# ANALYSIS OF PREMIUM LIABILITIES FOR AUSTRALIAN LINES OF BUSINESS

**BY**

**EMILY TAO**

**300-400 ACTUARIAL RESEARCH ESSAY**
**2005**

This essay is submitted for assessment as part of the requirements of the BCom Honours Year in the Centre for Actuarial Studies, Faculty of Economics and Commerce.

## DECLARATION

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Emily Tao
27/10/2005


## ACKNOWLEDGEMENTS

I am grateful to the Australian Prudential Regulation Authority and the Reserve Bank of Australia for their financial support through the Brian Gray Scholarship. I would like to thank my supervisor, Dr Allen Truslove for his support and helpful advice. I would also like to thank Mr Jackie Li, Ms Anna Jones and my family and friends who have provided encouragement and assistance throughout the writing this research paper.

# ABSTRACT

The prediction of future claims liability is highly speculative by nature and as a result, there has been a lacking in literature which explores the statistical mean and variance of Premium Liabilities. This paper provides a starting point to such analysis by presenting a simple model which can use past claims data to estimate the first two moments of future claims liabilities. A relationship is established so that the co-efficient of variation of the Outstanding Claims Liability can be estimated from the co-efficient of variation of the Premium Liability. It is found that the variability of the Outstanding Claims Liability for longer tailed claims can be reduced substantially by affects of averaging across independent accident years. This result suggests that the difference in the inherent uncertainty between Premium Liabilities and Outstanding Claims Liability is comparatively larger for long tailed claims than for short tailed claims and so the Premiums Liability Risk Capital Factors set by APRA should be increased for the long tailed claims.

The word count is approximately 9,887 words. The diagrams average 125 words each.

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# 1. INTRODUCTION

The purpose of this paper is to detail a method for estimating the mean and variance of Premium Liabilities using run-off data from the Australian Private Sector. This analysis will be performed on both short tailed risks (where claims are typically settled within one year from the occurrence of the incident), as well as long tailed risks (where the settlement of claims typically exceeds one year from the occurrence of the incident). The concept of 'Premium Liabilities' for general insurers is relatively new, therefore literature that examines its statistical nature is limited. This paper will add to the limited pool of current literature by acknowledging the random nature of this future liability and presenting a theoretical model that can be adopted to examine the statistical behaviour of Premium Liabilities.

General Insurance policies usually provide cover for durations that may overlap (partially or completely) two or more valuation periods. Thus it follows that at the time of liability valuations, the insurer is likely to be exposed to the risk of "future claim payments arising from future events insured under existing policies" (Australian Prudential Regulation Authority 2002(a)). A reserve that is set up to meet the total estimated liability arising beyond the valuation date for policies currently in force is referred to as the 'Unexpired Risk Reserve'. The Unexpired Risk Reserve can be calculated both prospectively and retrospectively. Premium Liabilities refer to the prospective valuation of the Unexpired Risk Reserve.

Prior to 2002, only the retrospective valuation was required to be carried out and disclosed for reporting purposes. The retrospective valuation involves the establishment of the Unearned Premium Reserve (UPR) and if required, a Premium Deficiency Reserve (PDR). General Insurers provisioned for the UPR by setting aside a constant portion of their premium income. However, this method can lead to reserving errors as the nature of the underlying liability is statistically random. The future claims liability is dependent upon the future claim frequencies and future claim cost for the policies currently in force, both parameters behave as random variables. It has become apparent that models which factor in these inherent uncertainties provide better insight into the behaviour of this future liability, and can contribute to more accurate reserving for the future claims liabilities.

**An Insurer's Total Liabilities at any point in time.**

<table>
<tr><th>Outstanding Claims Reserve</th><th>Unexpired Risk Reserve</th></tr>
<tr><td>Claims reported but not finalised</td><td rowspan="2">Claims not yet incurred but covered by existing policies</td></tr>
<tr><td>Claims incurred but not reported (IBNR)</td></tr>
</table>

## 1.1 Background

Traditionally, it was common practice to assume that both insured risks and premium income could be uniformly split over the duration of the policy, so that liability reserves could be calculated by prescribing a pro-rata proportion of net premiums. It was first suggested that the UPR should make up 40% of the premiums received during the valuation period. The 40% was determined by including an allowance of 20% for initial expenses and commission – an even distribution over the policy duration meant that approximately half of the period of risk was left unexpired. (Benjamin 1977)

As technology advanced, more exact methods were introduced. The 24ths method operated on monthly data where it was assumed that premiums were written evenly over the month, so that the average commencement date for the cover was in the middle of the month. For premiums written in the previous month, one twenty fourth is considered earned at the end of that month, leaving the remainder unearned. It also allowed for more accurate estimates of expense and could factor in actual experience rather than assuming a constant value of 20%. The 365ths method calculated the unearned fraction of the premium by comparing the number of days remaining from the cover, to the total number of days agreed by the policy (usually 365). Currently, this is the only method supported under accounting standards, AASB1023 (Buchanan, Hart et al. 1996).

It is worthwhile noting that these retrospective reserving methods work well where the insurance risk is spread evenly throughout the policy period, however, where uneven risk exposure exists, a substantial premium deficiency reserve may also be required during periods of high risk exposure to maintain an adequate unexpired risk provision. An example of this type of risk is crop damage insurance. For this line of business, crops will be damaged during extreme weather conditions such as hailstorms or hurricanes. The claims distribution will be concentrated during such events that may only happen during winter.

At the time of this research, there seems to be only three counties, namely Australia, Singapore and Canada, which require the assessment of Premium Liabilities to be performed by an Actuary for general regulatory reporting purposes. In Australia, the Australian Prudential Regulation Authority (APRA) requires the estimation of Premium Liabilities for both general financial performance reporting purposes as well as completing the minimum capital requirement (MCR) calculation for solvency purposes.

The process of 'Liability Valuation for General Insurers' is outlined in the Prudential Standard GPS 210. GPS 210 necessitates a prospective basis for the recognition and measurement of claims liabilities, this requires Premium Liabilities to be valued as the estimated losses that are expected to arise in the future from the business already written. From July 2002 onwards, insurers are required to recognise premium revenue fully from the date of acceptance. As a result, the Unearned

Premium Provision has been eliminated and replaced by the estimated value of 'Premium Liabilities'. The Approved Actuary is required to provide a prospective estimate of the unexpired risk reserve and risk margins relating to its inherent uncertainty. The risk margins should be established to provide a total Premium Liability for the insurer at a 75 per cent sufficiency level (Australian Prudential Regulation Authority 2002(a)).

## 1.2 Aim and Scope

The aim of this research is twofold. First, we construct a model that can be used as a starting point for the estimation of the mean and variance of the future claims liability. This model is applied to four classes of Australian lines of business, and the results calculated for the short tailed and long tailed classes are compared.

Second, after the variance of the Premium Liability is estimated, we then find a relationship between the Premium Liability and Outstanding Claims Liability. This can then be used to infer the variance of the Outstanding Claims Liability from the estimated variance of the Premium Liability.

The paper will conclude by addressing the adequacy of the Premiums Liability Risk Capital Factors, which are required by the Australian Prudential Regulation Authority (APRA) to calculate the Insurance Risk Capital Charge (see Appendix 1). It will be argued that the Premiums Liability Risk Capital Factor for the long tailed claims such as Compulsory Third Party and Public Liability is inadequate when compared to the Risk Capital Factors required for the Outstanding Claims Liability.

The scope of this paper is limited to stand-alone lines of business in the Australian General Insurance Market. Claims related expenses, the effects of reinsurance, and diversification between individual lines of business within an insurance portfolio will not be discussed in this paper.

# 2. LITERATURE REVIEW

Literature that specifically addressed methods of calculating the central estimate and variance of the unexpired risk appeared to be limited and lacking in detail, so there are no guidelines to assist in the construction of the modelling process. This could be related to the fact that only a small number of countries require the prospective valuation of the unexpired risk for reporting purposes. APRA Standard GPS 210 had set out general guidelines to estimating both the central estimate, and inherent uncertainty of Premium Liabilities. However, with little guidance regarding the application of specific methods or models, many of the valuation assumptions were left to the discretion of the Actuary.

Retrospective methods for calculating the central estimate of the unexpired risk reserve were discussed by Cantin & Trahan (1999) and Hart, et al (2002). Retrospective calculation methods used the pro-rata proportion of collected premiums to determine the value of the Unearned Premium Provision. While the determined value of the central estimate could be used as a guide or comparison to the results from the prospective valuations, retrospective methods give a poor quantification of the random error as they do not recognise the random nature of this future liability.

Buchanan (2002) and Collins & Hu (2003) addressed the differences between a retrospective and prospective approach for the valuation of the unexpired risk. The papers also focused on technical and practical issues related to data analysis for the calculation of Premium Liabilities. Collins & Hu (2003) recommended separating the total claims amount into risk claims and refund claims. The loss ratio for refund claims is generally higher than risk claims, so separating the two will give a more accurate estimate of the future claim costs. Due to data limitations, this method cannot be adopted for the analysis. Although both articles addressed the prospective valuation of the unexpired risks, specific methods were not presented and little was mentioned regarding the estimation of the variance of Premium Liabilities.

Analysis of the inherent uncertainty of general insurance liabilities was conducted independently by Bateup & Reed (2001) and Collings & White (2001). These reports mainly focused on estimating the variance of Outstanding Claims Liability. The variability of Premium Liabilities was not modelled or calculated, however, it was reported as a multiple of the variability of the corresponding Outstanding Claims Liability. The multiple was determined through subjective adjustments based on the authors' assumptions and industry experience. This seemed to be the only piece of literature that endeavoured to find a connection between the variance of the two liabilities. Bateup & Reed (2001) used the estimated variance of the Outstanding Claims Liability to infer the variance of the Premium Liability.

This research paper will progress in the opposite direction, it is primarily focused on estimating both the central estimate and variance of the Premium Liability, and then it will backtrack to find a relationship that can be used to infer the inherent uncertainty of the Outstanding Claims Liability.

# 3. A MODEL FOR FUTURE CLAIM PAYMENTS

Insight into the behaviour of future claim liabilities may be gained by examining the liabilities incurred during past and current accident years. As previously mentioned, it will be assumed that the underlying nature of Premium Liabilities is affected by two independent sources of randomness, the first being the number of claims that will occur and the second being the size of future claim payments. It follows that there is a need to develop a model to incorporate the uncertainty from these two sources of variability.

## 3.1 Aim

The objective of this paper is to detail a generalised process for estimating the mean and variance of Premium Liabilities. Keeping this in mind, the model must be applicable to a range of different situations with further assumptions to be incorporated depending on individual circumstances. As a result, the model developed is based on non-restrictive assumptions.

## 3.2 Notations

For a particular line of business:

1. Let the random variable $S^i$ denote the total dollar amount of payments made for claims incurred during accident year $i$.

When analysing past data figures, it is desirable to transform these payment amounts into currencies of a constant dollar value by removing the effects of inflation.

2. Let the random variable $N^i$ denote the total number of claims arising from that particular line of business during accident year *i*.
3. The random variable $X^i$ denotes the average payment per claim for claims that occurred during accident year *i*.

Again, the effects of inflation should be removed from these payments so that the analysis is performed on a stable currency. This process is discussed in Section 4.2.3

4. The total claim payment is the sum of individual claim payments and can be expressed as:

$$S^i = N^i X^i \tag{1}$$

   Note that $X^i$ is only random for different values of *i*.

## 3.3 Assumptions

1. It will be assumed that the two random variables, $N^i$ and $X^i$ are independent of each other.
2. It will also be assumed that $\{X^i\}_{i=1}^{\infty}$ is a sequence of random variables that are independent of each other.

## 3.4 Moments of $S^i$

The first two central moments of $S^i$ are of significant interest as they represent the mean and variance of the future claim payment.

It can be seen that:

$$E\left(S^i\right) = E\left(N^i X^i\right) \tag{2}$$

As $N^i$ and $X^i$ are assumed to be independent, it follows that:

$$E(S^i) = E(N^i)E(X^i) \tag{3}$$

This result is not surprising as it is saying that the expected mean of the total claim payments is equal to the expected mean of the total number of claims incurred multiplied by the expected average payment per claim.

It is also noted that:

$$V(S^i) = V(N^i X^i) \tag{4}$$

As the variance is not a linear function, the variance of the total claim payment is not simply the multiple of the individual variances of $N^i$ and $X^i$. For the purposes of this analysis, the first two moments of the random variables $N^i$ and $X^i$ will be estimated from the data, and a general probability distribution will be fitted using the estimated moments. Values of $N^i$ and $X^i$ can then be generated by simulation and multiplied with each other to give simulated values of $S^i$. The variance of a large sample of simulated values would give a close approximation to the actual random error of $S^i$.

## 3.5 Comments

These results can now be applied to the future claims liability. It is now possible to find the first two moments of the total future claims liability by estimating the mean and variance of both future claim numbers and future average payment per claim. This method will be adopted to find the mean and variance of Premium Liabilities and will require the estimation of $E(N^i)$, $V(N^i)$, $E(X^i)$, and $V(X^i)$ for the subsequent accident year.

The use of $X^i$ to represent the average cost per claim rather than the actual cost of the claim is a limitation imposed by the data used for the analysis. If individual claim amounts are recorded and accessible, then this analysis can be performed by assuming that $X_j^i$s represent the claim amount of the j$^{th}$ claim. If such information is available, then the results produced by the collective risk model may be used to find the moments of $S^i$ as outlined by Dickson (2005). Where $S^i$ is defined to be the aggregate claim amount, the mean and variance of $S^i$ can be found as follows:

$$E(S^i) = E(N^i)E(X_j^i) \tag{5}$$

$$V(S^i) = V(X_j^i)E(N^i) + V(N^i)E(X_j^i)^2$$

For derivations of these results, refer to Dickson (2005).

The model deviates slightly from the collective risk model by allowing the $X_j^i$s to take positive values as well as negative values. $X_j^i$s can be negative when the company receives recoveries from their previous claim payments or payments by reinsurers.

# 4. APPLYING THE MODEL TO THE AUSTRALIAN PRIVATE SECTOR DATA

The Australian Prudential Regulation Authority requires that business written by general insurers be grouped according to the underlying nature of the risk. These groups are referred to as 'lines of business' and include classes such as Domestic Motor, Consumer Credit, Worker's Compensation, Compulsory Third Party, Public and Product Liability etc. An insurer's Premium Liability is the sum of the individual Premium Liabilities for all lines of business within their insurance portfolio after taking into account the effects of diversification. The effects of diversification will not be examined, so the model constructed will only be used to estimate the stand-alone Premium Liabilities for Australian lines of business.

## 4.1 Data

Although aggregate data for the general insurance industry (both Public and Private Sectors) has been collected by APRA and its predecessor the Insurance and Superannuation Commission, it has not been made publicly available for a number of reasons, an example of which includes company privacy issues

The Insurance and Superannuation Commission did release detailed claims analysis data for certain lines of business over the period 1983 – 1996. These aggregate figures are restricted to the Private Insurance Industry only. Over this fourteen year period run-off data have been gathered for four lines of business, namely: Motor Vehicle, Public Liability, Compulsory Third Party, and Employers' Liability in NSW.

The general insurance industry has been evolving rapidly throughout this period of time, and many new prudential requirements are introduced to keep up with the evolution. The changes in reporting requirements produce certain inconsistencies with the format that the data is presented in. Certain lines of business are split up into smaller groups so the underwritten risks become more homogenous and new lines of business are frequently introduced. These new requirements alter the structure of the reported figures and in order to maintain reliability throughout the analysis, data from after the requirement changes are transformed so that they can be compared to all the figures preceding the change consistently.

Such alterations include; combining the figures for new lines of business of Domestic Motor and Commercial Motor (introduced in 1992) so that they can be compared to the old line of business named Motor Vehicle Insurance. New lines of business named Public Liability and Product Liability are also combined so that the figures can be compared to the old Public Liability.

The claim analysis tables provide aggregate figures for 'total number of claims reported', 'total number of claims outstanding', and 'total claim payments' broken down by the seven previous accident years and ten development years. From these figures, run-off triangles for 'total number of claims reported', 'total number of claims outstanding', 'total number of claims settled' and 'total claim payments' can be constructed over the years 1983 to 1996.

## 4.2 Premium Liabilities

### 4.2.1 Total number of Claims Reported $N^i$

Let $n_{i,j}$ be the total number of claims that occurred in accident year *i* and was reported in development year *j*.

- A run-off triangle can be constructed with these $n_{i,j}$ values for accident years 1983 until 1996.
- The missing entries below the diagonal of the run-off triangle can be filled in using a reserving method. The Chain Ladder method is adopted in this case because it is commonly used in practice and simple to apply.
- The claims analysis provides data for ten development years, so we make the assumption that all the claims are reported by the tenth development year.
- Let $N^i$ be defined as the total number of claims arising from the risk in accident year *i*, it can be expressed as:

$$N^i = \sum_{j=0}^{9} n_{i,j} \tag{6}$$

- The total number of claims reported for each accident year can be found by summing across the ten development years. Accordingly, $N^i$ values for *i* = 1983, 1984, 1985, … ,1996 can be calculated.

### 4.2.2 Calculating $\mathbf{E}\left(\mathbf{N}^i\right)$ and $\mathbf{V}\left(\mathbf{N}^i\right)$

As the progression of the $N^i$ values are not necessarily static, it is inadequate to simply estimate the mean and variance of the future $N^i$ values by finding mean and variance of the previous $N^i$ values obtained from the past data. It is quite likely that these figures have been and will be affected by inflationary effects, which produce trends. Bearing this in mind, the values of $E\left(N^i\right)$ and $V\left(N^i\right)$ will be calculated by fitting a trendline:

- The values of the total number of claims reported ($N^i$'s) are then plotted against each accident year.
- A trendline is fitted across the data points.

For this analysis, the trendline selected is linear in shape and fits the data well, however, where the figures are exposed to the compounding effects of superimposed inflation, the shape of an exponential or polynomial curve may provide a better fit. Microsoft Excel's LINEST function is employed during the analysis to find the parameters of the linear trendline. This function provides a linear regression by assuming the underlying distribution of the data is normal with a mean equal to the trendline and variance equal to the squares of the deviations about the mean.

The result of one such analysis performed on Motor Vehicle Insurance is shown below:

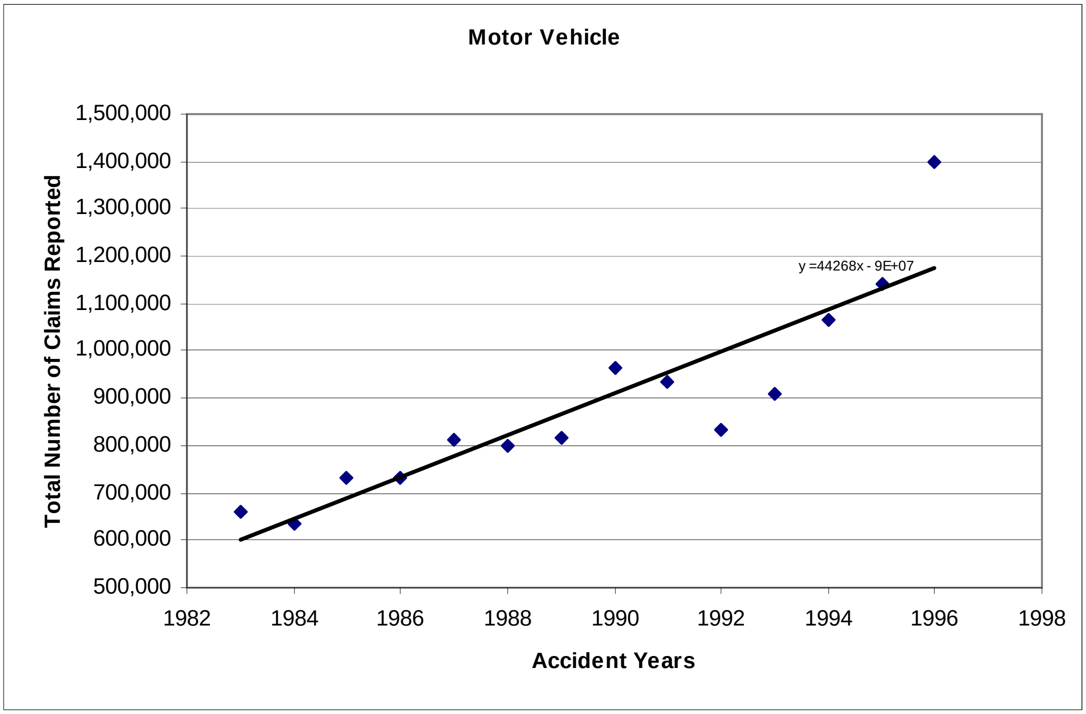


*Figure 1:* Number of claims reported for Motor Vehicle during 1983 - 1996

The trendline is a function of the accident years, and is representative of the total expected number of claims reported in each accident year. It is expressed as $Y = aX + b$, where $Y$ is the total number of claims reported, and $X$ is the accident year. Once the values of $a$ and $b$ are calculated, (in this case $a$ = 44268 and $b$ = -87183686) the trendline can be used to forecast the estimated value of $N^i$ for the subsequent year. In this instance, $X$ is replaced by the year 1997. This value will be an estimate of $E\left(N^{1997}\right)$.

As the data collected represent the aggregate experience of the Private Insurance Sector, it is reasonable to assume that all un-systematic risks are diversified away, so that the deviations from the trendline (the mean) correspond only to the systematic risk or the inherent uncertainty of the liability.

On the assumption that the individual accident years are independent, we can define the variance of the total number of claims for each individual accident year as:

$$V\left(N^i\right) = \frac{\left(\sum_{1}^{10}(deviaton\ of\ data\ point\ \ from\ the\ trendline\right)^2}{14 - 2} \qquad (7)$$

for $i$ = 1983, 1984, … ,1996

Two degrees of freedom are lost in the denominator due to the estimation of the two parameters for $E\left(N^i\right)$ and $V\left(N^i\right)$. We now have the estimated values for the mean and variance of $N^i$.

### 4.2.3 Average Payment per Claim $\mathbf{X}^i$

The average payment per claim is defined:

$$X^i = \frac{total\ claim\ payments\ for\ accident\ year\ i}{total\ number\ of\ claims\ settled\ in\ accident\ year\ i} = \frac{P^i}{\delta^i} \qquad (8)$$

- It is noted that the figures for ‘number of claims reported’ and ‘number of claims outstanding’ can be used to calculate ‘number of claims settled’.
- Let $s_{i,j}$ denote the number of claims that occurred in accident year $i$ and are settled in development year $j$.

- Let $o_{i,j}$ denote the number of claims that occurred in accident year *i* but remain outstanding at the end of development year *j*.
- A run-off triangle can be constructed for the values of $o_{i,j}$, similar to the triangle created for the $n_{i,j}$ values. Again, the Chain Ladder method will be used to fill in the missing entries below the diagonal.

Now, a complete set of $o_{i,j}$ and $n_{i,j}$ values have been calculated for all accident years across the whole development period, and $s_{i,j}$ values can be found using the figures of $o_{i,j}$ and $n_{i,j}$ as follows:

$$s_{i,j} = o_{i,j-1} + n_{i,j} - o_{i,j} \tag{9}$$

$$s_{i,0} = n_{i,0} - o_{i,0}$$

All values of $s_{i,j}$ can be found using the above equations. Similarly, we can sum across the rows to obtain the total number of claims settled for each accident year over the course of the ten development years.

The values of $\delta^i$ can be found for *i* = 1983, 1984, … , 1996 as follows:

$$\delta^i = \sum_{j=0}^{9} s_{i,j} \tag{10}$$

The claim payments are recorded as nominal amounts and in order to compare the figures, the claim payments should be adjusted to a stable currency. It will be assumed that the payments are made in the middle of each development year. The Average Weekly Earnings is used as the inflation index. Using the AWE is common practice as a large proportion of the claim costs, including income loss, and hospital or medical expenses are wage related.

Once all the claim payment figures are adjusted to the June 1996 dollar value, a run-off triangle can be constructed once again using $p_{i,j}$ values to represent the total claim payments made for claims which were incurred in accident year *i*, and paid in development year *j*. The total claim payments for each accident year, $P^i$ can then be found following the same process documented in 4.2.1, where a run-off triangle is constructed and the Chain Ladder method is applied. It should be noted that the projected future claim payments are in June 1996 dollar value.

The values of $P^i$ can be found for *i* = 1983, 1984, … , 1996 as follows:

$$P^i = \sum_{j=0}^{9} p_{i,j} \tag{11}$$

The values for $\delta^i$ and $P^i$ have now been calculated so that it is possible to proceed to find values of $X^i$ for all fourteen accident years.

### 4.2.4 Calculating $E(X^i)$ and $V(X^i)$

Once again, the values of $X^i$ are plotted against each accident year and a trendline is fitted to the data. Although the effects of general inflation have been removed, the gradient of the trendlines in all four lines analysed are still positive. A linear trendline still provides a reasonable fit (the $R^2$ values are 0.8061 for Motor Vehicle and 0.5491 for Public Liability), so the LINEST regression function is adopted once again. The following graph displays the results for the analysis of Public Liability:

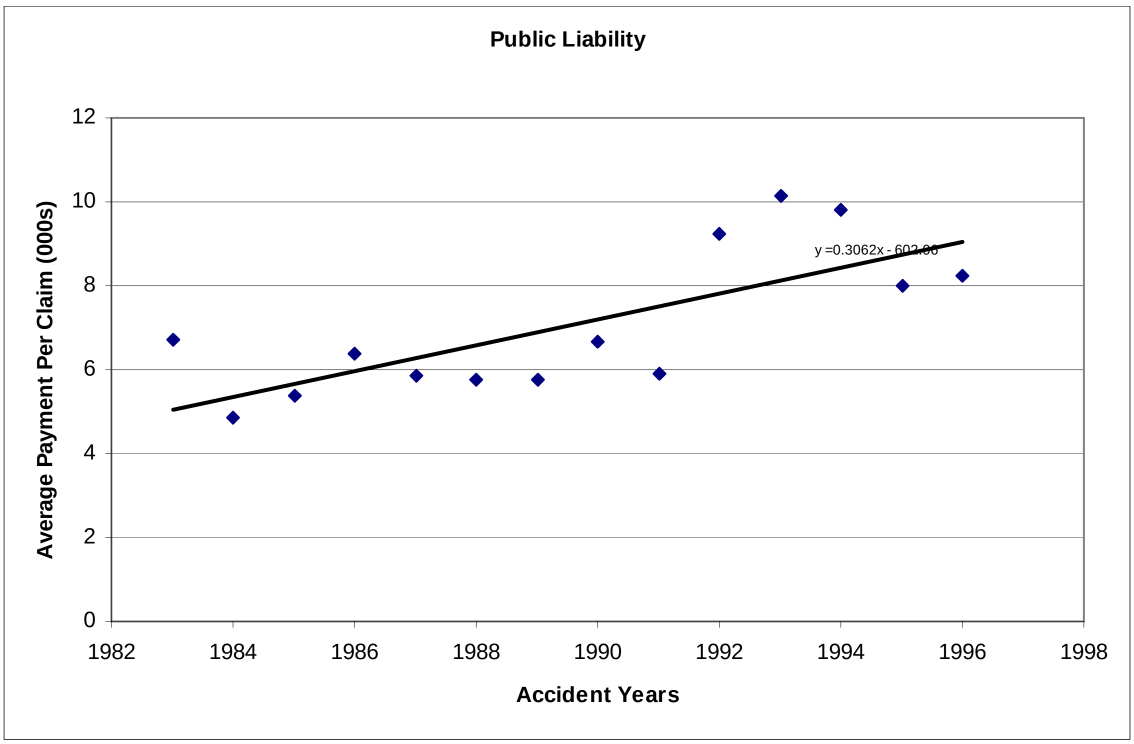


*Figure 2:* Average Claim Payments for Public Liability during 1983 – 1996

The trendline is expressed as a function of the accident years. In this case:

$$Y = 0.3062X - 602.06$$

Where $Y$ is the average payment per claim (in thousands), and $X$ is the accident year.

The trendline can be used to forecast the average payment per claim for the accident year 1997. The value calculated by the trendline will be the estimate of $E\left(X^{1997}\right)$.

As the claim payments represent the total payments made by the Private Insurance Sector, the assumption that all the fluctuations are caused by the non-diversifiable risk can once again be made. In other words, the inherent uncertainty of $X^i$ can be measured using the deviation of the data points from their mean (the trendline) as follows:

$$V\left(X^i\right) = \frac{\left(\sum_{1}^{10}(deviaton\ of\ data\ po\text{int}\ \ from\ the\ trendline\right)^2}{14 - 2} \qquad (12)$$

Using the data, all four values for $E\left(N^i\right)$, $V\left(N^i\right)$, $E\left(X^i\right)$, and $V\left(X^i\right)$ have been estimated. By applying the results derived in Section 3, we can proceed to find the mean and variance of the stand-alone Premium Liabilities for the four lines of business.

## 4.3 Outstanding Claims Liability

The variance of the Outstanding Claims Liability is estimated with respect to a number of accident years. In the estimation of the Outstanding Claims Liability, the values on the upper triangle have already been recorded. As a result, only a portion of the total number of claims reported for each accident year is considered random because the other portion is known at the time of valuation. The same result also applies for total claim payments. The variability of the Outstanding Claims Liability is considerably reduced compared to the variability of the Premium Liability where the total value is considered random.

Furthermore, the Outstanding Claims Liability spans over several accident years (in the case of this analysis, it spans over nine accident years) while the Premium Liability only spans one single year. For each accident year, ‘the total number of claims reported’ and ‘average payment per claim’ are regarded as random variables with a mean and variance. The Outstanding Claims Liability is a linear combination of nine individual random variables. By assuming that the individual accident years are independent, the results from the Law of Large Numbers then states that the variability of the Outstanding Claims Liability will be relatively lower than combined variability of the individual accident years. This result is due to the pooling or averaging effects across the independent accident years.

It can be shown that this averaging affect becomes more dominant when the Outstanding Claims Liability contributes to a bigger proportion of the total claim payments. As a result, the reduction in the variance of the Outstanding Claims Liability created by this averaging affect is particularly relevant for long tailed lines of business where the claim payment values are spread out more evenly across the later development years. This method cannot be applied to Premium Liabilities as it only spans one single year, so this result suggests that the comparative variability between the Premium Liability and the Outstanding Claims Liability should be greater for long tailed risks than for short tailed risks. We will proceed to measure the value of this comparative variability.

For each of the ten development years, let the proportion of total claims payable in each development year *j* be estimated by:

$$f_j = \frac{Total\ \ payments\ made\ in\ development\ \ year\ \ j\ \ across\ all\ \ accident\ years}{Total\ \ payments\ made\ across\ all\ \ accident\ years}$$

for $j = 0, 1, 2, \ldots, 9$

It is assumed that this proportion is constant for all accident years.

For each accident year *i*, the proportion of claims that belong to the Outstanding Claims Liability can be estimated as:

$$F_i = \sum_{j=11-i}^{9} f_j \qquad (13)$$

for $i = 2, 3, \ldots, 10$

For example, if the valuation is performed as at December 31 and the most recent accident year is considered, then only the claim payments made in the first development year (development year 0) is known at the time of the liability valuation. In this case the claims payable from development year 1 onwards is unknown and needs to be reserved as part of the Outstanding Claims Liability so *i* take the value 10. For this accident year, $\sum_{j=1}^{9} f_j$ is the proportion of claims considered to be outstanding.

Once again, let the total claim payment for accident year *i* be denoted by $S^i$. Unlike the valuation of Premium Liabilities, where the total value of $S^i$ is considered to be a random variable, only a fraction of $S^i$ for each of the nine accident years contributes to the Outstanding Claims Liability. These fractions are given by $F_i$ for *i* taking values of 2, 3, … ,10.

As required by APRA, the Capital Charge for each class of business is calculated by multiplying the Outstanding Claims Liability or the Premium Liability by the relevant Outstanding Claims or Premiums Liability Risk Capital Factor (Australian Prudential Regulation Authority 2002(b)). We define $\theta_x$ as the Risk Capital Factor the line of business $x$, we also define $E(S_x)$ and $SD(S_x)$ as the corresponding central estimate and standard deviation of the future liability respectively. As the Capital Charge is held to buffer the risk that the actual value of the liability is greater than its expected value, it is reasonable to assume thatt:

$$E(S_x)\,\theta_x \propto SD(S_x) \tag{14}$$

It then follows that:

$$\theta_x \propto \frac{SD(S_x)}{E(S_x)} \tag{15}$$

This result states that the size of the Risk Capital Factor should be proportional to the co-efficient of variation of the risk. We will now proceed to find a relationship between the co-efficient of variation for both the Outstanding Claims Liability as well as the Premium Liability.

The co-efficient of variation for Outstanding Claims Liability valued in accident year *i* is defined as $CV\left(OS^{i}\right)$. It can be seen that:

$$CV\left(OS^{i}\right) = \frac{\sqrt{V\left(OS^{i}\right)}}{E\left(OS^{i}\right)} = \frac{\sqrt{\sum_{i=2}^{10} F_i^2\, V(S)}}{\sum_{i=2}^{10} F_i\, E(S)} = CV(S)\frac{\sqrt{\sum_{i=2}^{10} F_i^2}}{\sum_{i=2}^{10} F_i} \tag{16}$$

We assume that $CV(S)$ is constant for all accident years, including accident year *i+1*.

The co-efficient of variation for the Premium Liability valued in accident year *i* is defined as $CV\left(P^{i+1}\right)$ and assuming that future policies written have the same characteristics as policies previously written, $CV\left(P^{i+1}\right)$ is equivalent to $CV\left(S^{i+1}\right)$ or $CV(S)$. We can now write:

$$CV\left(P^{i+1}\right) = CV(S); \text{ and } CV\left(OS^{i}\right) = CV(S)\frac{\sqrt{\sum_{i=2}^{10} F_i^2}}{\sum_{i=2}^{10} F_i} \tag{17}$$

It then follows that:

$$CV\left(P^{i+1}\right) > CV\left(OS^{i}\right) \tag{18}$$

As these results show, the co-efficient of variation of the Outstanding Claims Liability is smaller than the co-efficient of variation of the Premium Liability. This is due to the pooling effects over the independent accident years. The reduction in variability increases as $\sum_{i=2}^{10} F_i$ exceeds 1 by a large amount and the $F_i$ values are greater for long tailed risks as a smaller proportion of claims are settled in the earlier development years. This suggests that the averaging effect is more prominent for lines of business that are long tailed in nature.

# 5. OUTPUT

## 5.1 Total Number of Claims Reported $N^i$

Estimates of the 'total number of claims reported' for the fourteen accident years together with the fitted trendlines are displayed in Figures 3 to 6.

All four lines of business are analysed using the methods outlined in Section 4.2.1. Initially, linear trendlines were selected for all four lines of business, but after careful consideration, an exponential trend seems to provide a better fit for the data points in Compulsory Third Party. With the exception of Employers' Liability, all the trendlines display positive slopes, which seem to indicate that either the $N^i$ values are influenced by inflationary effects or that the business written has been expanding over time for the industry as a whole.

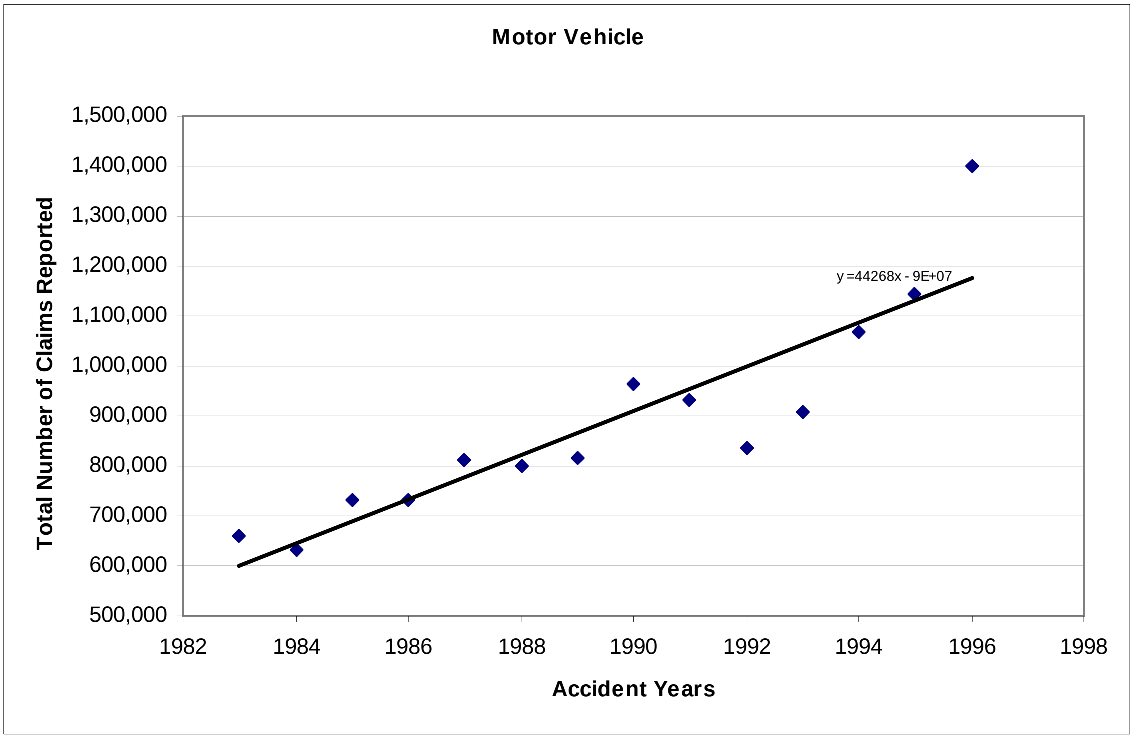


*Figure 3:* Total Number of Claims Reported for Motor Vehicle during 1983 – 1996

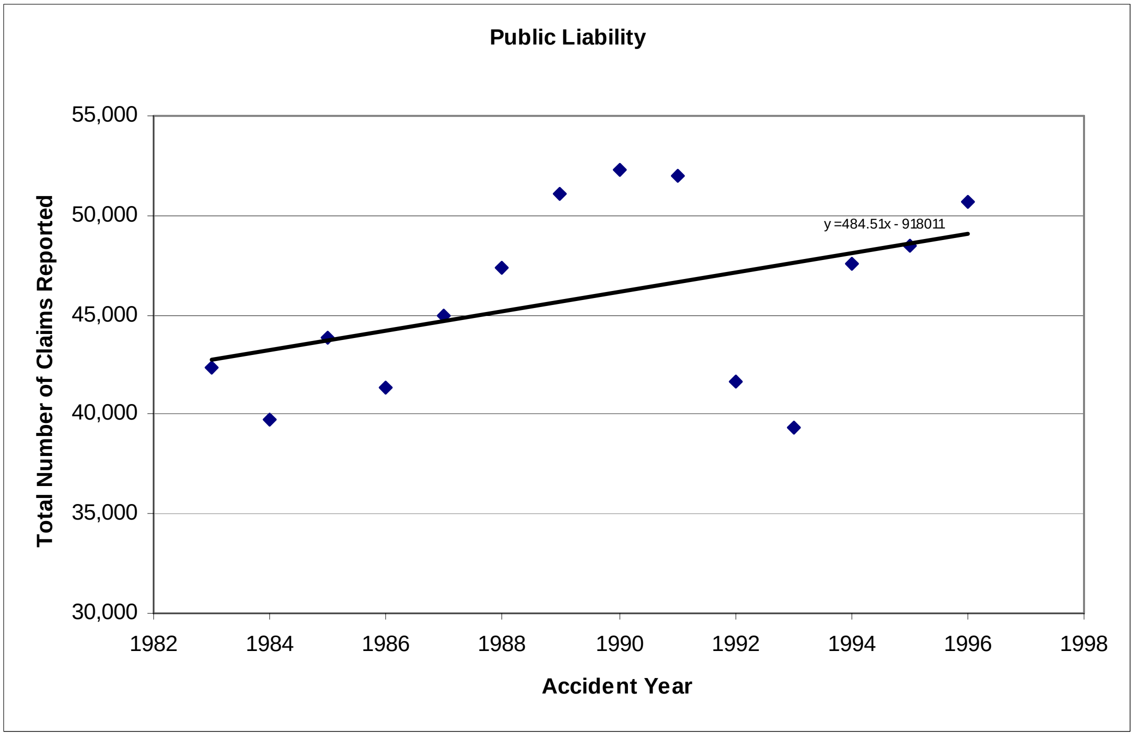


*Figure 4:* Total Number of Claims Reported for Public Liability during 1983 – 1996

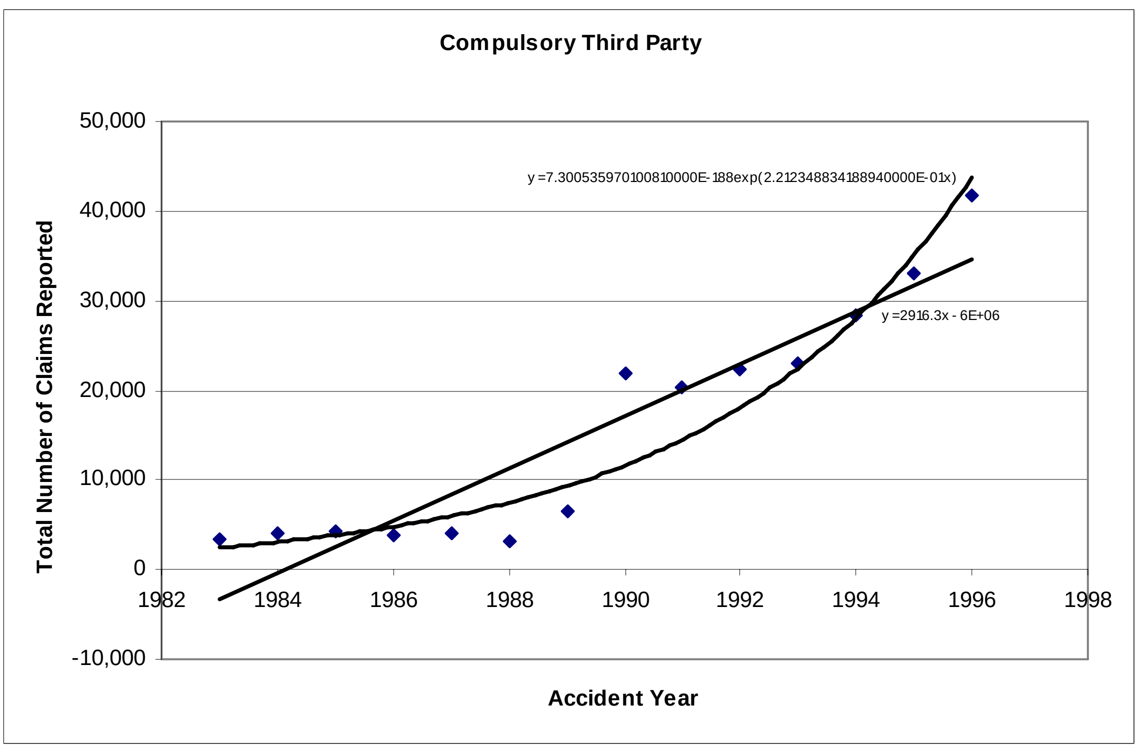


*Figure 5:* Total Number of Claims Reported for CTP during 1983 – 1996


*Figure 6:* Total Number of Claims Reported for Employers' Liability during 1983 – 1996

As previously observed, the trendline for Employers' Liability is the only line with a negative gradient. However, upon closer examination of the data, it is apparent that there is a discontinuity in the figures between 1987 and 1988. The total number of claims reported in 1988 dropped to be 10% of the total number of claims reported in 1987. This pattern is also reflected in the total number of outstanding claims as well as the claim payments.

Further investigation into this peculiarity revealed that around that time, New South Wales introduced the *1987 Worker's Compensation Act.* "The 1987 Act effected the cancellation of all licences granted under the 1926 Act with the exception of the GIO and specialised insurers." (CCH Australia Limited 1999). After the 1987 Act, the Government took over the underwriting of the Employers' Liability policies and the claims data were not published, resulting in the sharp drop between 1987 and 1988. The data are inconsistent and it is no longer viable to proceed any further with the investigation of the Premium Liability for the Employers' Liability line of business as an analysis of such incompatible data would give results with little bearing. The analysis is now restricted to the remaining three lines of business: Motor Vehicle, Public Liability, and Compulsory Third Party.

Significant data discontinuities are also observed in Compulsory Third Party between the years 1989 to 1990. A report analysing the NSW based Compulsory Third Party program (The Motor Accidents Scheme) indicates that there has been no stability in the NSW Compulsory Third Party field, and that this is contributed to by significant demographic and risk rating changes (Standing Committee on Law and Justice 2004). As a result, the data points relating to accident years prior to 1990 are excluded from the analysis. Although this will reduce the accuracy of the estimation, the exclusion is necessary due to the significance of the data discontinuity. We will now examine the behaviour of the claim payments data for this line of business during 1990 to 1996. The new trendline for Compulsory Third Party is displayed below.

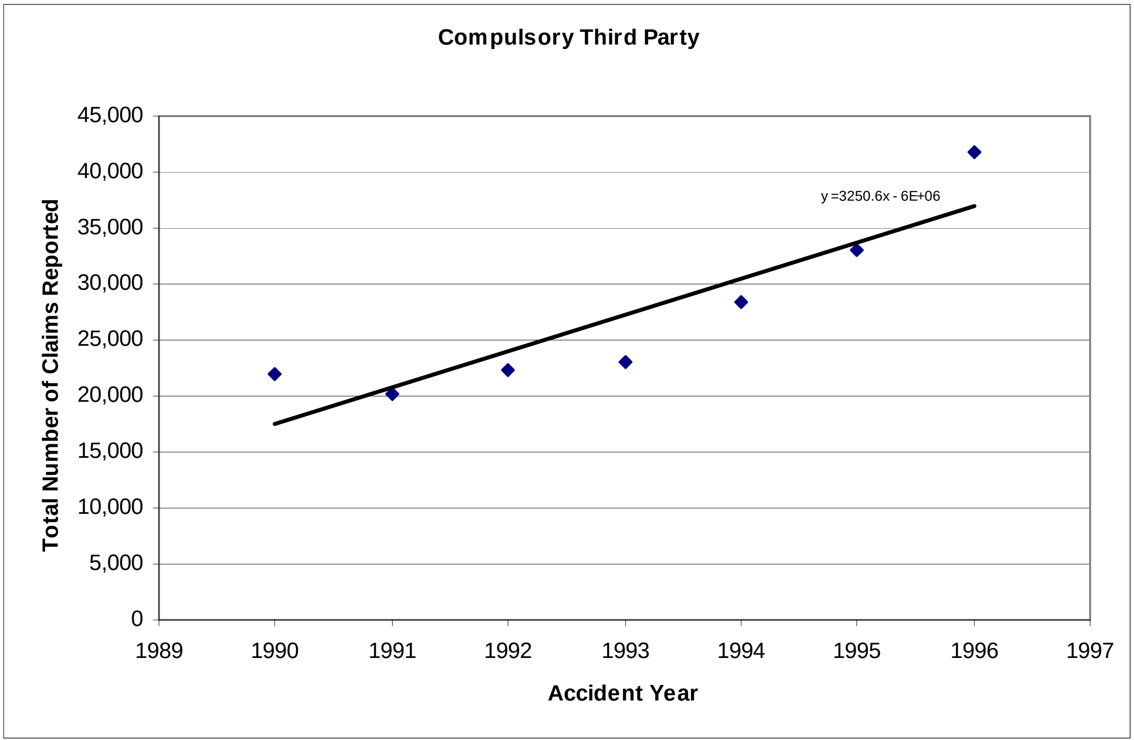


*Figure 7:* Total Number of Claims Reported for CTP during 1990 – 1996

## Trendlines

Public Liability: $Y = 484.5052X - 918011.04$

Compulsory Third Party: $Y = 3250.5919X - 6451185.02$

Motor Vehicle: $Y = 44268.1783X - 87183685.84$

| **Line of Business** | $\mathbf{E}\left(\mathbf{N}^{1997}\right)$ | $\mathbf{V}\left(\mathbf{N}^{1997}\right)$ |
|---|---|---|
| Public Liability | 49,546 | 18,584,613 |
| Compulsory Third Party | 40,247 | 13,769,239 |
| Motor Vehicle | 1,219,866 | 9,026,865,241 |

*Figure 8:* Summary of Total Number of Claims Reported for all three classes

## 5.2 Average Payment per Claim $X^i$

Estimates of the average payment per claim for the fourteen accident years together with the fitted trendlines are displayed in Figures 9 to 11.

The remaining three lines of business are analysed using the methods outlined in Section 4.2.3. The effect of general inflation is removed from these figures by using the Average Weekly Earnings Index. However, all three trendlines still display upward deviations when moving along the accident years. This seems to suggest that the claim payments are also exposed to the effects of superimposed claims inflation.

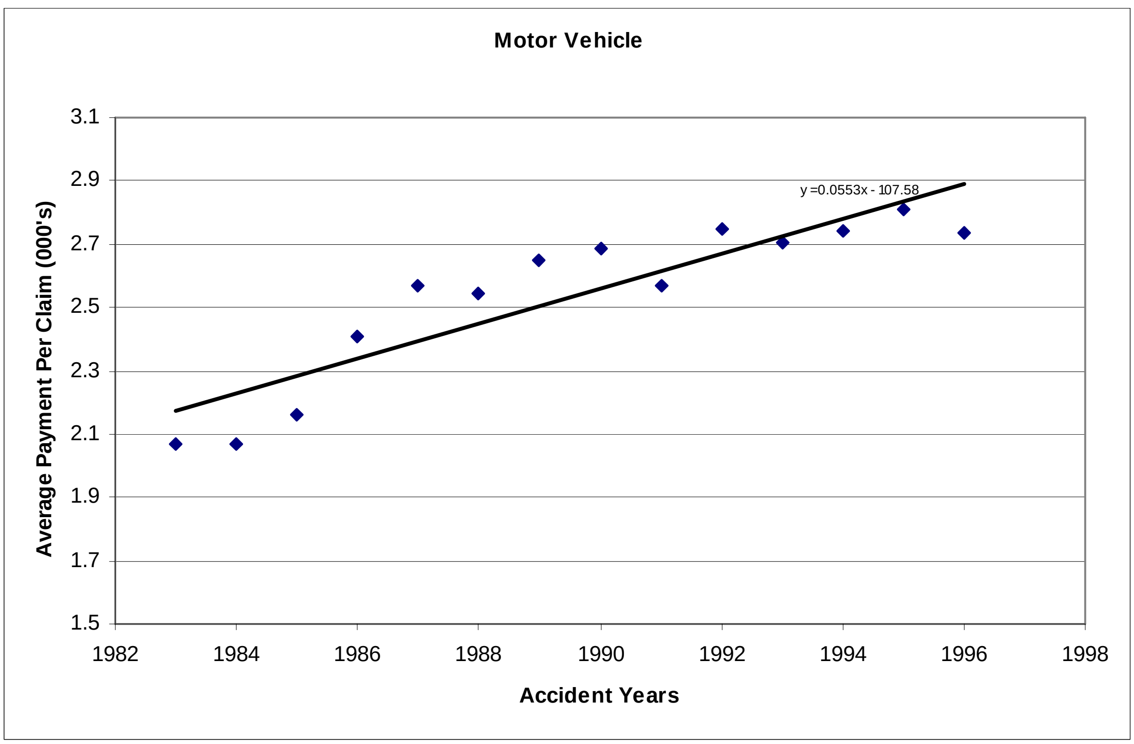


*Figure 9:* Average Claim Payments for Motor Vehicle during 1983 – 1996

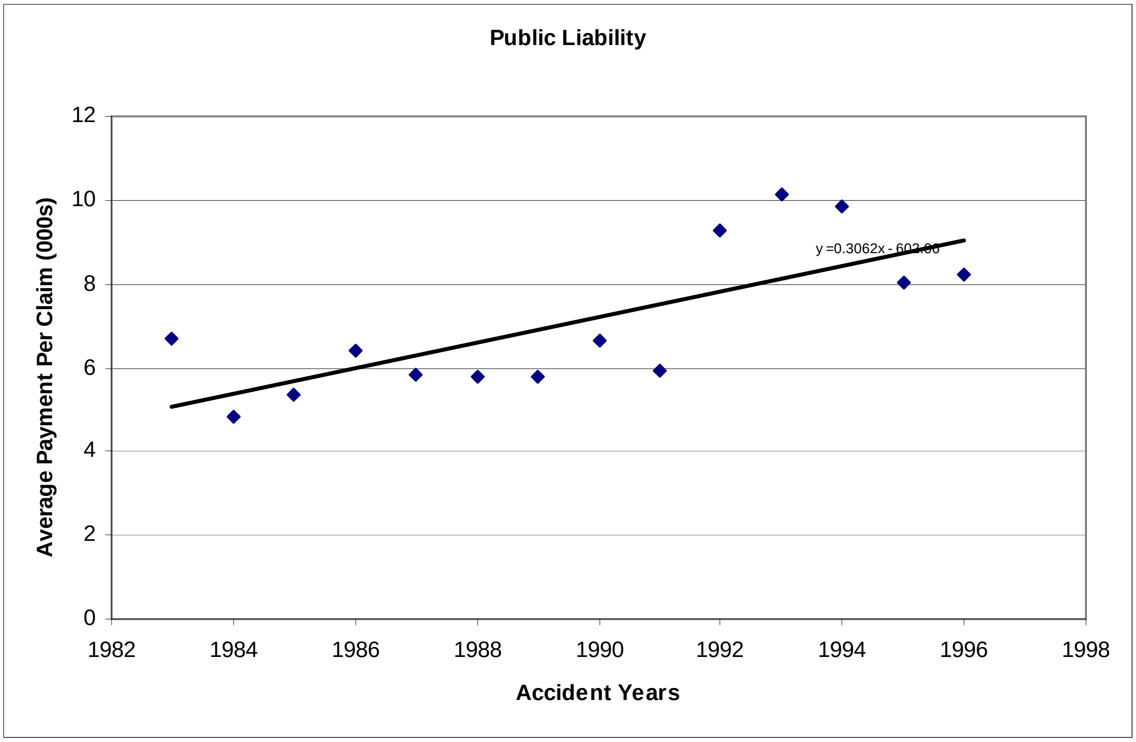


*Figure 10:* Average Claim Payments for Public Liability during 1983 – 1996

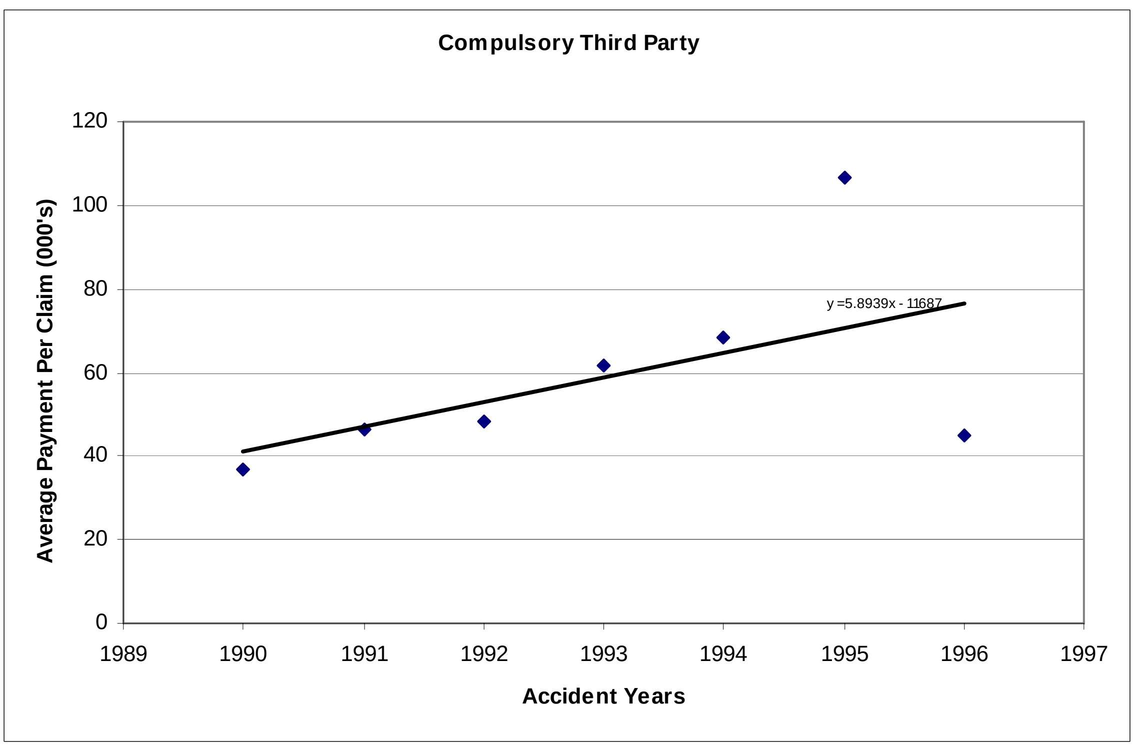


*Figure 11:* Average Claim Payments for CTP during 1983 – 1996

## Trendlines

The value of Y represents the average payment per claim in dollar amounts

Public Liability: $Y = 306.16403X - 602056.70$

Compulsory Third Party: $Y = 5893.8516X - 11687431$

Motor Vehicle: $Y = 55.344785X - 107575.52$

| **Line of Business** | $\mathbf{E}\left(\mathbf{X}^{1997}\right)$ | $\mathbf{V}\left(\mathbf{X}^{1997}\right)$ |
|---|---|---|
| Public Liability | 9,353 | 1,459,041 |
| Compulsory Third Party | 82,590 | 468,771,950 |
| Motor Vehicle | 2,948 | 13,970 |

*Figure 12:* Summary of Average Claim Payments for all three lines of business

## 5.3 Premium Liabilities

$$E\left(S^{1997}\right) = E\left(N^{1997}\right)E\left(X^{1997}\right) \tag{19}$$

$$V\left(S^{1997}\right) = V\left(X^{1997}N^{1997}\right) \tag{20}$$

The use of the LINEST function to fit the trendline implicitly assumes that the random variables of $N^i$ and $X^i$ are normally distributed with the mean equal to the trendline and variance equal to the average deviation from the trendline. These parameters have already been estimated for $N^{1997}$ and $X^{1997}$. From these results, the mean of $S^{1997}$ can be calculated directly from the estimated values of $E\left(N^{1997}\right)$ and $E\left(X^{1997}\right)$.

To calculate the variance of $S^{1997}$, actual values of $N^{1997}$ and $X^{1997}$ can be simulated and multiplied together to produce sample values of $S^{1997}$. This process is repeated to produce ten thousand samples and the variance of the total population can then be calculated. The standard deviation of $S^{1997}$ is shown instead of its variance to allow for direct comparison. The figures are reported in millions of dollars.

| **Line of Business** | $\mathbf{E}\left(S^{1997}\right)$ | $\mathbf{SD}\left(S^{1997}\right)$ |
|---|---|---|
| Public Liability | 463 | 72 |
| Compulsory Third Party | 3,324 | 922 |
| Motor Vehicle | 3,596 | 317 |

*Figure 13:* Summary of the mean and standard deviation for Premium Liabilities

Although $N^{1997}$ and $X^{1997}$ are assumed to be normally distributed in this analysis, it might sometimes be more realistic to assume other distributions, such as using the Poisson distribution for $N^{1997}$ and the lognormal distribution for $X^{1997}$. The selection of the distribution can be based on individual circumstances, and the method described to find the mean and variance of $S^{1997}$ is just as applicable for different distributions of $N^{1997}$ and $X^{1997}$.

## 5.4 Outstanding Claims Liabilities

To calculate the variance of the Outstanding Claims Liability, the run-off factors introduced in Section 4.3 need to be estimated. The $F_i$ values have been computed from the total claim payments data for all three lines of business.

| | $F_{10}$ | $F_9$ | $F_8$ | $F_7$ | $F_6$ | $F_5$ | $F_4$ | $F_3$ | $F_2$ |
|---|---|---|---|---|---|---|---|---|---|
| **PL** | 0.9083 | 0.7556 | 0.6287 | 0.5002 | 0.3846 | 0.2438 | 0.1581 | 0.0923 | 0.0401 |
| **CTP** | 0.9769 | 0.9175 | 0.7955 | 0.6326 | 0.4666 | 0.3264 | 0.2162 | 0.1183 | 0.0468 |
| **MV** | 0.2231 | 0.0270 | 0.0054 | 0.0026 | 0.0015 | 0.0008 | 0.0004 | 0.0003 | 0.0001 |

*Figure 14:* Claim run-off factors

As expected, the Motor Vehicle line of business has a run-off pattern that rapidly diminishes while the long tailed businesses such as Public Liability display a more gradual run-off pattern.

The co-efficient of variation for the Outstanding Claims Liability can be calculated using formula (16) where $CV(S)$ is assumed to be the co-efficient of variation estimated from the Premium Liability. This result is then compared to the co-efficient of variation for the Premium Liability. The difference between the co-efficient of variation, as a result of averaging over independent accident years is displayed in the table below.

| | $\frac{\sqrt{\sum_{i=2}^{10} F_i^2}}{\sum_{i=2}^{10} F_i}$ | $CV\left(P^{i+1}\right)$ (%) | $CV\left(OS^i\right)$ (%) | Increase in Variability $CV\left(P^{i+1}\right) \div CV\left(OS^i\right)$ |
|---|---|---|---|---|
| **PL** | 0.4072 | 15.61 | 6.35 | 2.46 |
| **CTP** | 0.3988 | 27.73 | 11.06 | 2.51 |
| **MV** | 0.8610 | 8.83 | 7.60 | 1.16 |

*Figure 15:* Comparisons between the co-efficient of variation of Premium Liabilities and that of Outstanding Claims Liabilities.

The results clearly show that the averaging effects are much greater for longer tailed businesses such Public Liability and Compulsory Third Party. In other words, the ratio between the co-efficient of variation of the Premium Liability to that of the Outstanding Claims Liability for long tailed liabilities should be larger than the ratio for short tailed risks.

## 5.5 Comments

For the estimation of Premium Liabilities, the co-efficient of variation is 28% for Compulsory Third Party, 16% for Public Liability, and 9% for Motor Vehicle. This result derived from the model implies that the variability for short tailed risks is comparatively smaller than for long tailed risks. This conclusion is both intuitive and consistent with expectations as Motor Vehicle claim payments are capped at the value of the vehicle and this would substantially reduce the variance of the claim payments. However, the value of a human life in Compulsory Third Party claims does not have an upper bound, so the claim payments would be more volatile.

This model is built on the assumption that the lines of business under analysis are both stable and mature, implying that any deviation from the mean is caused solely by the inherent uncertainty. This is not always the case as the future claim payments can be influenced by a number of additional factors. Such aspects to take into consideration are described by Collins and Hu (2003). In such circumstances, the expected value of the future claims liability needs to be adjusted accordingly.

For comparison of the co-efficient of variation between Premium Liabilities and Outstanding Claims Liabilities, the results show that the averaging effect across independent accident years can have a considerable impact on reducing the variability of the Outstanding Claims Liabilities. This reduction is particularly significant in longer tailed claims such as Public Liability where the co-efficient of variation of the Premium Liability is 250% of the Outstanding Claims Liability.

The Risk Capital Factors reflect the inherent uncertainty of the underlying liability and should therefore be proportional to the co-efficient of variation of the future liability. The results suggest that the Premiums Liability Risk Capital Factors required by APRA to calculate the Insurance Risk Capital Charge is inadequate for the more volatile lines of business (refer to Appendix 1). The Premiums Liability Risk Capital Factors set by APRA are 150% of the corresponding Outstanding Claims Liability Risk Capital Factors for *all* lines of business, this constant 50% loading would only be reasonable if the variability of the Premiums Liability exceeds the variability of the Outstanding Claims Liability by the same amount for *all* lines of business. This is not the case as the results show that the co-efficient of variation of the Premium Liabilities exceeds the co-efficient of variation of Outstanding Claims Liability by a much greater amount for the longer tailed risks. While the 50% loading for the Premiums Liability Risk Capital Factors can be applied to the short tailed risks, an increase in this loading would reflect the inherent uncertainty for long tailed risks more accurately.

# 6. LIMITATIONS

A major limitation to the validity of the results is access to relevant and consistent data. As previously mentioned, the data used during the analysis is collected from the Australian Private Sector Industry. Over the time horizon of the data collection, it is possible that sections of business were shifted from the Private Sector to the Public Sector or vice versa. These occurrences distort the data and create problems for the analysis, and if such instances are not identified, then the distortion can be mistaken for systematic fluctuations. Two of such instances that created significant data discontinuities have been discovered and documented (Employers' Liability in NSW and Public Liability).

Data are only available over a fourteen year time horizon. To find the total number of claims reported or the total claim payments for all fourteen accident years, the chain ladder method or a similar reserving method must be applied to estimate the values of the lower triangle. For the later accident years, the projections of future payments are based upon one or two reported figures. If the first few figures are subject to reporting or calculation errors, then this error is filtered through and magnified along the projected figures. As a result, the estimated variance of the total figures will be larger than the actual variance. Although this is a limitation placed upon this analysis, general insurers would be expected to have greater accessibility to historical data, which would provide the actual figures for a number of completed accident years. With more data points, a suitable distribution can also be fitted to $N^i$ and $X^i$.

The assumption that $N^i$ and $X^i$ are normally distributed random variables is a simplified assumption adopted because it is the basis for the LINEST function. Although it is possible to assume more sophisticated distributions, the lack of data will create uncertainty about the model parameters. By employing more complicated distributions, it may simply produce greater estimation errors rather than increase the accuracy of the results.

# 7. FURTHER RESEARCH

This paper only introduced one method for estimating Premium Liabilities using the Australian Private Sector Data. Different methods incorporating altered models could be assumed and their strengths and weaknesses explored. Such methods might include analysis of past loss ratios and making projections into future loss ratios. One might also consider multiplying a claim cost factor by a measure of exposure such as the number of policies underwritten, in which the claim cost factor will need to be estimated by the data.

The relationship between the variability of Premium Liabilities and that of Outstanding Claims Liability is briefly touched upon in this paper. This relationship could be developed more extensively and tested against different sets of data to validate the results.

## 8. CONCLUSION

The rapid advancement of technology has allowed us to build more complicated and realistic models. Although these models can produce results with higher levels of accuracy, they are often data and assumption intensive. If the right assumptions are not employed or unreliable data are used, these models may simply produce more statistical noise. This paper has provided a starting point to Premium Liability modelling by introducing a simple method with relatively few assumptions. The output of the model is consistent with general expectations that the variance of longer tailed risks such as Public Liability and Compulsory Third Party is comparatively larger than the variance of short tailed claims such as Motor Vehicle.

This paper has also highlighted a relationship between the co-efficient of variation for Outstanding Claims Liability and Premium Liability. The results show that the co-efficient of variation of the Premiums Liabilities for long tailed business is inadequately reflected by Premiums Liability Risk Capital Factors and that the 50% loading should be increased. Although the numerical values derived for the co-efficient of variation could have over-estimated the actual value because the model inputs are affected by data and estimation errors, these errors are then compounded through the application of the Chain Ladder method. However, the theoretical framework still holds, the example illustrates the point that the difference in random error between the Outstanding Claims Liability and Premiums Liability is greater for long tailed risks than short tailed risks. This is a result of the averaging or pooling effects across the independent accident years, and plays a more prominent role in long tailed lines of business.

The prediction of future claims liability is highly speculative by nature and this paper has only provided an introduction into the examination of its statistical nature. It is hoped that further research can construct and test more sophisticated models and incorporate further assumptions and parameters. Such analysis will improve our understanding and further our ability to predict and manage the random variation of these liabilities.

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# APPENDIX 1

**Table 1: Direct Insurance**

| **Class of Business** | **Outstanding Claims Risk Capital Factor** | **Premiums Liability Risk Capital Factor** |
|---|---|---|
| Householders<br>Commercial Motor<br>Domestic Motor<br>Travel | 9% | 13.5% |
| Fire and ISR<br>Marine and Aviation<br>Consumer Credit<br>Mortgage<br>Other Accident<br>Other | 11% | 16.5% |
| CTP<br>Public and Product Liability<br>Professional Indemnity<br>Employers' Liability | 15% | 22.5% |

"The Insurance Risk Capital Charge is in response to the risk that the true value of net insurance liabilities is greater than the value determined under GPS 210 *Liability Valuation*. It has two components: a charge in respect of Outstanding Claims Risk and a charge in respect of Premiums Liability Risk. The total Insurance Risk Capital Charge is the sum of the capital charge for each of the two components." (Australian Prudential Regulation Authority 2002(b))

The capital charge for each class of business is calculated by multiplying the net Outstanding Claims Liability or the net Premium Liability by the relevant Outstanding Claims or Premiums Liability Risk Capital Factor.