, if claims reserves are understated this would lead to collapse of a company (Gitonga, 2015). If claims reserves are overstated, this affects the profitability of a company.

This paper therefore seeks to investigate further cases where the development pattern of claims is not constant in each accident year. The paper then compares various stochastic and deterministic methods of IBNR calculation to find out which of these methods is best in different cases where the development pattern is not the same in each accident year.

Chapter 2: Literature Review

2.1. Seminal Works

There have been a number of other studies done with regard to the topic of IBNR reserves. These studies range from the estimation of loss reserves using various methods to the focus on the loss distribution features of a particular class of business. One thing is however common to all these studies; they are all related to the general insurance line of business and more specifically, the reserving element of this class of business.

Blum and Otto (1998) focus on the estimation of loss reserves as an important area in actuarial science. The paper identifies the primary aim of the reserving process as the estimation of those claim costs which have not yet been paid. Also, the paper defines the best estimate of a reserve as a point within a range of reasonable estimates which is better than all the other reasonable estimates. The study also considers the impact of the reserving process on various stakeholders of a general insurance company. These stakeholders are identified as the regulator, the policyholder and the tax agent. The regulator wants a prudent estimate that will be able to pay out all future liabilities. The policyholder wants a prudent estimate that will meet the claim cost without being overcharged for the cover while the tax agent wants the reserves to reflect the future claims liabilities as nearly as possible.

The Faculty of Actuaries (2014) identifies two main classifications of methods used to estimate claims reserves, namely; deterministic methods and stochastic methods. The deterministic methods are identified as the analytical methods of chain ladder method, Average-Cost-Per-Claim method and the Bornhuetter-Ferguson method which is a combination of the loss ratio method used to calculate future claims and the basic chain ladder method used to calculate past claims. The chain ladder method is used to refer to both the basic chain ladder method as well as the inflation-adjusted chain ladder method. The stochastic methods are split into three types, namely; analytical methods, simulation methods and Bayesian methods. The analytical methods include the Mack model, over-dispersed Poisson model, negative binomial model, the normal approximation to the negative binomial, log-normal model and the Hoerl curves. The simulation method identified is the over-dispersed Poisson model (bootstrap form) while the Bayesian method identified is the Bayesian form of the Bornhuetter-Ferguson method. Also, copulas are identified as a method of IBNR estimation. A copula is defined as a way in which a multivariate distribution is built into the reserving calculation so as to represent dependencies in the underlying variables.

However, the use of statistical methods to model claims development patterns may have its disadvantages. Schnieper (1991) says that the disadvantage of statistical methods is that they

may not always be what is happening in practice. One has to make sure that they have all the relevant information and take it into account.

2.2. Development Patterns

Herting (1985) focuses on the reserving of marine IBNR for reinsurers. He highlights the problem of the long tail of the marine class of business due to the fact that ships sail for several years with damages until they are docked. This sets a problem for an insurer in terms of pricing and setting the IBNR reserve. The reinsurer has an even bigger problem since they may not have all the individual information regarding policies. The author then shows the development of a treaty and sets up an IBNR reserve for a treaty and also for a portfolio.

Wang (2008) focuses on modelling claim development processes over time up to the ultimate claims. The author not only focuses on measuring the delays in claims settlement but also revises the model of claims upwards or downwards. Also, the problem of modelling long-tailed classes of business is outlined and the other problem of modelling ultimate claims in the existence of open claims is also highlighted.

Sahasrabuddhe (2013) concentrates on the relationship between claims development, trend and size factors. The idea of the paper is to calculate the development factors by layer once assumptions have already been determined with respect to a particular base. This base could be of trend, development patterns and claim size.

2.3. Methods used to estimate IBNR

A substantial amount of literature has been written about the best methods for estimating IBNR reserves. Some of these studies consider deterministic methods of estimation, others consider stochastic methods of IBNR estimation while there are those that consider both stochastic and deterministic methods of IBNR estimation.

2.3.1 Deterministic methods used to estimate IBNR

The most popular methods in IBNR calculation are the chain ladder method and the Bornhuetter Ferguson method (deterministic form). This is because of their simplicity, partly brought about by their deterministic nature and their distribution-free nature which eliminates the need to make extra assumptions about their distributions.

Weindorfer (2012) focuses on the practical use of the chain ladder method to calculate general insurance outstanding claims liabilities. Also, practical reasons are given as to why the basic chain ladder assumption of constant development patterns in each accident year may not be the case in practice. Such reasons include a change in the legal environment as well as the presence of abnormally small or large claim amounts. Weke (2008) also examines the basic chain ladder model observing that in this method, it is observed that all exogenous influences are small. Also, the paper mentions the inflation-adjusted chain ladder model which adopts a generalized model by introducing an assumed index of claim cost.

Bornhuetter and Ferguson (1972) was the first paper published with regard to the Bornhuetter Ferguson technique of calculating IBNR reserves. The paper considers the use of external factors such as exposure to estimate IBNR reserves. The IBNR is deduced to be a partial function of the exposure in previous years. Weke (2008) also examines the Bornhuetter Ferguson method. Professor Weke makes three explicit various assumptions about the technique. These assumptions are: the loss ratio given is correct, claims development is relatively stable and the past claims development is not useful in providing extra information on future claims development.

The Faculty of Actuaries (2013) explains on four deterministic methods used to calculate IBNR in the CT6 module (Statistical methods for actuaries). These methods are the basic chain ladder method, the inflation-adjusted chain ladder method, the Bornhuetter Ferguson method and the average-cost-per-claim method.

2.3.2 Stochastic methods used to estimate IBNR

Schnieper (1991) was one of the early studies on stochastic estimation of IBNR. This paper assumes that the expected value of the IBNR only depends on the accident year and on a factor that depends on the development year. Other assumptions made are that the decrease in IBNER claims (Incurred But Not Enough Reported) is proportional to the cumulative claims amount in the previous accident year and that the incremental claims and decrease in IBNER claims in the same accident and development year are stochastically independent. The paper also combines the Bornhuetter Ferguson and Chain Ladder methods of IBNR calculation. The standard error of the ultimate claims rate is calculated using a Taylor series approximation. The estimator in this model is also assumed to be unbiased.

Mack (1993) tries to improve on Schnieper's work by narrowing down to a pure chain ladder case. This, according to the author of this paper leads to methods which are more accurate than

the Taylor series approximation in estimating the standard error of the reserve estimates. The development factors are shown to be unbiased and uncorrelated. The expected value and stochastic error of the cumulative claims amount in a certain development year is proportional to the cumulative claims amount the previous development year in the same accident year. The prediction variance is deduced to be a summation of the process variance (stochastic error) and the estimation variance. The estimators of the constants of multiplication are then derived to show that the expected value of cumulative claims is the same as that of the basic chain ladder method. This essentially made the Mack model a basic chain ladder method with an extra inclusion of variability. Also, this paper assumes that the first accident year is fully run-off. Mack (1999) makes an improvement on this by including the presence of a tail factor thus making the first accident year not to be fully developed.

Renshaw and Verrall (1998) also come up with a stochastic version of the chain ladder technique. The difference between this paper and the Mack model (previous paragraph) is that in this model, the incremental claim amounts are assumed to follow a Poisson distribution while in the Mack model, the claim amounts are distribution-free. The Poisson distribution in this model is however different from the usual Poisson distribution. The difference is due to the fact that the variance is made to be greater than the mean making the model to be an over-dispersed Poisson distribution rather than the Poisson distribution. Also, generalized linear models are applied to the mean where the covariates are the accident year and the development year. The link function is the log link function as in the Poisson distribution.

England and Verrall (2002) concentrates in the use of various stochastic methods to estimate reserves in general insurance. This paper begins by examining chain ladder models in its deterministic form. The authors then examine various stochastic methods used to calculate IBNR. Some of the methods studies are the over-dispersed Poisson model, the negative binomial model and the normal approximation to the negative binomial. Also, the Mack model is examined and its similarity with the normal approximation to the negative binomial model. The lognormal model and gamma model are also studies in this paper as well as other parametric models, non-parametric smoothing models and Bayesian models. Various prediction errors are also studied in this paper.

Braun (2004) continues on the work of Mack (1993 and 1999) on the prediction of the standard error of chain ladder estimates. The fundamental difference between Mack's paper and Braun's paper is that Braun (2004) calculates the standard error of chain ladder estimates when the runoff triangles are correlated. These estimates therefore allow the actuary to calculate a more prudent outstanding claims reserve by taking into account correlations between various runoff triangles. Such correlations may be assumed to be dependent on the development year but may not be assumed to be dependent on the underwriting year.

Weke and Ratemo (2013) concentrates on the use of Archmidean copulas to estimate calculation of IBNR reserves. The Archmidean copulas concentrate on the dependencies of different variables by analysing these dependencies to build multivariate distributions. The paper also criticizes the use of correlations of variables in IBNR estimation. The use of correlations is criticised as an inadequate measure of dependency with regard to IBNR calculation. This is because of the inability to build a multivariate distribution using correlations and marginal distributions alone among other reasons.

Chapter 3: Methodology

3.1. Introduction

Data was collected from annual IRA (Insurance Regulatory Authority) reports. This included claims data as well as premium data for various classes of business. Incremental future and past claims were fitted using Microsoft excel to be in line with IRA report data. The fitted data was six accident years' worth of claims experience. The data fitting was done in such a manner that the development patterns varied in each accident year. The variation in development patterns was set to be small at first and was made more and more volatile. The data was reconciled to the financial statements as a check to confirm that it was indeed in line with the financial statements.

Different stochastic and deterministic methods were then used to calculate IBNR reserves based on the past claims experience. The methods were then compared to see which one is the best in estimating IBNR under different circumstances of varying development patterns. The two deterministic methods used were the basic chain ladder and the Bornhuetter Ferguson method. Stochastic methods accounted for the majority of methods used as they have an allowance for element of variability in the future claims. The stochastic methods used were the Mack model and the over-dispersed Poisson model at different percentiles. The percentiles for the stochastic methods were chosen to be the tenth, twenty-fifth, seventy-fifth and the ninetieth percentiles.

3.2. Research Design

The research design was a quasi-experiment. This type of research design allows the researcher to intervene and control the assignment in the treatment condition. Such a research design was suitable for this paper as it enabled the development patterns to be changed by the researcher subject to certain restrictions.

3.3. Characteristics of general insurance classes

Rather than studying a population, the claims runoff patterns of different classes were examined. The reason for calculating claims on a per-class basis was due to the fact that different classes of general insurance have different features that define them. This makes the development of different classes of general insurance to have relatively homogeneous claims experience for claims and the same class of business. This limits the volatility of claims experience thus enabling many methods of IBNR calculation e.g. basic chain ladder method to be more accurate.

These classes that will be explored in this paper are: the motor class of business, the public liability class of business and the fire class of business. These classes were chosen by the author

of this paper due to their fascinating characteristics. Each of the mentioned classes has a special characteristic that exists for various reasons.

The motor class of business is special as it is usually one of the largest classes of business in the books of a Kenyan general insurer. The reason for this is that motor vehicle insurance is a mandatory requirement for almost every vehicle in the country. This means that the motor vehicle IBNR usually constitutes a large proportion of IBNR for a general insurance company and thus its accurate estimation is crucial.

The fire class of business also has a special characteristic. This characteristic is the few and large claims that are present in this class. This is because the occurrence of a fire, whether a domestic fire or an industrial fire can cause huge economic losses which the insurer will have to settle. The insurer's profits for one year can be wiped out by the occurrence of only one large fire in the insurer's portfolio of covers during the year.

3.4. Data Acquisition Constraints

In carrying out this study, the researcher encountered a lot of challenges in getting practical data from the Kenyan general insurance market. Originally, the idea of this paper was to use insurance premium and claims registers from Kenyan general insurance companies. Acquisition of these registers was however not possible. Also, financial statements and more specifically revenue accounts of all general insurance companies were originally planned to be used for the study. Unfortunately, not all financial statements of general insurance companies in Kenya were easy to obtain.

3.5. Solutions to Data Acquisition Constraints

The problems encountered in acquiring the data were met in various ways. The problem of acquiring claims and premiums data was met by the use of simulation of present and future claim amounts. The justification of using simulation was that it would not undermine the objective of the study. This is because the study is based on the best method to estimate the IBNR in various situations of differing development patterns. This meant that the change in development patterns was determined in advance rather than obtained from actual real-life data. Such a difference in data was not deemed as materially different to the purpose of the study.

The problem of obtaining financial statements was met by using IRA annual reports that could be obtained easily. The problem of this and the lack of claims registers was that a reconciliation of data is not possible to carry out due to lack of registers. This was met by simulating the data while placing restrictions on the data with regard to the claims amounts in each accident year in the financial statements. In such a case, a data reconciliation would indeed be possible and would in fact give no errors since the data was simulated from the financial statements. Such a reconciliation would in this case just be a check to see that the simulation process was done properly.

3.6. Data Collection and Simulation

IRA annual reports of general insurers for the last eleven years (2005-2015) were obtained online from the IRA website. From the financial statements, data was obtained. This data was the NEP (Net Earned Premiums) as well as the net claims incurred as at the end of each financial year. The figures for three classes of business were calculated. These three classes were motor, fire and public liability. Figures from only one insurer were used as this was deemed sufficient for the study.

Incremental net claims incurred were then simulated using Microsoft excel. Restrictions were placed on the data to closely match the industry data. Care was also taken to ensure that development patterns varied within each development year. An example for simulation of incremental claims for calendar year 2010 is shown below. Note that the sum of the shaded region is equal to the total net incurred claim amount of 2010.

	1	2	3	4	5	6
2005						
2006						
2007						
2008						
2009						
2010						
Sum of shaded region = Net incurred claim of 2010						

Figure 1: Example Simulation for Calendar year 2010

Future data was also simulated to correspond to the IRA annual reports from 2011 to 2015. Using this, the full claims top and bottom triangles of claims incurred from 2005 to 2010 could be constructed thus allowing the researcher to compare IBNR calculated from different methods with the true value of the IBNR. A diagrammatic illustration of the full simulation process is shown in the next table:

	1	2	3	4	5	6
2000						
2001						
2002						
2003						
2004						
2005						
2006						
2007						
2008						
2009						
2010						
2011						
2012						
2013						
2014						
2015						
Shaded region simulated using net claims incurred data from 2005-2015						

Figure 2: Illustration of Full Simulation

Public liability claims incurred were simulated based on Automatic Facultative General Liability Data excluding Asbestos and Environmental in 1991, which was picked from England and Verrall (2002). Fire claims incurred were simulated based on SCOR disclosure in 2012. SCOR is global insurance and re-insurance company. Motor data was simulated from CAS (Casual Actuarial Society) triangles.

3.7. Assumptions

1. The first accident year is fully run-off: This assumes that claims for the earliest accident year in the run-off triangle have all been fully reported and paid. This assumption may be practical in some cases and may also not be the case in other cases in practice. The effect of this assumption could be very big as the inclusion of a tail factor could cause the IBNR value to increase by leaps and bounds. Taking all this into account, the aforementioned assumption was made for purposes of simplicity. Also, an appropriate adjustment can be made for the inclusion of tail factor.
2. Net values: This paper will only consider quantities after reinsurance i.e. net values. In practice, general insurance companies usually transfer the risk of extremely large losses to reinsurance companies. This means that the general insurance company only ends up paying losses net of reinsurance while the reinsurer pays the difference between the gross amount and the net amount. As compensation for this, the insurer transfers some of its premiums to the reinsurer. In its financial statements the insurer usually indicates gross

and net values. In this paper, the assumption of calculating only net values has been made because only net values could be obtained from the IRA reports.

3. Inflation: Inflation is assumed to be taken into account in the weighted average of development factors in the chain ladder methods. This assumption is applicable in Kenyan general insurance practice.
4. Development patterns: The development patterns are assumed not to be the same in each accident year. This is in line with the purpose of the study which is to determine the best method of IBNR estimation when the development patterns are not the same in each accident year.

3.8. Research Procedures

Once the run-off patterns were obtained from simulation, combinations of different development patterns were selected for different accident years. The data was still divided into the individual classes of business.

Various IBNR reserving methods in light of only past claims experience were then compared to find out which ones are the best in different cases of varying development patterns. This was done by getting a point estimate of each method and comparing it to future claims experience. The calculation of IBNR was separated between different accident years. The IBNR methods used included both stochastic and deterministic methods. The methods were then compared to see which one is the best in estimating IBNR under different circumstances of varying development patterns.

The two deterministic methods used were the basic chain ladder and the Bornhuetter Ferguson method. The stochastic methods used were the Mack model and the over-dispersed Poisson model at different percentiles. The percentiles for the stochastic methods were chosen to be the tenth, twenty-fifth, seventy-fifth and the ninetieth percentiles. These percentiles were chosen according to triangle disclosure by Aspen Insurance Holdings Limited.

These data methods would then be compared to the true value of IBNR simulated in the future according to IRA reports to find out which one of them has the lowest error in each accident year and is thus the best. As usual, the calculation of the errors and the comparison of each method will be split between the three classes of business.

3.9. Data analysis methods

3.9.1. Runoff triangle

	1	2	3	4	5	6
1	W_{11}	W_{12}	W_{13}	W_{14}	W_{15}	W_{16}
2	W_{21}	W_{22}	W_{23}	W_{24}	W_{25}	W_{26}
3	W_{31}	W_{32}	W_{33}	W_{34}	W_{35}	W_{36}
4	W_{41}	W_{42}	W_{43}	W_{44}	W_{45}	W_{46}
5	W_{51}	W_{52}	W_{53}	W_{54}	W_{55}	W_{56}
6	W_{61}	W_{62}	W_{63}	W_{64}	W_{65}	W_{66}

Figure 3: Incremental paid claims run-off triangle

Above is an incremental claims run-off triangle. The value W_{ij} indicates an incremental claim amount at accident year i and development year j . An example of this is the value W_{23} . This represents a claim amount underwritten in accident year 2 and paid in development year 3 which in this case would be two years after the policy was written. The reason the development period starts at one rather than zero is for convenience purposes. As at the end of accident year 6, the amounts above the triangle are already known while those below the triangle are future values that are to be estimated

	1	2	3	4	5	6
1	C ₁₁	C ₁₂	C ₁₃	C ₁₄	C ₁₅	C ₁₆
2	C ₂₁	C ₂₂	C ₂₃	C ₂₄	C ₂₅	C ₂₆
3	C ₃₁	C ₃₂	C ₃₃	C ₃₄	C ₃₅	C ₃₆
4	C ₄₁	C ₄₂	C ₄₃	C ₄₄	C ₄₅	C ₄₆
5	C ₅₁	C ₅₂	C ₅₃	C ₅₄	C ₅₅	C ₅₆
6	C ₆₁	C ₆₂	C ₆₃	C ₆₄	C ₆₅	C ₆₆

Figure 4: Cumulative paid claims run-off triangle

Above is a cumulative paid claims run-off triangle. This is a slight modification to the incremental claims table by adding the cumulative claims amounts in each accident year. The value C_{ij} indicates the cumulative claim amount at accident year i and development year j . As at the end of accident year 6, the amounts above the triangle are already known while those below the triangle are future values that are to be estimated

3.9.2. Basic Chain Ladder method

The basic chain ladder method assumes that development patterns are the same in each accident year. Therefore, the estimation of the future cumulative claim amount,

$$C_{ij} = \lambda_{j-1} * C_{i,j-1} \quad i+j \geq 8$$

$$\text{Where, } \lambda_{j-1} = \frac{\sum_1^{6-j-1} C_{kj}}{\sum_1^{6-j-1} C_{k,j-1}}$$

An additional feature of the chain-ladder method is its distribution-free nature.

3.9.3. Bornhuetter Ferguson method

This method uses external information to calculate the exposure which is in turn used to estimate the future IBNR and ultimate claims. The exposure measure to be used in this paper is the GEP (Gross Earned Premium).

The ultimate claim in this case would be at development year 6 because we assume the claims are fully run-off in this development year. Taking the product of all future development factors (λ 's), we get the cumulative development factor.

The cumulative development factor will then be defined as:

$$f_6 = \prod_0^{i-1} \lambda_{6-k}$$

Due to ultimate development in year 6, $\lambda_6 = 1$

Therefore,

$$C_{i6} = \left(1 - \frac{1}{f_6}\right) * ULR + H_i$$

Where,

C_{i6} : Ultimate claim amount in accident year, i.

ULR: ultimate loss ratio which is equal to $\frac{\text{claims reported} + IBNR}{GEP}$

H_i : Paid/Reported claims so far in accident year, i (it depends on whether the run-off triangle is paid or incurred claims)

The loss ratio for each accident year was chosen as the arithmetic average of the ultimate loss ratios from the other methods.

3.9.4. Mack model

The Mack model in this paper is basically a chain ladder model with an allowance for variability of claims. The expected value of future cumulative claims is equal to the basic chain ladder estimate.

$$E[C_{ij}/C_{i,j-1}] = \lambda_{j-1} * C_{i,j-1} + j \geq 8$$

The variance of future claims is given by,

$$\text{Var} [C_{ij}/C_{i,j-1}] = \sigma_j^2 * C_{i,j-1} + j \geq 8$$

The parameter σ_j^2 will be estimated by:

$$\sigma_j^2 = \frac{1}{5-j} \sum_{i=1}^{6-j} C_{ij} \left(\frac{C_{i,j+1}}{C_{ij}} - \lambda_j \right)$$

The advantage of this method is its stochastic nature thereby making it possible to make more prudent estimates. Also, just like the chain ladder method, this model is distribution-free. The percentiles were calculated by fitting a log-normal distribution. The positive skewness of this distribution deemed it appropriate for the purpose. Other positively skewed distributions also gave similar results.

3.9.5. Over-dispersed Poisson model

In this method, the future claim estimates are not derived from previous years' claims, instead, the incremental are assumed to be over-dispersed Poisson random variables. The difference between over-dispersed Poisson random variables is that unlike Poisson random variables where the variance is equal to the mean, the variance is greater than the mean.

For the incremental claim amount, W_{ij} ,

$$E[W_{ij}] = m_{ij} \quad i+j \geq 8$$

$$\text{Var}[W_{ij}] = \phi m_{ij}, \text{ where } \phi \geq 1 \text{ and } i+j \geq 8$$

The variance above is the process variance and arises due to errors in random fluctuations.

The parameter, m_{ij} is then treated as a log link function of a generalized linear model, where,

$$\log(m_{ij}) = c + \alpha_i + \beta_j$$

where, α_i and β_j are covariates representing the accident year and the development year respectively.

Over and above the process variance mentioned above, an estimation variance was also calculated by estimating the variances and the covariances of the linear predictors. The overall prediction variance in every accident year was then estimated by summing up the process variance in each accident year and the estimation variance. Since 2005 is assumed to be fully run-off, the prediction variance for this year was set to be zero.

The generalized linear model calculations were done in R statistical software and then imported into Microsoft Excel to be compared with the other methods. The percentiles were calculated by fitting a log-normal distribution. The positive skewness of this distribution deemed it appropriate for the purpose. Other positively skewed distributions also gave similar results.

4. Findings

4.1. Introduction

In this chapter, the results of the study will be presented and illustrated using diagrams. The discussion of each of the results in detail will be done in the next chapter as well as how the results of the study answer the research questions of this study. The illustration of results will be split into three parts with each part corresponding to each of the studied business classes i.e. motor, fire and public liability insurance.

Within an illustration of the results of each class, there will be five diagrams. The first one will illustrate the simulated past cumulative claims from 2005-2010 i.e. only the top part of the development triangle. The second diagram will be graph of the past development patterns between the different accident years. The third diagram will be a table showing the past and the chosen development factors from the cumulative claims that have been simulated. The fourth diagram will show the future development factors from the simulated future values i.e. the true development factors that occur in the bottom part of the triangle. The fifth diagram is a table that compares the various IBNR estimation methods by considering the errors of their values with respect to the true IBNR that arises. The errors are both positive and negative to reflect both the over-estimation and the under-estimation of the true IBNR by various methods.

4.2. Special Conventions

In this chapter, there will be some special conventions used for the purposes of this study. Past claims will refer to claims incurred on the top part of the triangle from 2005-2010. Future claims incurred will be the bottom triangle of this time period (2005-2010). As shown in the list of abbreviations, BF will refer to the Bornhuetter-Ferguson method, BCL will refer to the basic chain ladder method, Mack will refer to the Mack model and ODP will refer to the Over-dispersed Poisson distribution method.

The percentiles attached to the stochastic methods represent the percentiles i.e. Mack 75% represents the results of the Mack model at the 75th percentile. Also, the words “public liability” and “liability” are used interchangeably to refer to that particular class of business. Finally, all figures used in the tables for the cumulative claims are in thousands of Kenyan shillings.

4.3. Public Liability Class of Business Results Illustration

The past cumulative claims triangle result from the simulation is shown below:

	Cumulative claims					
	1	2	3	4	5	6
2005	437.02	865.57	2,487.21	3,904.88	8,240.05	9,159.63
2006	76.52	3,339.45	5,971.63	9,127.01	10,211.57	
2007	582.65	5,878.90	11,737.50	12,526.90		
2008	945.74	12,733.89	14,199.59			
2009	2,104.98	5,054.11				
2010	526.62					

Figure 5: Public liability class of business cumulative past claims

The graph of past development patterns is shown below:

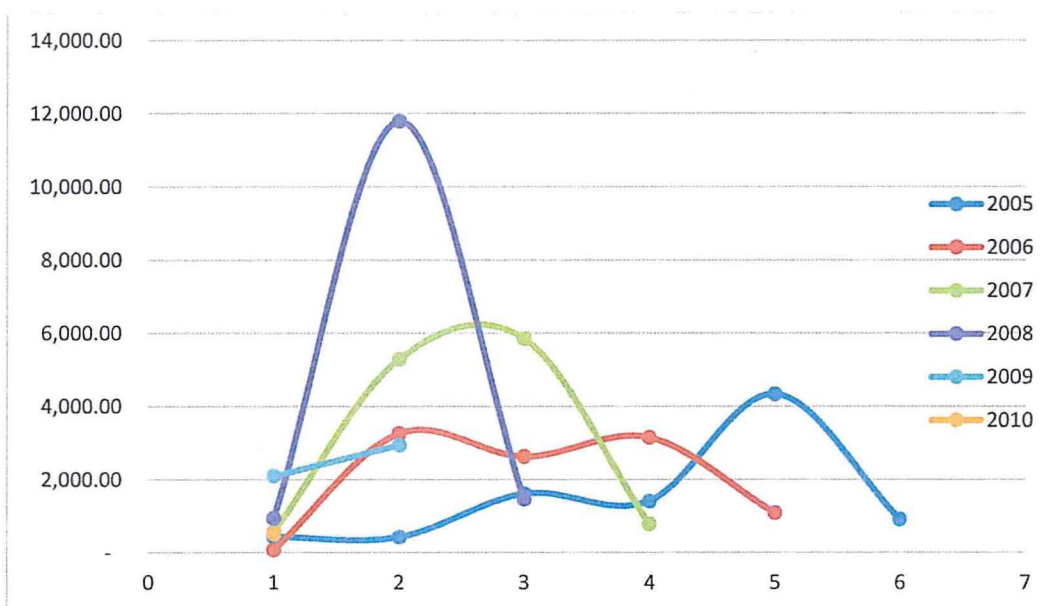


Figure 6: Public liability class of business past claims development patterns

From the above table, it is clear that the development patterns of claims in each accident year is not the same. The table of the past claims development factors as well as the chosen development factors for each accident year using the weighted average approach is shown below:

Past Development factors						
	1	2	3	4	5	6
2005	1.98061	2.87349	1.56998	2.11019	1.11160	
2006	43.63873	1.78821	1.52840	1.11883		
2007	10.08991	1.99655	1.06726			
2008	13.46454	1.11510				
2009	2.40103					
2010						
Factors	6.72113	1.50742	1.26552	1.41588	1.11160	1.00000

Figure 7: Public liability class of business past development factors

The future claims development factors experience obtained during the simulation is shown below:

True Future Development factors						
	1	2	3	4	5	6
2005						1.00000
2006					2.07820	1.00000
2007				2.03661	1.14094	1.00000
2008			1.66562	1.17931	1.01218	1.00000
2009		4.47216	1.13656	1.01559	1.01151	1.00000
2010	68.05027	1.15992	1.00701	1.00846	1.22350	1.00000

Figure 8: Public liability class of business future development factors

The comparison of various methods in the calculation of IBNR for this simulated data with regard to the simulated true IBNR is thus shown below for each accident year:

	BCL	BF	Mack 10%	Mack 25%	Mack 75%	Mack 90%	ODP 10%	ODP 25%	ODP 75%	ODP 90%
2005	-	-	-	-	-	-	-	-	-	-
2006	-90%	-90%	-100%	-100%	-95%	-83%	-98%	-97%	-88%	-79%
2007	-57%	-26%	-98%	-95%	-61%	-4%	-71%	-66%	-55%	-49%
2008	0%	69%	-87%	-75%	14%	125%	-19%	-13%	2%	10%
2009	-53%	0%	-93%	-86%	-44%	5%	-64%	-61%	-51%	-46%
2010	-80%	-36%	-98%	-96%	-79%	-55%	-85%	-84%	-80%	-78%

Figure 9: Public liability class of business method comparison

4.4. Fire Class of Business Results Illustration

The past cumulative claims triangle result from the simulation is shown below:

	Cumulative claims					
	1	2	3	4	5	6
2005	9,625.64	34,270.13	42,872.36	44,695.29	45,234.18	45,787.12
2006	8,779.65	45,167.05	47,049.99	47,890.20	48,710.69	
2007	2,721.38	11,993.77	12,762.50	13,895.64		
2008	27,469.57	39,268.93	42,500.41			
2009	18,691.88	49,121.76				
2010	30,809.07					

Figure 10: Fire class of business cumulative past claims

The graph of past development patterns is shown below:

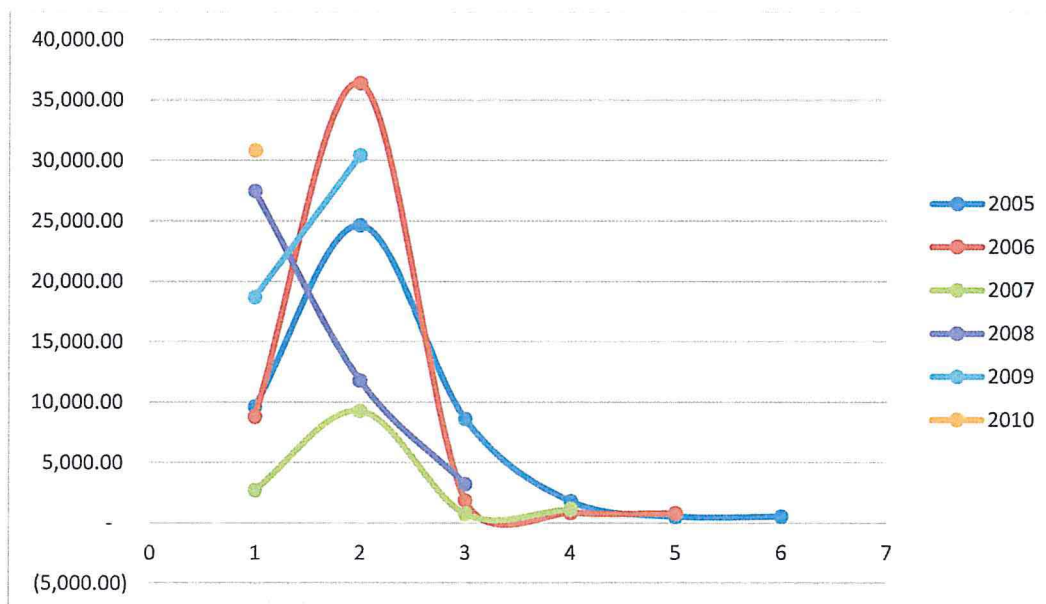


Figure 11: Fire class of business past development patterns

It is clear from the graph above that the development patterns are not the same in each accident year. However, the claims development for this class is much easier to predict than the liability class of business. The past development factors as well as the chosen development factors for each year using the weighted average approach are shown on the next page:

Past Development factors						
	1	2	3	4	5	6
2005	3.56030	1.25101	1.04252	1.01206	1.01222	
2006	5.14451	1.04169	1.01786	1.01713		
2007	4.40724	1.06409	1.08879			
2008	1.42954	1.08229				
2009	2.62797					
2010						
Factors	2.67241	1.11083	1.03697	1.01468	1.01222	1.00000

Figure 12: Fire class of business past development factors

The simulated future development factors are shown in the table below:

True Future Development factors						
	1	2	3	4	5	6
2005						1.00000
2006					1.00912	1.00000
2007				1.04204	1.01252	1.00000
2008			1.05917	1.01650	1.01338	1.00000
2009		1.08957	1.03665	1.02773	1.00844	1.00000
2010	2.05094	1.04244	1.04821	1.01369	1.00787	1.00000

Figure 13: Fire class of business future development factors

The comparison of results between various methods is thus shown below:

	METHOD COMPARISON (ERROR VALUES)									
	BCL	BF	Mack 10%	Mack 25%	Mack 75%	Mack 90%	ODP 10%	ODP 25%	ODP 75%	ODP 90%
2005	-	-	-	-	-	-	-	-	-	-
2006	34%	19%	10%	20%	46%	60%	-96%	-86%	88%	514%
2007	-51%	-10%	-79%	-70%	-39%	-15%	-99%	-97%	-26%	209%
2008	-29%	-11%	-78%	-66%	-10%	39%	-84%	-73%	-17%	37%
2009	7%	39%	-66%	-48%	35%	106%	-41%	-28%	14%	39%
2010	68%	46%	-33%	-5%	110%	199%	53%	58%	69%	75%

Figure 14: Fire class of business method comparison

4.5. Motor Class of Business Results Illustration

The simulated past claims for the motor class of business are shown below:

	Cumulative claims					
	1	2	3	4	5	6
2005	101,761.08	170,631.76	211,593.78	239,891.47	260,830.61	268,835.74
2006	70,245.36	126,845.38	161,541.50	194,983.55	215,660.78	
2007	63,119.17	115,188.58	159,722.35	195,589.15		
2008	126,959.36	220,655.42	287,616.03			
2009	195,633.56	311,757.97				
2010	305,989.84					

Figure 15: Motor class of business cumulative past claims

The graph of past development patterns for the motor class of business is shown below:

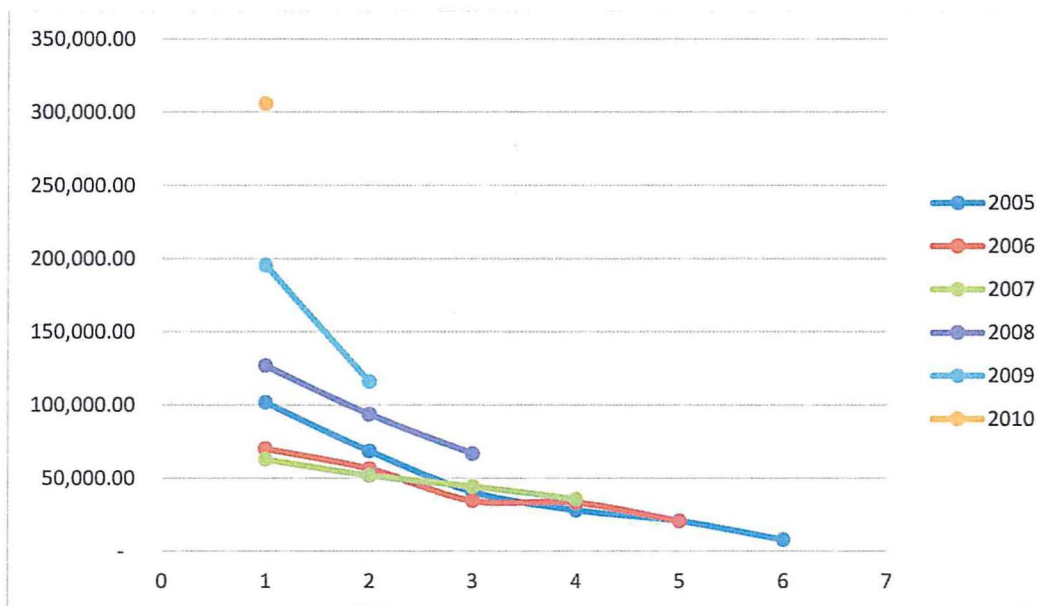


Figure 16: Motor class of business past development patterns

From the above diagram, it can be seen that the development patterns in each accident year differ slightly. The past development factors for the motor class of business as well as the chosen development factors in each development year are shown on the next page:

Past Development factors						
	1	2	3	4	5	6
2005	1.67679	1.24006	1.13374	1.08729	1.03069	
2006	1.80575	1.27353	1.20702	1.10605		
2007	1.82494	1.38662	1.22456			
2008	1.73800	1.30346				
2009	1.59358					
2010						
Factors	1.69454	1.29551	1.18318	1.09570	1.03069	1.00000

Figure 17: Motor class of business past development factors

The simulated future development factors for the motor class of business are shown below:

True Future Development factors						
	1	2	3	4	5	6
2005						1.00000
2006					1.02829	1.00000
2007				1.08751	1.03362	1.00000
2008			1.14471	1.08543	1.02581	1.00000
2009		1.20545	1.15003	1.06920	1.02058	1.00000
2010	1.40690	1.22591	1.12732	1.05810	1.02249	1.00000

Figure 18: Motor class of business future development factors

The comparison of results from various methods of IBNR is thus shown below:

	METHOD COMPARISON (ERROR VALUES)									
	BCL	BF meth od	Mack 10%	Mack 25%	Mack 75%	Mack 90%	ODP 10%	ODP 25%	ODP 75%	ODP 90%
2005	-	-	-	-	-	-	-	-	-	-
2006	8%	14%	-49%	-31%	34%	80%	-19%	-11%	12%	24%
2007	4%	7%	-37%	-22%	24%	53%	-4%	-1%	5%	8%
2008	22%	5%	-23%	-6%	44%	76%	20%	21%	23%	24%
2009	43%	8%	9%	23%	60%	80%	41%	42%	43%	43%
2010	75%	14%	54%	63%	86%	98%	75%	75%	75%	75%

Figure 19: Motor class of business method comparison

5. Discussion

5.1. Introduction

This chapter is dedicated to the explanation of the results given in the previous chapter. The discussion of results will be split between the three classes of business. In each class, the discussion of results will consider each accident year separately. Since the first accident year is fully run-off and is assumed to be so by all the methods, all the methods correctly estimate the IBNR to be zero in this accident year. Therefore, the discussion of IBNR will begin from the second accident year (2006).

The development patterns will be discussed with regard to the relation between past and future development patterns arose. The best/most accurate method in each accident year will then be analysed with respect to the development patterns that arise. Methods that give absolute errors of less than 10% are considered to give a reasonably accurate estimation of the IBNR. This analysis of the best method will answer one of the research questions given at the beginning of this report. The other two research questions of how various methods underestimate IBNR as well as the conditions necessary for the most accurate estimation of IBNR for each method will also be considered later in this chapter.

5.2. Public Liability Class of Business Results Discussion

In accident year 2006, the development factor for development year 5 was almost double that which was estimated from the cumulative past claims (shown in figure 7 and figure 8). Therefore, all of the methods greatly underestimated the IBNR that actually ended up occurring. In practice, this can be due to an unfavourable experience. The best method for estimating IBNR in this accident year was the 90th percentile of the over-dispersed Poisson distribution (shown in figure 9).

In accident year 2007, both development factors for development years 4 and 5 were greater than the estimated development factors (shown figure 7 and figure 8). Therefore, all of the methods underestimated the IBNR that ended up occurring. However, despite this, the 90th percentile of the Mack model gave a reasonably good estimation of the IBNR (shown in figure 9).

In accident year 2008, the development factor for development year 3 was almost double that which was estimated from the cumulative past claims. The development factors for development years 4 and 5 were less than the estimated development factors. These results are shown in figure 7 and figure 8. The basic chain ladder method gave perfect estimation of IBNR (shown in

figure 9). This can be attributed to luck due to the differences in actual and estimated development patterns cancelling each other out. The 75th percentile of the over-dispersed Poisson model also gave a good estimation of IBNR.

In accident year 2009, the development factors for development years 3-5 were less than those estimated from the cumulative past claims while the development factor for development year 2 was almost three times greater than that which was estimated from the past claims (shown in figure 7 and figure 8). The Bornhuetter-Ferguson method gave the best estimate of IBNR by giving a perfect estimation of IBNR. The 90th percentile of the Mack model also gave a reasonable estimation of IBNR.

In accident year 2010, the development factors for development years 2-4 were less than those estimated from the cumulative past claims while the development factors for development years 1 and 5 were greater than those which were estimated from the past claims (shown in figure 7 and figure 8). However, the development factor for development year 1 was very large as it was more than ten times the estimated development factor. This can be attributed to an unfavourable experience. Due to this phenomenon, all of the methods used underestimated the IBNR. The best method of estimating IBNR was the Bornhuetter Ferguson method.

5.3. Fire Class of Business Results Discussion

In accident year 2006, the development factor for development year 5 was slightly lower than that which was estimated (shown in figure 12 and figure 13). As a result, most of the methods used ended up over-estimating the IBNR. The 10th percentile of the Mack model gave the best estimation of IBNR due to the lower development factor than was expected (shown in figure 14).

In accident year 2007, the development factor for development year 4 was higher than that which was estimated while the development factor for development year 5 was slightly higher than that which was estimated (shown in figure 12 and figure 13). As a result, most of the methods ended up underestimating the IBNR. The Bornhuetter Ferguson method gave the most accurate estimate of the IBNR (shown in figure 14).

In accident year 2008, the development factors for development years 3-5 were all higher than those estimated from the cumulative past claims. As a result, most of the methods ended up under-estimating the IBNR. The 75th percentile of the Mack model gave the most accurate estimation of the IBNR (shown in figure 14).

In accident year 2009, the development factors for development years 2, 3 and 5 were higher than those which were estimated from the cumulative past claims. The development factor for development year 4 was lower than that which was estimated from the cumulative past claims. These results are shown in figure 12 and figure 13. The basic chain ladder method gave the most accurate estimation of IBNR (shown in figure 14). This can be attributed to luck due to the differences in actual and estimated development patterns cancelling each other out.

In accident year 2010, the development factors for development years 1 and 2 were significantly lower than estimated. The development factor for development year 3 was higher than the estimated development factor while those of years 4 and 5 were lower than estimated. These results are shown in figure 12 and figure 13. On aggregate, the development factors were lower than the estimated development factors. As a result, most of the methods ended up over-estimating the IBNR. The 25th percentile of the Mack model was the most accurate method in estimating the IBNR (shown in figure 14).

5.4. Motor Class of Business Results Discussion

In accident year 2006, the development factor for development year 5 was lower than the estimated development pattern (shown in figure 17 and figure 18). As a result, most of the methods over-estimated IBNR for this year. The basic chain ladder method was the most accurate method for estimating IBNR (shown in figure 19).

In accident year 2007, the development factor for development year 4 was lower than the estimated development factor while that of development year 5 was higher than the estimated development factor (shown in figure 17 and 18). The best method for calculating IBNR in this accident year was the 25th percentile of the over-dispersed Poisson distribution. The basic chain ladder method, Bornhuetter-Ferguson method and the other three percentiles of the over-dispersed Poisson distribution also gave reasonably accurate estimates. These results are shown in figure 19.

In accident year 2008, the development factors for development years 3-5 were all less than the estimated development factors (shown in figure 17 and figure 18). As a result, most of the methods under-estimated IBNR. The most accurate method in IBNR estimation was the Bornhuetter Ferguson method. The 25th percentile of the Mack model also gave a reasonably accurate estimation of IBNR. These results are shown in figure 19.

In accident year 2009, the development factors for development years 2-5 were all less than the estimated development factors (shown in figure 17 and figure 18). As a result, all of the methods under-estimated IBNR. The Bornhuetter Ferguson method gave the best estimation of IBNR. The 10th percentile of the Mack model also gave a reasonably good estimation of the IBNR. These results are shown in figure 19.

In accident year 2010, the development factors for development years 1-5 were all less than the estimated development factors (shown in figure 17 and figure 18). As a result, all of the methods under-estimated IBNR. The Bornhuetter Ferguson method gave the best estimation of IBNR (shown in figure 19).

5.5. Other Considerations

Using the results discussed so far, we are now better placed to answer the two pending research questions on the underestimation of variability of IBNR by each method as well as the conditions necessary for each method to accurately estimate IBNR. Also, special issues highlighting the data from the IRA (Insurance Regulatory Authority) financial statements with regards to the insurer selected and how these results affect the results of this study will be considered.

The basic chain ladder technique is better placed to give an accurate estimation of IBNR when the development patterns are the same in each accident year. Indeed, the assumption of development patterns being the same in each accident year is the main assumption in the basic chain ladder technique. In this study, the basic chain ladder was the most accurate method only in cases where the differences between actual and expected development patterns cancelled each other out. When the development pattern experienced is less than the weighted average of prior accident year development patterns, this method over-estimates the IBNR while it under-estimates IBNR when the development pattern experienced is greater than the weighted average of prior accident year development patterns.

The Bornhuetter Ferguson technique is better placed to give an accurate estimation of IBNR in later accident years. This is due to the fact that the Bornhuetter Ferguson technique relies more on exposure rather than past claims development to calculate the future claims development. Therefore, in the later accident years where claims have not developed sufficiently, this method becomes more suitable in estimating the IBNR. In the results in this report, this fact is shown in many instances. However, there are a few exceptions e.g. Fire IBNR for 2007, where the Bornhuetter Ferguson technique gives the best estimate for IBNR in earlier accident years.

The 10th and 25th percentiles of the Mack model and the over-dispersed Poisson distribution tend to be more accurate when the development pattern experienced is less than the prior accident year weighted average of development factors. Where this is not the case, these methods tend to greatly under-estimate the IBNR. The accuracy of these methods is clearly shown in the motor class of business results where these methods are very accurate due to lower development factors than estimated occurring. The downside of these methods is clearly shown in the public liability class of business results where they greatly under-estimate the IBNR due to higher development factors than estimated occurring.

The 75th and 90th percentiles of the Mack model and the over-dispersed Poisson distribution tend to be more accurate when the development pattern experienced is greater than the prior accident year weighted average of development factors. Where this is not the case, these methods tend to greatly over-estimate the IBNR. The accuracy of these methods is clearly shown in the public class of business results where these methods are relatively accurate compared to the other methods in most cases due higher development factors than estimated occurring. The downside of these methods is clearly shown in the motor class of business results where they greatly over-estimate the IBNR.

There were also other considerations with regard to the data from which simulation was done. The fire class of business for 2006-2010 concerning the insurer chosen for this study was generally favourable. This is due to the fact that the net earned premiums were generally much higher than the net incurred claims for this time period. This affected the results as the simulated claims were generally not as erratic as can sometimes be the case with the fire class of business due to the occurrence of large claims from large fires. Nevertheless, the fire results were still judged by the researcher to be credible because simulation was done based on real-life Kenyan insurance data.

There is also a consideration concerning how an actuarial expert will be able to choose the best method of estimating IBNR based on this study. This is due to the fact that the study links the development patterns to the best method but does not explicitly concentrate how to find these development patterns. One way this can be done is by analysing the trend of various development factors. A clear example of this trend is shown in the motor class of business for the first development year where the development factors show a downward trend in the final three accident years as shown in figure 17. However, the study of development patterns is an entirely different topic in itself that would require a separate research project to study.

5.6. Limitation of the study

The main limitation of the study was the lack of claims registers as data. This prevented the researcher from making adjustments for unfavourable experience by removing large claims. Also, the use of claims registers would have made the study more credible. Despite this, the use of data simulated in line with financial statements was credible enough.

5.7. Scope for future study

As mentioned in section 5.5, there is a scope to study the occurrence of development patterns. Such a study, in conjunction with this study would give a complete guide on how to select the best method to calculate IBNR. Also, despite the comprehensiveness of this report in terms of methods used to calculate IBNR, future studies can explore various other methods with respect to calculating IBNR. However, most of these other methods would not differ greatly to those selected in this report.

6. Conclusion

In conclusion, the study of how various development patterns affect IBNR calculation is very relevant as development patterns are rarely the same in practice. The basic chain ladder technique, though being the basis for most other methods of IBNR calculation is often not sufficiently accurate to calculate IBNR. Therefore, stochastic methods as well as other deterministic methods such as the Bornhuetter Ferguson technique can be used to calculate IBNR more accurately.

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