



POST-CATASTROPHE INSURANCE SUPPLY AND DEMAND:
THEORY AND EVIDENCE

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A thesis submitted in partial fulfilment of the requirements for the Degree of

Doctor of Philosophy in Finance

in the

Department of Economics and Finance

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Declaration

I, MUMO Richard Kitati, hereby declare that this thesis is my own unaided research work. It is being submitted in partial fulfilment of the requirement for the award of Doctor of Philosophy in Finance in the University of Canterbury, Christchurch, New Zealand.

I further declare that this work has never been submitted in part or whole for award of any degree anywhere, and that the thesis is presented with the consent of my senior supervisor, Prof. Richard and co-supervisor, Prof. Glenn. Due acknowledgement has been made to the authors where appropriate.

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Certification

The undersigned certify that they have read and hereby recommend for acceptance by the University of Canterbury a thesis entitled “**POST-CATASTROPHE INSURANCE SUPPLY AND DEMAND: THEORY AND EVIDENCE**” in fulfilment of the requirements for the degree of Doctor of Philosophy in Finance in the Department of Economics and Finance, University of Canterbury, Christchurch, New Zealand.

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Abstract

In September 2010 and February 2011, the Canterbury region experienced devastating earthquakes with an estimated economic cost of over NZ\$40 billion (Parker and Steenkamp, 2012; Timar et al., 2014; Potter et al., 2015). The insurance market played an important role in rebuilding the Canterbury region after the earthquakes. Homeowners, insurance and reinsurance markets and New Zealand government agencies faced a difficult task to manage the rebuild process. From an empirical and theoretic research viewpoint, the Christchurch disaster calls for an assessment of how the insurance market deals with such disasters in the future.

Previous studies have investigated market responses to losses in global catastrophes by focusing on the insurance supply-side. This study investigates both demand-side and supply-side insurance market responses to the Christchurch earthquakes. Despite the fact that New Zealand is prone to seismic activities, there are scant previous studies in the area of earthquake insurance. This study does offer a unique opportunity to examine and document the New Zealand insurance market response to catastrophe risk, providing results critical for understanding market responses after major loss events in general. A review of previous studies shows higher premiums suppress demand, but how higher premiums and a higher probability of risk affect demand is still largely unknown. According to previous studies, the supply of disaster coverage is curtailed unless the market is subsidised, however, there is still unsettled discussion on why demand decreases with time from the previous disaster even when the supply of coverage is subsidised by the government.

Natural disaster risks pose a set of challenges for insurance market players because of substantial ambiguity associated with the probability of such events occurring and high spatial correlation of catastrophe losses. Private insurance market inefficiencies due to high premiums

and spatially concentrated risks calls for government intervention in the provision of natural disaster insurance to avert situations of noninsurance and underinsurance. Political economy considerations make it more likely for government support to be called for if many people are uninsured than if few people are uninsured. However, emergency assistance for property owners after catastrophe events can encourage most property owners to not buy insurance against natural disaster and develop adverse selection behaviour, generating larger future risks for homeowners and governments.

On the demand-side, this study has developed an intertemporal model to examine how demand for insurance changes post-catastrophe, and how to model it theoretically. In this intertemporal model, insurance can be sought in two sequential periods of time, and at the second period, it is known whether or not a loss event happened in period one. The results show that period one demand for insurance increases relative to the standard single period model when the second period is taken into consideration, period two insurance demand is higher post-loss, higher than both the period one demand and the period two demand without a period one loss.

To investigate policyholders experience from the demand-side perspective, a total of 1600 survey questionnaires were administered, and responses from 254 participants received representing a 16 percent response rate. Survey data was gathered from four institutions in Canterbury and is probably not representative of the entire population. The results of the survey show that the change from full replacement value policy to nominated replacement value policy is a key determinant of the direction of change in the level of insurance coverage after the earthquakes. The earthquakes also highlighted the plight of those who were underinsured, prompting policyholders to update their insurance coverage to reflect the estimated cost of rebuilding their property. The survey has added further evidence to the existing literature, such as those who have had a recent experience with disaster loss report increased risk perception if

a similar event happens in future with females reporting a higher risk perception than males. Of the demographic variables, only gender has a relationship with changes in household cover.

On the supply-side, this study has built a risk-based pricing model suitable to generate a competitive premium rate for natural disaster insurance cover. Using illustrative data from the Christchurch Red-zone suburbs, the model generates competitive premium rates for catastrophe risk. When the proposed model incorporates the new RMS high-definition New Zealand Earthquake Model, for example, insurers can find the model useful to identify losses at a granular level so as to calculate the competitive premium.

This study observes that the key to the success of the New Zealand dual insurance system despite the high prevalence of catastrophe losses are; firstly the EQC's flat-rate pricing structure keeps private insurance premiums affordable and very high nationwide homeowner take-up rates of natural disaster insurance. Secondly, private insurers and the EQC have an elaborate reinsurance arrangement in place. By efficiently transferring risk to the reinsurer, the cost of writing primary insurance is considerably reduced ultimately expanding primary insurance capacity and supply of insurance coverage.

Keywords: Catastrophe Risk, Earthquake Commission, Intertemporal Insurance Model, Pareto Model, Actuarial Perspective, Residential Insurance, Natural Disaster, Christchurch Earthquakes.

Contributions of Authors

The first author was responsible for survey design, gathering of data, formative procedures involved in the methodology for data analysis, the data analysis, and preparing the manuscripts for journals' submissions. Associate Professor Richard Watt is the senior supervisor of this thesis; he designed the intertemporal insurance model to investigate how insurance demand would change post-loss and provided numerous guidance and technical advice on how to proceed in each chapter of this thesis. He also, on numerous occasions, reviewed and edited each chapter of this thesis to meet the final version of this thesis. Ass. Prof. Watt is also a co-author of the manuscripts submitted and recently accepted in the *Asia-Pacific Journal of Risk and Insurance* and the paper published in the *Journal of Insurance and Risk Management*. Prof. Glenn Boyle from department of economics and finance, University of Canterbury, is the co-supervisor; he remained a vital guide in reading and reviewing this thesis, and also helped to complete all the PhD milestones requirements as an integral part of this thesis. Prof. Bob Reed and Dr. Andrea Menclova from department of economics and finance, University of Canterbury, provided technical guidance on econometric modelling during the data analysis stage. Dr. Victor Ongoma of Nanjing University of Information Science and Technology in China has been a dedicated key resource person to guide the first author on numerous occasions in the course of this research.

Chapter 8 of this thesis was presented at the American Risk and Insurance Association (ARIA) annual meeting held in Boston, Cambridge, MA on August 7th - 10th, 2016. The chapter was later published in *Journal of Insurance and Risk Management* see, Mumo, R. K., and Watt, R. (2016). The Dual Insurance Model and Its Implications for Insurance Demand and Supply Post-Christchurch Earthquakes in New Zealand. *Insurance and Risk Management*, 83 (3-4), 135-167.

Chapter 6 of the thesis was presented at the 57th New Zealand Association of Economists (NZAE) annual conference held at Auckland University of Technology Auckland June 29 – July 1 2016. The chapter was later published in *Asia-Pacific Journal of Risk and Insurance* see, Mumo, R. & Watt, R. (2017). An Investigation of Residential Insurance Demand-side Reactions after a Natural Catastrophe: The Case of the 2010–11 Christchurch Earthquakes. *Asia-Pacific Journal of Risk and Insurance*, 11(2).

Chapter 5 of the thesis has been submitted for publication in *North American Actuarial Journal*: Mumo, R. & Watt, R. (*revised and resubmitted*). A Risk-Based Pricing Model for Natural Disaster Risk: An Actuarial Perspective for Residential Insurance Cover. *North American Actuarial Journal* - manuscript ID: NAAJ-1541.

Dedication

This thesis is dedicated to the people in my native village of *Kakima, Tulimani* location in *Mbooni*. It's a special feeling to have the thesis completed and I do so with an appreciation of the true admiration and responsibility that such accomplishment brings. I will never forget where I have come from nor the people whose guidance effectively instil self-discipline during my childhood, which founded the path I walk today.

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List of Acronyms and Abbreviations

ACC	Accident Compensation Corporation
ACV	Actual Cash Value
CEA	California Earthquake Authority
CEBR	Centre for Economics and Business Research
CERA	Canterbury Earthquake Recovery Authority
CPI	Consumer Price Index
CRRA	Constant Relative Risk Aversion
DARA	Decreasing Absolute Risk Aversion
EQC	Earthquake Commission
EU	European Union
FEMA	Federal Emergency Management Agency
GDP	Gross Domestic Product
GEJE	Great East Japan Earthquake
G-R	Gutenberg-Richter
GST	Goods and Services Tax
GWP	Gross Written Premium
ICNZ	Insurance Council New Zealand
JER	Japanese Earthquake Reinsurance
LAE	Loss Adjustment Expenses
LMX	London Market Excess
NFIP	National Flood Insurance Program
NDF	Natural Disaster Fund
PML	Probable Maximum Loss
Q-Q	Quantile-Quantile
RCV	Replacement Cost Value
RMS	Risk Management Solutions
TCIP	Turkish Catastrophic Insurance Pool
XOL	Excess-of-loss
ZIP	Zone Improvement Plan

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CHAPTER ONE

1. INTRODUCTION

1.0. Overview

Homeowners, the insurance industry and numerous state agencies were faced with a major difficult task of rebuilding the Canterbury region in the aftermath of the 2010-11 Christchurch earthquakes. One of the biggest challenges was to manage the relationship between all the interested parties of the post-earthquake rebuild period. From an empirical and theoretic point of view, the Canterbury disaster calls for an investigation of the insurance market response and an assessment of how the insurance industry deals with such disasters in the future.

Despite the fact that New Zealand is highly prone to seismic activities, there is scant previous research work in the area of earthquake insurance. This thesis investigates the impact of extreme events of catastrophic nature such as earthquakes and floods, to the residential insurance business class based on the case of the 2010-11 Christchurch earthquakes. The investigations look at the pre- and post-disaster periods to examine how insurance companies and insurance consumers are impacted by catastrophic losses from extreme disasters. The two approaches from the demand and supply perspectives will converge to provide results that are critical for understanding market responses after major loss events. While this is not the first study in the area of natural disasters, it does offer a unique way of understanding the insurance market. Numerous studies that previously looked into natural disaster insurance do not examine both supply and demand side responses in the aftermath of the same disaster within the same period. This is a novel approach to document the impact of the earthquake from both sides of the market which could offer useful information to insured, insurers, government social insurance agencies, scholars and all other interested parties.

The rest of the chapter is organised as follows: Section 1.1 gives the research background, sub-sections 1.1.1 and 1.1.2 discuss the global outlook of natural disasters and insurance for natural disasters and the challenges respectively. Section 1.2 states the research hypotheses. Section 1.3 describes the overall objectives of the study. Section 1.4 justifications of the study. Section 1.5 gives a summary of the thesis outline.

1.1. Research Background

1.1.1. Global Outlook of Natural Disasters

A natural disaster can be defined as an event, or series of events, triggered by the forces of nature resulting in socio-economic losses beyond the capacity of the affected community/geographical area to cope with them. Natural disasters include floods, droughts, heat waves, hurricanes, tornadoes, winter storms, wild fires, gusts, and earthquakes.

In the recent past, concerns about natural disasters, more particularly, earthquakes and floods have attracted a lot of attention from scholars and practitioners. Researchers (Aseervatham et al., 2013, 2014, 2015; Bond et al., 2012; Born and Viscusi, 2006; Browne and Hoyt, 2000) have begun to explore the threats that disasters pose to the society and their implications on the broader insurance markets. Despite the increasing familiarity with the consequences of these natural disasters, losses due to disasters are on an upward trend, both in human and economic terms. Over the last 50 years, the number of reported losses, both insured and uninsured, and their impact on human and economic development have been increasing. The Swiss Re and Munich Re data shows that the rise in insured losses is primarily driven by increasing occurrences of natural catastrophes (McAneney et al., 2016; Michel-Kerjan et al., 2015). A look at the past claims burden due to natural disasters, shows that approximately US\$3 billion per year was paid in the 1970s. This increased to US\$16 billion in the period 1987–2003, and in the years 2004 and 2005 it reached US\$45 billion and US\$78 billion, respectively (Swiss Re, 2015).

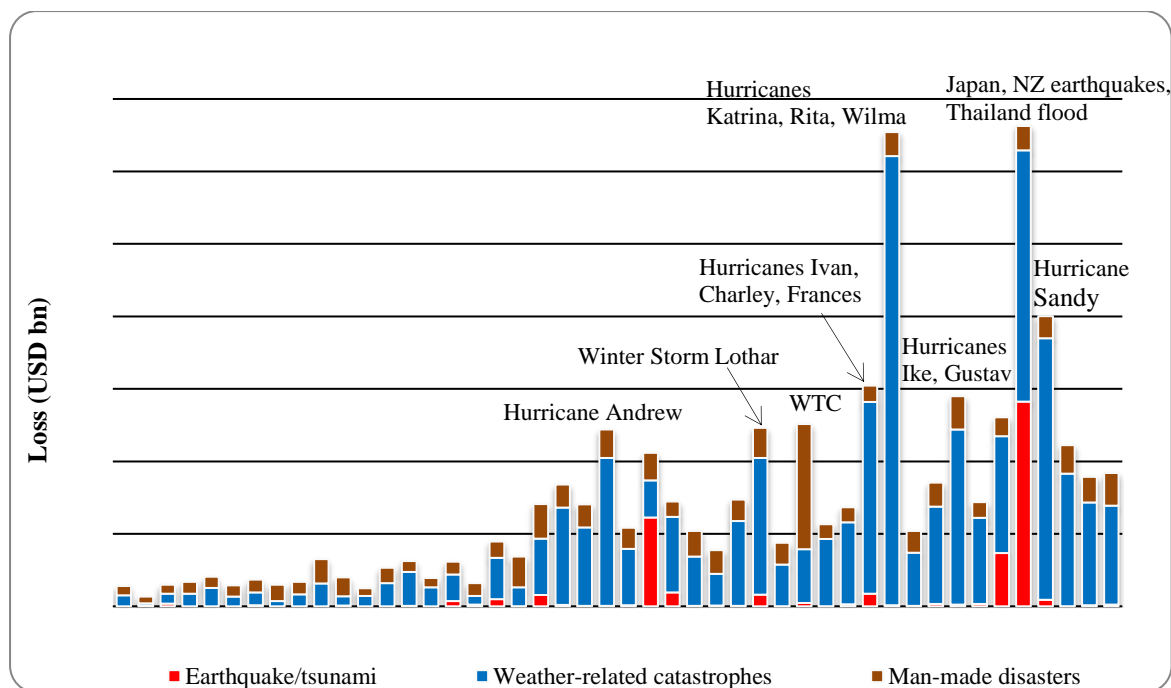


Figure 1-1: Insured Loss (USD bn) by Catastrophic Events

(Data Source: Swiss Re Economic Research and Consulting and Cat Perils)

The upward trend in total economic losses from natural catastrophes over the last four decades with the highest ever catastrophe-related economic losses recorded in 2011 shows the increasing importance for societies to maintain adequate insurance coverage. Table 1-1 shows the top 10 costly insured catastrophic events between the year 1980 and 2015. The peak of catastrophic related cases was in the year 2011 with New Zealand and Japan recording the highest losses from earthquakes followed closely by floods in Thailand. Tornadoes and hurricane related losses in the USA were the costliest disasters during this period.

Similarly, in early 2012, Swiss Re published in the annual sigma report that the number of natural catastrophe events had reached an unprecedented record level of 175 events in 2011 (Kish, 2016; Munish Re, 2015). In the same year, insurers were liable for insured catastrophe losses amounting to US\$116 billion worldwide. This translates to a 142 percent increase relative to losses incurred in the year before.

Table 1-1: Top 10 Costliest Global Insured Catastrophe Events for the Period 1980-2015

Location	Event	Year	Insured Loss (2014 \$M (USD))	Share of Losses Insured
USA	Hurricane Katrina	2005	75,884	0.50
Japan	Earthquake/Tsunami	2011	42,400	0.19
USA	Hurricane Sandy	2012	30,680	0.43
USA	Hurricane Andrew	1992	28,900	0.64
New Zealand	Canterbury Earthquake	2011	25,476	0.78
USA	Earthquake	1994	24,633	0.35
USA	Hurricane Ike	2008	20,535	0.49
USA	Hurricane Ivan	2004	17,388	0.60
Thailand	Flooding	2011	16,960	0.37
USA	Hurricane Wilma	2005	15,250	0.57

(Data Source: Munich Re, 2015)

The total economic catastrophic losses to society due to disasters both insured and uninsured reached an estimated US\$370 billion by the end of 2011. The gap between the total economic loss and the total insured liability amounting to US\$254 billion in 2011 is an indication that lack of sufficient insurance coverage is a global problem. This continues to leave the majority of individuals and organisations financially vulnerable to catastrophic events. This economic damage is mostly shouldered by corporations, government agencies, relief organisations, and ultimately by individuals, which is an indication of a widespread lack of insurance protection against consequences of natural disasters. It must not be lost that the biggest percentage of the insured catastrophic loss comes from the developed nations. Therefore the reported insured losses are only the tip of the iceberg since there is virtually no disaster insurance coverage in most of the developing countries that are very vulnerable to effects of natural disasters. This compounds the global catastrophic problems at a time when the gap between insured and uninsured is increasingly widening Figure 1-2, while the frequency of disasters is on an upward trend.

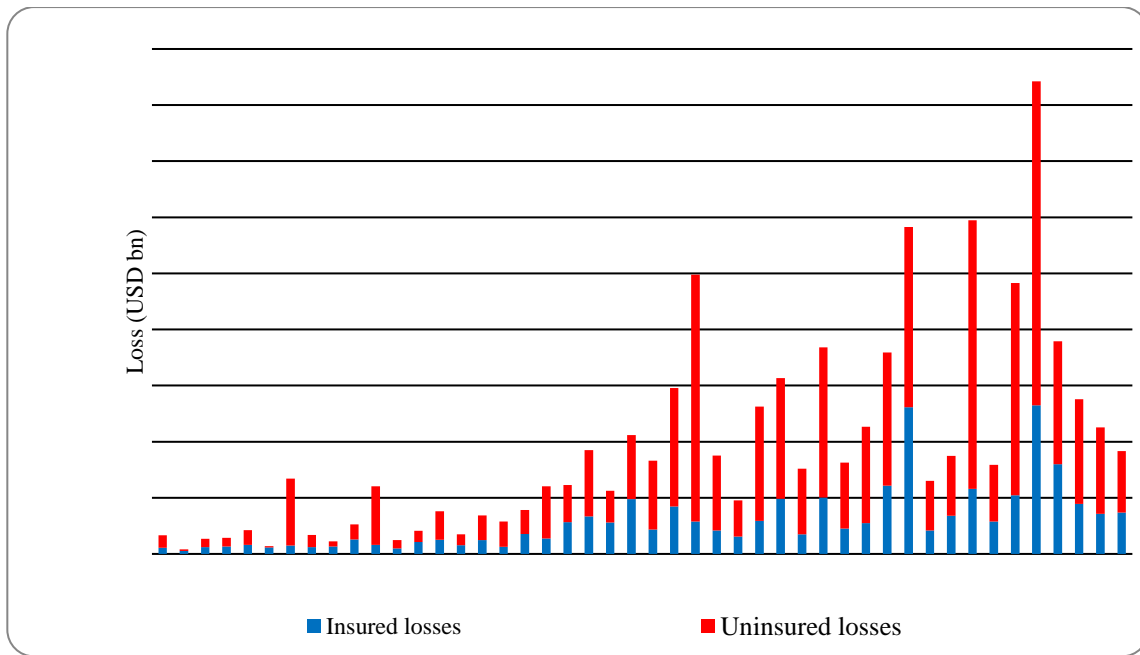


Figure 1-2: Global Catastrophe Losses, Insured (Blue) and Uninsured (Red), for the Period 1970-2015

(Data Source: Swiss Re Economic Research and Consulting and Cat Perils)

However, a recent study by Born and Klimaszewski-Blettner (2013) noted that the increases in catastrophes should not be the subject of much debate, unlike the usefulness of models to predict catastrophic events and the appropriateness of the corresponding models to estimate losses following natural disasters. Thus, the importance of studies on the impact of natural disasters and insured losses upon the global catastrophe market, and more specifically upon the world's insurance and reinsurance market, cannot be overstated. Justifiably, a number of recent researches on catastrophe risk have focused on the topics of industry capacity, reinsurance, mitigation and securitisation (Cummins and Trainar, 2009; Powell and Sommer, 2007; Rode et al., 2000). Similarly, a number of stakeholders: insurers, regulators, and consumers, have kept an unwavering focus on natural disasters and catastrophe risk management issues enhancing the understanding and co-operation between private insurers, state agencies and insurance demanders in seeking insurance coverage.

1.1.2. Insurance for Natural Disasters and the Challenges

Insurance is one of the widely recognised risk transfer tools for ex-ante management of natural disaster risks (Dacy and Kunreuther, 1969). However, despite the existing loss estimation models, insurance of natural catastrophes is somewhat unique compared to the more well-known general insurance or life insurance. The insurability of natural disasters is impeded by difficulties in precisely predicting loss probabilities, compared to high-frequency, low-severity risks such as automobile accidents. A major limitation on the availability of coverage in many countries is mainly the result of insurability constraints, particularly the independence between insured portfolios with the consequences of high accumulation risk and serious loss potential for insurers. According to Hogarth and Kunreuther (1989), the willingness of insurers to provide coverage against natural catastrophic threats is affected by a host of ambiguity issues. In addition to their nature as low-frequency, high-severity, and strongly dependent perils, increased construction activity in extremely high-risk areas, climate change, and global warming complicate the insurability of these risks for underwriters. Natural disaster events often result in large unexpected property losses persuading insurers to take various actions to stabilise their underwriting performance. Some of the immediate remedies for maintaining financial stability and viability might include a reassessment of the portfolio of risks undertaken by the insurer and a re-evaluation of alternative measures to manage them. Perhaps, most post-catastrophe reassessments would entail changing the underwriting risks and rating factors. This results in changes in premiums; changes in coverage levels, implementation of new incentives for policyholders to mitigate losses, changes in the terms and conditions of reinsurance arrangements, complete exits from some catastrophic markets, and perhaps entries into others. It may also encourage the consideration of alternative forms of risk management.

The catastrophes experienced in the last few decades have raised public policy awareness and spurred debate about the appropriate partnership between public and private insurance markets

in addressing natural disaster exposures. Around the world, these debates include the consideration of the proper role for government intervention. Consequently, policy groups and academic researchers have proposed guiding principles for the development of this role. There are now a number of countries with state-sponsored national/government programs for natural catastrophes, including New Zealand, Turkey, France, Japan, Spain, Switzerland, Taiwan, Australia and some states in the USA, which demonstrates that government involvement in insurance is essential (Castellano, 2010). In the USA for example, such principles generally recognise the benefits of encouraging private markets to provide coverage while in New Zealand the government appreciates the extreme exposure to natural disasters to which citizens are exposed, making risk-based private insurance premiums very expensive. The need for state regulatory intervention in the private property insurance market hinges on the ability of private insurers to adapt to changes in the risks they choose to bear, and consequently to meet the demand for coverage. Conversely, the ability of private insurers to adapt to changes in the underlying risk exposure is affected by the regulatory regimes in which they operate. In most of the countries prone to natural disasters, there is a range of proposals for successful strategies for managing catastrophic risks, including the appropriate role of both the private sector and government and the feasibility of capital market solutions. There is a need to fully understand the impact of existing regulatory and legal regimes on the dynamics of the market due to the increasing catastrophic exposures.

This work looks at natural disaster insurance in New Zealand. The study focuses on New Zealand because of its susceptibility to high magnitude earthquakes and the elaborate unique private-government insurance mechanism for residential and contents coverage against the effects of earthquakes. A successful study of the New Zealand insurance market will open-up the unique features that make New Zealand one of the countries with the highest percentages of homeownership, with insurance coverage globally at above 90 percent (Brown et al., 2016;

McAneney et al., 2016). This study will similarly contribute to the growing scholarly interest in natural disasters and it will propose measures to help in alleviating the catastrophic losses associated with underinsurance or total uninsured. This is the first research that uses both theory and empirical data to demonstrate the market reaction post-loss and proposes the necessary interventions.

1.2. Research Hypotheses

There is sufficient empirical evidence to confirm that the reason why the private insurance industry has been reluctant to cover a number of natural hazards is the ambiguity associated with either the probability of specific events occurring and/or the magnitude of the potential consequences (Kunreuther and Hogarth, 1990, 1992; Kunreuther et al., 1995). Insurers may lack the information needed to estimate loss probabilities and thus to accurately price disaster insurance policies. If there is considerable ambiguity or uncertainty associated with the risk, insurers may wish to charge a much higher premium than if they had more precise estimates of the risk (Kunreuther et al., 1995). Moreover, if the capacity of the insurance industry is reduced due to recent large loss events, then premiums may rise due to the immediate shortage in supply which is hypothesised to normalise after a short period.

This study is based on the hypothesis that, insurance and reinsurance markets are increasingly facing challenges to offer natural disaster insurance coverage because of the substantial ambiguity associated with the probability of such events occurring and the insurers' losses are potentially high and often spatially correlated. Premium rates of such events would be relatively higher than the expected loss. The insurer has to provide a large amount of capital in case of catastrophic events. This is hypothesised to lower insurance demand since it is not optimal for the policyholders to purchase insurance cover at a very high premium. The private insurance markets would, therefore, find it uncompetitive to offer coverage for an extreme catastrophe exposure. To avoid the insurance market inefficiency due to extremely high

premiums and spatially concentrated risk, government intervention in the provision of natural disaster insurance is of absolute necessity which in the end averts situations of noninsurance and underinsurance.

1.3. Objectives of the Study

The overall objective of the study is to understand the challenges faced by insurers in providing coverage for natural disasters, in the context of the aftermath of Canterbury quakes in New Zealand. The specific objectives of the study are:

- (i.) To offer a comprehensive survey of the existing literature on the insurance reaction in the aftermath of major catastrophes.
- (ii.) To develop and simulate a theoretic intertemporal insurance model that examines the demand for insurance.
- (iii.) To assess the optimal supply and demand for natural disaster insurance coverage for homeowners.
- (iv.) To examine the aftermath effects and reactions of the demand-side aspect of residential property insurance coverage.
- (v.) To examine the aftermath effects and reactions of supply-side aspect of residential property insurance coverage.
- (vi.) To present a pragmatic premium pricing model to price natural disaster insurance while incorporating New Zealand's unique residential insurance market characteristics.

In the end then, this dissertation generally aims to undertake a theoretic and an empirical comprehensive analysis to examine if indeed catastrophic events affect the insurance industry with major impacts on pricing and if so, whether new post-earthquake pricing structures affect insurance uptake and disaster preparedness. Further, an important question that is more precise to the study's objectives is whether natural catastrophes directly lead to changes in premiums, changes in risk perception, and changes in demand and in supply. If so, what mechanisms of

supply and demand reactions comprise these effects and the necessary natural disaster mitigation measures to be put in place?

With the above research objectives, it must be noted that residential home insurance in New Zealand enjoys an insurance penetration of about 98 percent for fire and general cover. This implies that 98 percent of homes automatically have natural disaster insurance cover provided by the Earthquake Commission (EQC). Opting out of catastrophe cover above the EQC sub-limit does not occur. But competitive insurance market identification of risk, appetite for risk and pricing for risk are matters that each insurer will assess across all their lines of business so they can operate as competitively as possible. Thus it is anticipated that some of the supply-side and demand-side signals may not always be linear. However, in theory it is expected that the price of an insurance contract corresponds to the underlying probability of a loss event and the exposed value, as well as a measure of risk aversion, plus a premium loading that comprises operational costs and the cost of capital amongst other overheads.

1.4. Justification of the Study

Evidence shows that individuals have difficulties with assessing probabilities associated with low-probability but high-impact risks with which individuals and organisations have few experiences, such as natural disasters (Kunreuther et al., 2001). This translates into poor decision making with respect to natural disaster insurance purchases (Kunreuther et al., 2013). This dissertation provides an extensive review of existing studies on the post-catastrophe insurance reaction with the aim of establishing concise results on how the insurance market, in general, reacts to extreme events of a catastrophic nature. The research extends the current literature on natural disaster insurance deducing both theoretical and empirical reactions of insurance markets post-catastrophe. This literature review on previous studies and the current research findings will be a major contribution to New Zealand scholarly work, from the current unclear, or lack of, local literature to explain how the local insurance industry is affected by

disasters. This is the first research that uses both theory and empirical data to demonstrate the insurance industry's reaction pre- and post- extreme losses and proposes the indispensable intervention measures in terms of wider insurance coverage. This study will similarly be an invaluable contribution to the growing scholarly interest in natural disasters and proposes measures to help in alleviating the catastrophic losses associated with underinsurance and/or un-insurance.

In a broader perspective then, our research will contribute to a better understanding of post-catastrophe insurance reactions which would efficiently help address insurance consumer needs, improve insurance underwriting capacity to provide adequate and affordable insurance coverage and improve responsiveness in the occurrence of a major catastrophic event in the future. In the end, results from this dissertation provide better understanding and co-operation between private insurers companies, state agencies and insurance consumers and could be a base for suggestions on how to change inefficient contract arrangements and developing alternative financial and policy instruments that will seek to address future challenges and understanding of disaster insurance by all interested parties.

The research results, if widely disseminated, will also provide a key to guiding other disaster-prone regions in designing resilient disaster insurance mechanisms and hence contribute to remedying the current global underinsurance in major disaster-prone territories.

The intertemporal insurance model used in the theoretical simulations is a completely new extension and approach to the standard model of the demand for insurance which is based on a single period. The model generates results that can be compared to, and contrasted with, those of the standard environment. Above all, this model is a novel approach to studying the effects of: changes in size of first period's loss, increases in risk aversion, increases in the premium, and increases in the perceived probability of loss. In particular, then, the model is a natural theoretical way to establish how the demand for insurance is affected by the size of the loss

suffered in the previous period (that is, the post-catastrophe insurance demand effects). Future studies could extend this model by examining multiple periods with an identical (and different) insurable risk in each period; and identical (and different) insurance supply characteristics in each period.

The comprehensive survey on insurance demand offers a unique investigation of the actual experience of insurance consumers in a market with very high insurance penetration. This by itself is the first survey of its kind to empirically examine consumer reaction post-disaster and compare the findings with those of the proposed intertemporal model of insurance. There are ranging opinions about the implications of sum insured to the insurance market more so to the insured. Whilst this survey did measure the voluntarily changes in the level of coverage post- quakes, the possible introduction of a voluntary deductible by the policyholder due to this policy modification remains unexplored. Future research could seek to investigate the level of voluntary deductible that the policyholder is willing to bear when given an option to nominate a sum insured for their property and/or a possibility of under (over)-insurance. The question of whether such a measure introduces moral hazard or adverse selection could be similarly explored in the future.

Lastly, a look into the existing insurance market arrangement in New Zealand homeowners' coverage reveals that there are complexities and challenges posed by the integration of compulsory EQC cover to the primary underwriting of natural disaster under the fire and general insurance risks. This research introduces an actuarial pricing framework to provide a structure with which to examine the complexity of natural disaster risk pricing and, as such, it offers several opportunities for empirical testing as well as future extensions and improvements.

1.5. Thesis Outline

This thesis consists of nine chapters. The chapters can be grouped into three parts. The first part consists of three chapters that present a general introduction, literature and methodology of the thesis. The second part gives five consistent, but stand-alone chapters that examine and model both demand-side and supply-side of insurance market in the aftermath of a natural disaster. The third and final part presents the last chapter of this thesis that provides a summary, conclusions and recommendations of the study. The thesis structure is outlined as follows:

Chapter 1 - Introduction. This first chapter of the study gives an overview of the research to provide a brief opening preamble the dissertation and the problems that inspired this study. The rest of the chapter is organised as follows: Section 1.1 gives the research background, with sub-sections 1.1.1 and 1.1.2 discussing the global outlook of natural disasters and insurance for natural disasters and the challenges respectively. Section 1.2 states the research hypotheses. Section 1.3 describes the overall objectives of the study. Section 1.4 gives the justification for the study. Section 1.5 gives a summary of the thesis outline.

Chapter 2 - Literature review. This chapter looks at previous studies and identifies the research gaps that exist in the provision of insurance to natural disasters, and in how demand and supply for insurance respond to extreme events. This literature review is built on the pioneering work on the economics of insurance, incorporating the recent empirical works which take a novel approach to understanding the disaster-insurance relationship.

The chapter is organised as follows: Section 2.0 gives a brief introduction and objectives of this study. Section 2.1 presents the background of pioneering work on optimal insurance. Section 2.2 looks at relevant studies on the impact of catastrophes on the supply-side of the insurance industry. Section 2.3 discusses the studies investigating the reactions in terms of demand-side impacts from catastrophes. Section 2.4 presents a review of supply-side reactions

post-catastrophe: indirect effects on insurers' profitability and market valuation. Section 2.5 presents a summary of the key findings from the previous studies.

Chapter 3 - Research methodology and design. This chapter describes the research methodology and data set used in this study. On methods, this chapter uses both empirical and theoretical models to demonstrate the implication of catastrophes on the insurance market from both the supply and the demand sides. Section 3.0 gives a brief introduction to the chapter. Section 3.1 outline the research strategy used in the supply-side. Two chapters, chapter seven and chapter eight, of this work examine the supply-side of insurance market in the aftermath of a major natural disaster. Sub-section 3.1.1 gives the theory methodology while sub-section 3.1.2 gives the empirical methodology. Sub-sections 3.1.2.1 and 3.1.2.1 describe the data source and data analysis respectively. Section 3.2 presents the research strategy used in the demand-side analysis. Similarly, chapter five and chapter six, of this work examine the demand-side of insurance market in the aftermath of a major natural disaster. Sub-section 3.2.1 gives the theory methodology while sub-section 3.2.2 gives the empirical methodology. Sub-sections 3.2.2.1- 3.2.2.6 present data source, pilot study, questionnaire design and coding, conception and execution of the survey and ethical consideration, data analysis, and some survey limitations respectively. Section 3.3 gives the conclusions.

Chapter 4 - An empirical analysis of general insurability of natural disasters. This chapter provides a comprehensive empirical analysis of the challenges faced in providing insurance coverage for natural disaster risks. The main objective of this chapter is to present a coherent discussion of the global challenge faced by private insurance market to insure catastrophe risk and the possible solution to address these challenges. The chapter is organised as follows: Section 4.0 gives a brief introduction and objective of this chapter. Section 4.1 describes the challenges faced in insuring natural disasters. Section 4.2 presents a probabilistic catastrophe

loss model for natural disasters. This is an earthquake model is used to reasonably determine the probability of losses occurring and likely severity when disastrous earthquake event strike. Section 4.3 demonstrates the need for government involvement in the provision of natural disaster insurance coverage. Sub-sections 4.3.1 - 4.3.4 present a discussion of important government-sponsored natural disaster schemes worldwide. Section 4.4 gives the discussion and conclusions of the study.

Chapter 5 - Optimal insurance demand based on an intertemporal model. This chapter presents a basic theoretical model that examines insurance demand post-loss based on an intertemporal approach. The chapter gives an in-depth analysis and discussion on the performance of the proposed insurance model. The chapter is organised as follows: Section 5.0 gives a brief introduction and objective of this chapter. Section 5.1 presents a review and discussion of the previous insurance demand models and where the present study stands. Section 5.2 provides an introduction to the theory on intertemporal insurance demand. This section also discusses the underlying research question in this chapter: That is, how demand for insurance changes post-catastrophe and how to model it theoretically. Section 5.3 presents both analytical and numerical illustrations of the proposed insurance model. Sub-section 5.3.1 gives the analytical framework and the properties of the intertemporal model. Sub-section 5.3.2 presents an illustrative example of intertemporal modelling using hypothetical datasets. Section 5.4 gives a discussion of several findings that can be drawn from the simulation results and conclusions.

Chapter 6 - An investigation of residential insurance demand-side reactions after a natural catastrophe: the case of 2010-11 Christchurch earthquakes. This chapter gives an empirical analysis of the post-Christchurch earthquakes insurance reactions using survey data. The chapter illustrates and explains how the insurance market reacted after the earthquakes focusing on the demand-side aspect of residential property insurance coverage. The chapter is organised

as follows: Section 6.0 gives a brief introduction and a comprehensive review of the previous studies on post-catastrophe market responses. Section 6.1 presents the hypothesis and research question studied in this chapter. Section 6.2 presents data and methods used in this study. Sub-section 6.2.1 describes the data sources and data collection techniques used in the study. Sub-section 6.2.2 presents a detailed profile of the survey respondents. Sub-section 6.2.3 describes the data analysis process use in the analysis of the survey questionnaire. Section 6.3 presents the main results and discussions. Simple descriptive results to illustrate what happened after the earthquakes are presented in sub-section 6.3.1; while some simple statistical analysis results are presented in sub-section 6.3.2. Section 6.4 gives the conclusions and recommendations of the study.

Chapter 7 - A risk-based pricing model for natural disaster risk: an actuarial perspective for residential insurance cover. The objective of this chapter is to present a pragmatic approach that can be used in the rate-making of fire and general cover for residential property with natural disaster risk as a rider. This is an actuarial risk-based pricing perspective that takes into consideration the key features of New Zealand natural disaster insurance as provided by the Earthquake Commission (EQC). The chapter is organised as follows: Section 7.0 gives a brief introduction and objective of this chapter. Section 7.1 introduces the challenges faced in the provision of insurance for natural disaster risks and how the New Zealand insurance market copes with these challenges. Section 7.2 describes the current paradigm in natural disaster insurance pricing and the opportunities provided by the proposed pricing model. Section 7.3 presents the model's framework. This section also gives a discussion of the actuary's role in insurance pricing and demonstrates how the model fits in New Zealand's residential insurance coverage using an empirical claims data from earthquakes disasters. Section 7.4 gives the conclusions and recommendations.

Chapter 8 - The dual insurance model and its implications for insurance demand and supply post-Christchurch earthquakes in New Zealand. This chapter looks at the empirical implication of the earthquake for the insurance market by doing an empirical analysis of post-Christchurch earthquakes insurance reactions. The chapter is organised as follows: Section 8.0 gives an introduction and objective of this chapter. Section 8.1 gives an introductory background and economic impact of the 2010-11 Christchurch earthquakes. Section 8.2 gives a broad discussion of natural disaster insurance. Sub-section 8.2.1 discusses the need for government participation in natural disaster insurance. Subsection 8.2.2 discusses the New Zealand natural disaster insurance through the Earthquake Commission and subsection 8.2.3 gives a description of some natural disaster insurance programs worldwide with government involvement. Section 8.3 gives a description of reinsurance of the dual insurance model framework in New Zealand. Section 8.4 presents results for various empirical analyses of New Zealand insurance industry reaction post-Christchurch earthquakes. Section 8.5 gives the conclusions

Chapter 9 - Summary, conclusions and recommendations. A brief introduction to this final chapter of the complete thesis is given in section 9.0. The rest of the chapter is organised as follows: Section 9.1 outlines the summary and conclusions of this research. Section 9.2 presents the contributions and significance of the study. Finally, section 9.3 presents the recommendations and discusses the key policy implications of the study.

CHAPTER TWO

2. LITERATURE REVIEW

2.0. Introduction

This chapter looks at previous studies and identifies the research gaps that exist in the provision of insurance to natural disasters, and in how demand and supply for insurance respond to extreme events. There is a substantial literature investigating how insurance companies respond to losses in the aftermath of catastrophes globally, but many of these previous studies concentrate on the insurance supply-side reaction. This literature review is built on the pioneering work on the economics of insurance, incorporating the recent empirical works which take a novel approach to understanding the disaster-insurance relationship.

The rest of the chapter is organised as follows: Section 2.1 presents the background of pioneering work on optimal insurance. Section 2.2 looks at relevant studies on the impact of catastrophes on the supply-side of the insurance industry. Section 2.3 discusses the studies investigating the reactions in terms of demand-side impacts from catastrophes. Section 2.4 presents a review of supply-side reactions in the post-catastrophe: indirect effects on insurers' profitability and market valuation. Section 2.5 presents a summary of the key findings from the previous studies.

2.1. Background of Pioneering Work on Optimal Insurance

A number of works on the economic theory of insurance (Arrow, 1960, 1963, 1970; Borch, 1960, 1962; Mossin, 1968; Smith, 1968) provide a theoretical foundation for the analysis of

the strategic behaviour of insurers. Borch (1960) proved that any Pareto optimal set of treaties¹ is equivalent to a pool arrangement. Significant contributions to the theory of optimal insurance by developing necessary and sufficient conditions for Pareto optimal exchanges in risk pooling arrangements were made by Borch (1962). The study showed how risk aversion affects the optimal coverage of participants in the pool. In Borch's analysis, however, insurance is costless, and there are no constraints imposed on the feasible insurance policy. Since this pioneering work, a lot of work has been done on understanding insurance contracts and the necessary constraints on insurance policies. Regarding risk-shifting, Arrow (1960, 1963) discusses three of the main reasons that risk shifting is limited: moral hazard, adverse selection, and transaction costs. Arrow (1963) showed that in the absence of moral hazard, full insurance above a deductible is optimal when the premium contains a fixed- percentage security loading². He also proved that risk aversion on the part of the insurer is another explanation for coinsurance. Arrow (1965) emphasised on the problem of moral hazard and suggested that coinsurance arrangements in insurance contracts can be explained by this information problem. His analysis presents a framework that explains the role of different institutional arrangements for risk-shifting such as insurance markets, stock markets, implicit contracts, cost-plus contracts, and futures markets. All of these institutions transfer risk to parties with a comparative advantage in risk bearing. In the usual insurance mechanism, risk averse individuals confronted with risk are willing to pay a fixed price to a less risk averse organisation, in exchange for the latter undertaking the risk.

Mossin (1968) looked into the problems concerned with rational behaviour in buying insurance coverage against given risks. In particular, the Mossin study directs attention to the wealth

¹ A treaty is merely an agreement in between two or more insurance companies whereby one (direct insurer) agrees to cede and the other or others (reinsurer) agree to accept reinsurance business as per provisions specified in the agreement.

² Fixed value charged in excess of premium over the actuarial value.

effect on the propensity to take insurance coverage. It is shown that this effect is negative if the individual's utility function displays risk aversion that decreases with wealth (decreasing absolute risk aversion, or DARA). In more general terms, the study noted that if an individual has DARA, he would assume more risk relative to wealth.

Smith (1968) used the analogy that the problem of optimal insurance coverage is formally similar to the problem of optimal inventory stock age under uncertainty. In his work, formalisation of the household's insurance purchasing decision is modelled in an expected utility maximisation framework. The model suggests that given an actuarially fair premium, the homeowners would purchase an amount of insurance coverage that fully protects against the potential loss. This is a very good observation, and as such, it helps in this research to unveil how homeowners' respond to insurance demand in the aftermath of a catastrophe. Furthermore, if the probability of total loss is less than the insurance price per-dollar of coverage, then partial insurance coverage is optimal for the household. This is the same as saying that if the premium is actuarially unfavourable then it will never be optimal to take full coverage under Mossin (1968). Due to the reputed government subsidy in natural disaster insurance rates, it seems likely that the marginal insurance premium is less than the probability of total loss. At least; at this stage there is not sufficient literature to suggest to the contrary.

More closely related to the present thesis, Smith (1968) also looked into the standard deductible model of the demand for property insurance by individuals. Smith implicitly assumes that individuals are able to estimate the probabilities related to all possible and anticipated loss outcomes. In Smith's analysis, factors which are key determinants of the demand for insurance include wealth, the probability of loss, the price of insurance and the ultimate value of the property exposed to risk, as well as the individual's risk aversion. The present research appreciates Smith's key insurance demand determinants and seeks to essentially incorporate

them into both the intertemporal theoretical model and the research survey questionnaire. More importantly, the probability of loss parameter in Smith's model is assumed to be known to both the insured and insurers. This is a fundamental assumption that is frequently made to model the demand for insurance, and this study retains the assumption. All these pioneering works have been further enriched and extended in numerous papers on the economics of insurance. In this analysis, the theoretical model and empirical investigation of the supply and demand of insurance markets take a narrower approach to concentrate on the effects of disasters on homeowners' insurance consumption.

On optimal contracting and reallocation of risk, Raviv (1979) is premised on the optimal contracting work of Arrow (1970, 1974). Raviv (1979) suggested that every phase of economic behaviour is affected by uncertainty, and the economic system has adapted to uncertainty by developing methods that facilitate the reallocation of risk among individuals and firms. By examining different insurance contracts for single as well as multiple losses, Raviv shows that the Pareto optimal insurance contract involves a deductible and coinsurance of losses above the deductible. In his conclusion, the deductible feature is shown to depend on the insurance costs while the coinsurance is due to either risk or cost sharing between the two parties and upper limits on insurance are shown to be Pareto suboptimal. The major shortcomings of Raviv (1979) analysis are that; first, adverse selection problems are not clearly analysed by assuming both the insurer and the insured know the probability distribution function of the losses, and secondly, moral hazard problems are ignored by assuming the monetary loss exogenous and not under the insured's control.

In conclusion, if the demand for insurance is not inelastic, the empirical evidence is consistent with the theory that low-risk insureds³ would be inclined to purchase less insurance in a market

³ The class of policyholders who's exposure to risk is relatively low as only a small number of them are likely to suffer a loss

with adverse selection than in a market free of adverse selection (Chiappori and Salanie, 2000; Dionne and Doherty, 1992; Pauly, 1974). This is further supported by the adverse selection literature (Crocker and Morgan, 1998; Jeleva and Villeneuve, 2004; Rothschild and Stiglitz, 1976) which postulate that insureds are better informed about their actual probability of loss than insurance companies. Kunreuther (1984) argues that property owners may not purchase flood insurance and other natural disaster policies because they underestimate their true probability of loss. Kunreuther's proposition points to a possible second difference between the natural disaster insurance market and those insurance markets characterised by adverse selection. In most of the adverse selection literature, the market is made up of high-risk and low-risk insureds, each with different probabilities of loss. Both high- and low-risk insureds estimate their probability of loss, but the insurance company does not estimate individual insureds' risk level. The optimal contract achieves self-selection, so in the end the company knows perfectly who is high-risk and who is low-risk by the contract that they each select. In the case of flood insurance, Kunreuther's suggestion is that without distinction to risk class, insureds underestimate their loss probability (Kunreuther, 1984). From the perspective of an individual who underestimates the true probability of loss and must make the decision whether or not to purchase insurance as modelled by Smith (1968), the price of insurance quoted by the insurer would appear high. If the insured underestimates the actual loss probability, subsidised insurance premiums may still remain expensive. Kunreuther and Kleffner (1992) showed that the incentive to voluntarily adopt self-insurance is reduced if the insured is required to purchase full insurance and that individuals tend not to use the maximisation of expected utility to make their decisions but rather use simple decision rules that result in their under-investing in self-insurance. To extend this argument, Kleffner and Kelly (2001) noted that if premiums are not risk-based, the insured would invest less in self-insurance.

2.2. Recent Studies that Investigate the Insurance Supply-side Impact from Catastrophes

The supply of post-catastrophe insurance coverage has also received considerable attention. Some studies (Grace and Klein, 2009; Grace et al., 2006; Klein and Kleindorfer, 1999) give detailed investigations of the performance of the Florida insurance market with a special focus on prices, availability of coverage, policy terms, and profitability. Key results in their analyses are that market restructuring, increased prices and tightening the availability of insurance, as well as the substantial losses suffered by insurers, have adversely affected the supply of coverage. Using results by Angbazo and Narayanan (1996) who worked on catastrophic shocks in the property-liability insurance industry, Born and Viscusi (2006) and Grace et al. (2004) examined the homeowners' insurance market response to natural catastrophes. They found that the impact of disaster shocks on insurers' performance is addressed by subsequent premium increases, and in most extreme cases firms exit from the affected territories. However, their results are incomplete without an analysis of how such catastrophes affect market-structure and performance culminating in firm exits from the affected region.

An extensive investigation by Choi and Weiss (2005) looked into the relationships between market structure and performance of property liability insurers over the period 1992-1998 using data at the company and group levels. The findings provide support for the efficient structure⁴. Further empirical work is also provided by a section on the impact of catastrophes, Hurricane Andrew and the Northridge Earthquake, on the price and profit models they used.. The results prove that more efficient firms can charge lower prices than competitors, enabling them to capture larger market shares and economic rents, leading to increased concentration. Although

⁴ The efficient structure hypothesis holds that stock insurers and mutual insurers will be sorted into market segments where they have comparative advantages in minimizing costs and maximizing revenues.

the overall results suggest that cost-efficient firms charge lower prices and earn higher profits, they do not point out the ramifications of concentrated risk in the event of catastrophic exposure. Similarly, Chen et al. (2008) investigated the effects of 9/11 on the insurance industry, hypothesising a short-run claim effect resulting from insufficient premium ex-ante for catastrophic losses, and a long-run growth effect resulting from ex-post insurance supply reductions and risk updating.

Another important contribution of this research is to look into the cost of risk and the amount of risk assumed by the insurer. A review of such work starts with the work of Kleffner and Doherty (1996) who studied the relationship between the cost of bearing risk and the amount of risk insurers assume in their underwriting portfolio. This work is centered on an analysis of the variety of insurer's characteristics that affect their ability to write earthquake insurance. Kleffner and Doherty's work estimates a cross-sectional model of earthquake insurance that incorporates firm characteristics expected to affect an insurer's cost of risk bearing, such as its marketing system, organisational form, profitability, leverage, diversification, taxes, and the percent of business in personal lines. Using an empirical test to examine whether the magnitude of an insurer's earthquake exposure is negatively related to its cost of risk bearing; they observed that the higher the firm's leverage, the less earthquake risk it assumes; and the more diversified it is as an insurer. As measured by how concentrated it is, stock insurers assume a greater amount of risk than mutual insurers, and insurers that use the independent agency system assume less earthquake risk than those that use the direct writer marketing system. These are very strong empirical findings that set the stage for future research to extend to how the magnitude of catastrophe, the cost of bearing the risk and the availability of government subsidy affect the demand and supply of residential property insurance. Based on Kleffner and Doherty's findings it is safe to postulate that, if firm-specific risk does not affect the value of the firm, then it will not affect operating decisions. However, when risk bearing is costly, then

we expect firms' optimal risk level to equate the marginal cost of risk and the marginal cost of reducing that risk. Evidently, this implies that firms with a higher cost of bearing risk should assume less risk. In this context, the existence of costly risk bearing implies that not all insurers are equally equipped to insure catastrophic lines of insurance business. The insurers concentrating on commercial or residential property insurance could have different risk bearing capacity and supply constraints. Born and Klimaszewski-Blettner (2009) show that following an unexpected catastrophe, commercial property insurers perform better than residential property insurers. Although this could be explained by differences in exposure and underwriting flexibility, a difference also exists in the distinct degree of regulation intensity. The existing studies do not document how premiums, policy forms, and contract terms vary in different territories. In their more recent work, Born and Klimaszewski-Blettner (2013) found that a strict regulatory environment distorts the ability of homeowner's insurers to offer insurance coverage relative to their commercial property counterparts. They observed that it is not only the different degrees of regulation that make a comparison of homeowners and commercial lines' responses to catastrophes worth being further investigated; but also found differences in the underlying risk exposure as well as insurers' flexibility in negotiating insurance contract terms. Moreover, they observed differences in reinsurance structures and geographical diversification. All these differences provide the authors with the sort of natural experiment with which to evaluate and compare personal and commercial lines insurers' responses to unanticipated catastrophic events. In their research, they attempted to identify the crucial factors that drive insurers' decisions to offer insurance coverage in catastrophe-prone lines of business. The authors' empirical results suggest important policy implications for improving the availability of insurance against catastrophic threats. They derived empirically founded strategies that might help to expand the limits of insurability, improving the supply of coverage capacity. Special focus is given to the impact of regulatory constraints; to the extent

that the paper found a negative effect of regulatory actions on insurers' willingness to offer coverage. This would suggest that some regulations may unintentionally hinder insurers' ability to respond to any changes in risk as they see fit and, thus, it endangers the adequate supply of coverage against natural disasters. This contributes to the discussion on a reasonable program of handling mega disasters, both in the private insurance context and with regard to public-private partnerships. The present study acknowledges the fact that such areas are more intensely regulated in the homeowners' insurance context than in commercial property insurance, but it seeks to put emphasis on homeowners' insurance.

Another crucial area of literature for review on is studies that examine insurer's willingness to offer insurance coverage. Born and Klimaszewski-Blettner (2013) examined the main factors that drive insurers' willingness to offer coverage in catastrophe-prone property insurance lines. They compare insurers' supply decisions in personal and commercial lines, with an emphasis on insurers' responses in the aftermath of natural disasters. Catastrophic property risks pose severe problems for insurers and thus, affect the supply of insurance coverage in catastrophe-prone lines of business. Limitations on the availability of coverage mainly result from insurability constraints. The study observed a lack of critical independence between insured units with the consequence of high accumulation of risk and serious loss potential for insurers (Born and Klimaszewski-Blettner, 2013). A further observation is that the insurability of catastrophic risk is hindered by difficulties in precisely predicting loss models, compared to high-frequency, low-severity risks, for instance, automobile accidents. This puzzling problem is documented by Hogarth and Kunreuther (1989), and Kunreuther and Hogarth (1990), who note that the willingness of insurers to provide coverage against natural catastrophic threats is affected by ambiguity issues. In addition to catastrophes being low-frequency, high-severity, and strongly dependent perils, increased construction activity in high-risk areas, global warming, and climate change complicate the insurability of these risks for insurers, and some

researchers are already paying attention to such areas (Bellman and Hemmingsson, 2016; Gurenko, 2015; Surminski et al., 2016).

On the actual implication of catastrophe to the insurer, Born and Viscusi (2006) provides a comprehensive investigation of natural disasters. Using a very large dataset on homeowners' insurance coverage by state, by firm, and by year for the period 1984 to 2004 in the USA general insurance market, their work documents the positive effect on losses and loss ratios of both unexpected catastrophes as well as large events which they term as blockbuster catastrophes. Insurers adapt to these catastrophic risks by raising insurance rates, leading to lower loss ratios after the catastrophic event. There is a widespread effect of unexpected catastrophes and blockbuster catastrophes that reduce total premiums earned in the state, which reduces the total number of firms writing insurance coverage in the state, and that leads to the exit of firms from the state. Firms with low levels of homeowners' premiums are most adversely affected by the catastrophes. In conventional insurance markets, such as automobile insurance, the insurer faces a large number of independent risks that tend to follow a fairly predictable pattern across time. By charging premiums that the firm can invest and earn a return on before paying off the losses, the firm would be able to run a profitable insurance business.

Catastrophic losses caused by natural disasters are much more problematic from an insurance standpoint. Rather than a large number of risks that on average follow a quite predictable year-to-year pattern, catastrophic losses tend to be lumpy. According to Born and Viscusi (2006), catastrophic risks pose a variety of problems for insurers. First, because the losses arise from a small number of lumpy events, the insurer may not have sufficient resources to cover the losses. In the absence of adequate reinsurance, the firm may go bankrupt or may choose to exit the country in which there is a substantial exposure to such catastrophic risks. The second implication of catastrophic losses is that they influence the rate structure even for firms that

remain quite viable in the presence of natural disasters. Suppose that an insurer is writing coverage in a very high-risk region that experiences a major disaster once every decade, and in disaster year, the firm will suffer losses well in excess of premiums. For it to be profitable to write coverage in the region, the insurer uses a common practise that charges more for insurance in the subsequent years in which there are no catastrophes than it would if there were no the threat of catastrophic risks. On the contrary, the present study believes that so long as the firm charges at least expected indemnity as premium in each year, then on average they would be solvent. Although the indemnities are lumpy and large on their arrival, premiums should not be higher in subsequent non-loss years. Non-loss premium income needs to be sufficiently spread as a catastrophe reserve fund against claims in a loss year, and then the insurer can either fund loss claims directly, or re-insure them, or use the continued premium income to fund a short-term loan to cover for losses. In any of these cases, premiums should not be different in loss and in non-loss years. A third phenomenon linked to natural disasters is the need for learning about the risks over time. The distribution of losses due to catastrophes may change over time for a variety of reasons. Locational patterns may have shifted over time, as reflected in increased construction in high-risk regions.

To the extent that insurers are rational Bayesian decision makers, one would expect them to update their risk beliefs over time when writing insurance coverage. Surprisingly, Born and Viscusi (2006) found no econometric analysis whatsoever that addresses these and other fundamental aspects of how catastrophic risks affect insurance markets. There have been extensive discussions of a conceptual nature as well as analyses of the potential role of reinsurance, but there has been no empirical examination of how catastrophic risks affect insurance company behaviour. Born and Viscusi's work provides a detailed empirical examination of how catastrophic risks affect the performance of the market for homeowners' insurance. The dataset they used is unprecedented in the homeowners' insurance literature in

terms of its level of detail. A major concern in the literature on insurance is how premiums are adjusted over time in response to fluctuations in interest rates. This phenomenon, which is known as the underwriting cycle, is often captured in empirical analyses of insurance markets by including some type of interest rate variable. Total premium payments reflect both the price of insurance as well as the quantity of insurance, so in many respects are a less instructive measure than the loss ratio, which serves as an ex-post measure of insurer profitability. Born and Viscusi (2006) includes a measure of the one-period-lagged homeowners' premiums in the analysis to capture the fact that there is a strong autoregressive character to insurance underwriting, as firms that write a large number of premiums in a given year would tend to continue to do so in subsequent years. They found the elasticity of premiums earned to homeowners' premiums from the previous year to be 0.973. Catastrophic events have a mixed effect on insurance premiums. One would expect these unexpected catastrophic events to raise the rate that firms charge for insurance. Thus, for any given number of policies written, the total premiums rise. However, these major catastrophes may also reduce the quantity of insurance written, both because of the higher rates and insurance rationing, as well as due to the effect of exiting of firms from the market.

Aseervatham et al. (2014) observed that natural catastrophes are threats to insurance markets. The authors observed significant supply distortions in the aftermath of natural disasters when insurers tend to exit affected areas, resulting in a lack of available coverage (Born and Klimaszewski-Blettner, 2013; Grace et al., 2006; Kraut and Richter, 2015). Aseervatham et al. (2014) infers how the availability of private market insurance can be ensured even in the aftermath of large scale and unprecedented catastrophes. For this, they first take a closer look at hazard specific insurance market reactions. Although insurance market reactions after natural catastrophes have been analysed extensively in recent years, there is no intensive study which analyses hazard-specific market reactions. The pioneering work in this analysis is

provided by Aseervatham et al. (2014). Most of the previous studies have either focused on one type of natural hazard (Browne and Hoyt, 2000; Grace and Klein, 2009), while others do not differentiate between different types of catastrophes at all (Aseervatham et al., 2013; Born and Klimaszewski-Blettner, 2009; Thomann, 2013). The main aim in analysis of this nature is to test whether there is one general type of insurance market reaction to natural catastrophes by comparing insurers' supply decisions after major catastrophic events. Supply decisions might differ because the hazards vary in damage size, predictability and correlation. Therefore, analysis examining the extent of the characteristics that drive the insurability problems is required in order to deduce recommendations for mitigating market distortions.

2.3. Recent Studies that Investigate the Insurance Demand-side Impacts from Catastrophes

The implications of catastrophes on insurance consumers have also drawn the attention of recent scholarly work. Kousky and Cooke (2012) examined the premiums a solvency constrained insurer would have to charge given a loss distribution with fat-tails, micro-correlations, or tail dependence. They found that, faced with those premiums, it may be rational for a utility-maximising homeowner not to purchase insurance. Grace and Klein (2003) estimated the demand for catastrophe insurance using data from the Florida homeowners market. They reported that the demand for catastrophe coverage is more price-elastic than the demand for non-catastrophe coverage.

Several studies that have examined the reaction and conduct of property insurance markets in the aftermath of catastrophes; and more particularly the theory supporting demand for catastrophe insurance, have attracted considerable attention. These analyses mainly concentrate on more recent catastrophic events and their implications for the property insurance market. Kriesel and Landry (2004) investigated the factors that determine consumers'

participation in the National Flood Insurance Program (NFIP) in the USA insurance market. Their empirical results for coastal homeowners confirm earlier findings on the overall flood insurance programs, indicating that flood insurance demand is price inelastic and responsive to the level of storm risk. The results also indicate that homes located further from the shoreline have a lower probability of holding flood insurance, all else equal. Locating away from the shoreline was interpreted as a form of self-insurance, which should lower the demand for formal insurance. For the seminal analysis of the relationship between self-insurance and market-insurance, see Ehrlich and Becker (1972). Similarly, Grace et al. (2004) analysed factors affecting homeowners' insurance contracts in markets subject to different levels of catastrophe risk. Using a slightly different approach and data sets to Kriesel and Landry (2004), Grace et al. (2004) investigated the demand for home insurance coverage in USA using two-stage least squares regression and data on insurance contracts, housing and demographic variables. Their model estimated the demand effects of standard variables, such as price and income, as well as variables more specific to residential insurance transactions under catastrophe risk, such as coverage options and an insured's risk characteristics. Grace et al. (2004) reported that the demand for catastrophe coverage is more price elastic than the demand for non-catastrophe coverage. A general observation is that options that expand coverage tend to increase demand, suggesting that consumers are willing to pay the incremental cost of additional coverage. Results from most of these studies can, to a certain extent, be used to generalise that lower deductibles are also associated with higher demand. A common explanation for this phenomenon is that consumers tend to follow experts' advice to decrease their deductibles and use the savings to purchase additional coverage that offers a better value in terms of protection against risk.

Michel-Kerjan and Kousky (2010) went further to study the demand for flood insurance using a database of more than 7.5 million NFIP policies and claims filed for the years 2000-2005.

Their work focussed on the characteristics of the buyers of flood insurance, the types of contracts (deductibles and coverage levels), the claims handling process, price determination, and the costs of the NFIP. Some of findings are in accordance with well-documented expectations of homeowners' decision making regarding insurance purchasing, for instance the choice of very low deductibles. It was also revealed that the response to the 2004 hurricane season also suggests that homeowners may desire more coverage and that this demand become more pronounced if another devastating hurricane season is expected, but their finding does not indicate the magnitude the change in insurance demand. To give an indication of the magnitude of post-disaster shift in insurance demand, Kousky (2017) provides a recent investigation on insurance demand. This study observes that the occurrence of disasters alters risk management choices, including the decision to insure. Using a database of flood insurance policies for all states on the Atlantic and Gulf coasts of the USA between 2001 and 2010, the research uses fixed effects models to examine how up-take rates respond to the occurrence of hurricanes and tropical storms. The key interesting finding is that, being hit by at least one hurricane disaster in the previous year increases net flood insurance purchases by 7.2 percent. But this effect dies out by three years after the storm.

Aseervatham et al. (2013) investigated whether, and to what degree insurance demand reactions of less sophisticated homeowners differs from the reactions of more sophisticated businesses in the aftermath of catastrophe. Using the annual statement data and financial information for all USA property insurers for the period 1984-2007, Aseervatham et al. (2013) found strong evidence for different demand reactions to catastrophes between the residential insurance market and the commercial insurance market. In the findings, homeowners seemed to demand more insurance after catastrophic events while businesses do not record major drastic changes in their insurance consumption level. Assuming that businesses behave more rationally and are more sophisticated in insurance contracts; Aseervatham et al. (2013)

concluded that the informational value of the occurrence of a catastrophic event is extremely low. The model used in their study hypothesises that the individual's overreactions to catastrophic events cause an insurance demand shift resulting in a 2.9 percent change in premium rates. In conclusion, the authors provided evidence that risk perception increases even if households were not directly affected. Although sufficient evidence is provided for the difference in post-catastrophes reactions for both the residential and the commercial insurance market, and a need for a behavioural approach in explaining individuals' demand for residential cover, there is a need for conclusive discussions to explain the behaviour. Their study however, provides the groundwork for the direction of future research work on post-catastrophe analysis. The authors proposed that future research should focus on distinguishing between different types of catastrophe risk, a case study as an avenue to extend this work is also proposed.

The key determinant of insurance demand is another area of interest that links the current research to the previous literature. There are theoretical reasons that determine the buyer's characteristics of insurance, but this may differ among policyholders. Browne and Hoyt (2000) estimated a catastrophic flood insurance demand model. In this demand model, the key drivers are the price of insurance, the loss probability and the loss amount. The factors are related such that if the loss probability increases while the insurance premium remains constant, a risk-averse agent demands a higher insurance coverage. In line with the existing literature, the insurance demand is expected to be high in the aftermath of catastrophes if the insured do not adjust their coverage accordingly after price increases. If this is the case, then it allows Browne and Hoyt's demand model to test a number of different hypotheses which remained puzzling prior to the event, explaining why relatively little catastrophic insurance is purchased in the USA. First, the model allows the authors to test whether price is a significant factor in the decision to purchase flood insurance. Second, they can test the extent to which the purchase of insurance coverage depends on the consumer's perception of the need for coverage. Greater

insurance purchases following floods are expected. Third, they also test whether mitigation efforts undertaken by the government to reduce the frequency and severity of catastrophe losses influence insurance consumption. In their work, Browne and Hoyt (2000) reported that flood insurance purchases are positively related to income and negatively related to price. Consistent with earlier studies (Gallagher, 2014; Hudson et al., 2014; Smith and Katz, 2013), they found that the purchase of flood insurance policies in a given USA state is positively related to the dollar value of flood losses that occurred during the prior year in that state.

As to whether insurance consumers are adequately insured, Dumm et al. (2015) observed an interesting phenomenon in insurance markets for catastrophic risks where individuals tend to underinsure for catastrophic risks prior to their occurrence. On the other hand, other works documented that when catastrophic events have recently occurred, individuals tend to demand more insurance (Kunreuther, 1978; Kunreuther and Pauly, 2005; Zeckhauser and Sunstein, 2008). Reasonable explanations for this uneven demand for catastrophe insurance include expected government subsidies, framing of the risk (Johnson et al., 1993), and overreaction to recent events (Palm, 1995). Although these numerous studies document some form of reaction post-catastrophe, the approach of the current work to investigate the actual effect of a catastrophe is novel in that, it seeks to interview the insurers, insured and other stakeholders to document the actual experience as well as to run a theoretical model to simulate the anticipated post-catastrophe reaction.

2.4. Supply-Side Reactions Post-Catastrophes: Indirect Effects on Insurance Market

The theme of this work is centered on supply and demand of residential property insurance and how this is affected in the event of a major catastrophe. An indirect effect of catastrophes on insurance industry profitability and market valuation is deemed appropriate to establish a complete holistic picture of the extent to which an insurance company's operations could be

curtailed. An interesting study by Shelor et al. (1992) found a positive effect of the 1989 California Earthquake on property-liability and multiple line insurers' market valuation. As a result, the researchers noted an increase in insurers' stock prices independent of their actual written business in the affected areas. Aiuppa et al. (1993) confirmed these findings in a related study. These results point to an argument that despite the high indemnity payments immediately post-disaster, investors expect positive business prospects due to an increase in insurance demand. Chen et al. (2008) used the 9/11 terrorist attack in USA to analyse the influence of catastrophic losses on insurers' profitability. By analysing abnormal earnings forecast revisions the authors were able to detect two opposing effects of catastrophes on insurers' performance. First, in the short run insurers suffer from a claimed effect since they did not expect a terrorist attack of this magnitude. Second, insurers benefit in the long-run from a positive growth effect due to an increase in demand for insurance coverage. Interestingly, this brief review leaves the gap of showing if there are correlations between the long-run growth of insurance sector post-natural catastrophes and availability of insurance coverage.

2.5. Summary

This work has given a comprehensive review and summary of the key studies that touch on extreme events insurance and how such events affect demand and supply of insurance coverage. The review would be incomplete without either making remarks or mentioning the essential features that lead to the insurability of risks emerging from disaster events. Natural disasters create challenges for insurers because there is substantial ambiguity associated with the probability of such events occurring, and the insurers' losses are often highly correlated. Most importantly, catastrophic risks are typically characterised by two main features. First, many catastrophes, from earthquakes to hurricanes, have been shown to be fat-tailed (Muir-Wood, 2012; Newman, 2005; Schoenberg et al., 2003). Statistically, an event with a fat-tailed

loss distribution implies that the probability of the event declines slowly relative to its severity. This in turn implies that the premium for such events should be much higher than the expected loss because the insurer has to provide a large amount of capital should a catastrophic event occur. It is evident that higher premiums suppress demand, but how higher premiums and higher a probability of risk actually affect demand is still largely unknown. Similarly, this review demonstrates that the supply of disaster coverage is curtailed unless the market provides some form of subsidy, but there is still unsettled discussion on why demand decreases with time from the last disaster, even when the supply of coverage is highly subsidised by the state.

The second feature of catastrophic risks is that losses are spatially correlated (Vaughan and Elliott, 1978). This means that a large number of buildings and other assets in close proximity are simultaneously affected by the occurrence of the natural disaster. Due to this high correlation between insured risks, there is little or no risk diversification within the insurance pool. These features, along with the last few year's increases in natural disaster events and the uncertainty surrounding their occurrence compounds the non-insurability of natural disasters in a free-insurance market economy due to the implied larger risk of insolvency for the private insurers. With these unique prerequisites, this work extends major parts of these gaps and seeks to develop reasonably accurate estimates of post-catastrophe reaction using a mix of empirical data and a theoretical model. This is not an easy task with low-frequency, high-severity events affected by a wide range of factors and subject to considerable ambiguity as described herein. To address all these problems, this study incorporates actuarial modelling techniques as it attempts to measure catastrophe risk and diversify this risk exposure as well as propose an actuarial-based pricing approach. Perhaps a major challenge would be how to allocate natural disaster costs amongst the primary stakeholders in a manner that is consistent with non-catastrophe events. For example, in automobile coverage, extensive historical data are always available and deployed to estimate insurance premiums for individuals with different risk

attributes. All this information gives a better understanding and quantification of the different drivers of the increase of extreme losses due to major catastrophes in the last few decades and the reactions of the insured and insurers to post-disasters would be critical to define better strategies for private companies and implement more effective public policies to deal with future disasters.

CHAPTER THREE

3. RESEARCH METHODOLOGY AND DESIGN

3.0. Introduction

This chapter introduces the research methodology used in this study and how it has guided data collection, analysis and development of the theoretical framework of the study. This methodology chapter gives a description of the research methods used in the analysis of chapter four all through to chapter eight. The five chapters independently contribute to the thesis on post-catastrophe insurance supply and demand: theory and evidence.

The rest of the chapter is organised as follows: Section 3.1 outline the research strategy used in the supply-side. Sub-section 3.1.1 gives the theory methodology while sub-section 3.1.2 empirical methodology. Sub-sections 3.1.2.1 and 3.1.2.1 describe the data source and data analysis respectively. Section 3.2 presents the research strategy used in the demand-side. Two chapters, chapter five and chapter six, of this work examine the demand-side of the insurance market in the aftermath of a major natural disaster. Sub-section 3.2.1 gives the theory methodology while sub-section 3.2.2 empirical methodology. Sub-sections 3.2.2.1 - 3.2.2.6 present data source, pilot study, questionnaire design and coding, conception and execution of the survey and ethical consideration, data analysis, and some survey limitations respectively. Section 3.3 gives the conclusions.

3.1. Research Strategy on Supply-side

On the analysis of supply-side, this study developed a theoretic framework that can be used to price natural disaster risk, and an illustration of the model using empirical data from Christchurch earthquake claims for the red-zoned properties is presented. This part of the investigation also conducted written interviews with local insurance companies and regulators with the aim of collecting business statistics pre- and post-Christchurch earthquakes. The business statistics help to analyse how the premium rates and other contract terms changed post-Christchurch disaster from a supply-side perspective. The ICNZ proved to be a valuable and resourceful organisation that provided a descriptive account of the insurance and reinsurance responses post-Christchurch disaster besides providing business statistics from all local underwriters in Christchurch residential insurance market.

In essence, the method used to study the insurance supply-side effect and reaction post-loss is of twofold. First, the methodology develops a theory in the form of a statistical model that takes into consideration the rating parameter of catastrophic risk using New Zealand residential property as a case study. Second, the methodology uses an empirical research into the effects of the Christchurch earthquakes supply-side of insurance. The empirical analysis aims to investigate the effect of the Christchurch earthquakes on the insurance industry using pre-loss and post-loss business statistics.

3.1.1. Theory Methodology

The theory method here presents a pragmatic premium pricing formula to price fire and general cover for residential property with a natural disaster as a rider. This is a unique actuarial perspective pricing formula that is based on the standard statistical method and international actuarial notation. This approach takes into consideration the key

features of New Zealand's residential property and contents insurance coverage which is made up of two layers of insurance contract run in a dual-insurance system.

Hypothetical pricing data is used to demonstrate how the formula is used to price natural disaster risk. This model will play an important role in setting internal benchmark rates in the pricing of natural disaster insurance coverage.

3.1.2. Empirical Methodology

The empirical research in this part of the thesis chapter investigates the supply-side implications of earthquakes to insurance markets. The methodology is centered on the supply-side of the insurance market to examine how catastrophe risks are insured in New Zealand. The method gives a diagnostic analysis of the natural disaster insurance market for residential property and contents. The empirical analysis is carried out using data sets of business statistics in all business lines for the local insurance products. A similar analysis for residential property and contents coverage is independently examined.

3.1.2.1. Data Source

The main source of dataset for this chapter was insurance industry business statistics. The data collection process involved both primary data and secondary data sources. This process started by writing to all insurance companies and government departments that were involved with earthquake claims in Christchurch. The correspondence emails aimed to set-up interviews to gather primary data on premiums, claims and exposure measures amongst others data variables. The main aim was to gather as much data as possible, but the degree of responses from the private insurers was very low. One confidential private insurer provided data for this analysis. The private insurer provided

business statistics for the years 2006 to 2014. However, before the data was released the insurer required signing of a non-disclosure/confidentiality agreement.

The main source of secondary data was the Insurance Council of New Zealand (ICNZ), Earthquake Commission (EQC) and Canterbury Earthquake Recovery Authority (CERA). The data used in this analysis is from two sources: Insurance Council of New Zealand (ICNZ) and one confidential private insurer that provided comparable data for this analysis. The ICNZ data contains business statistics on the data portal for the periods 2008 to 2015 which is published annually, therefore it gives a broad presentation. The Council currently has 28 members who collectively write more than 95 percent of fire and general insurance in New Zealand. The secondary data from the ICNZ, in particular, gives a broader representation of the business statistics of both the entire industry and a specific class of interest from 2008 to 2014. This information is published annually by the ICNZ. Using this data, the study gives a brief analysis of how New Zealand's insurance business statistics as well as any noticeable reactions in the aftermaths of the Christchurch earthquakes.

3.1.2.2. Data Analysis

Both data sets, one from the private insurer and the other from ICNZ, for the period 2006 to 2014 were concurrently analysed in order to present a clear picture of the effects of the earthquakes on the entire industry and on a particular single insurer. Insurance ratios, data plots, statistical analyses and the relevant tests were performed using IBM SPSS Statistics version 20 and Microsoft Excel 2013. Simple descriptive and visualization figures and tables are also used to explain what happened after the earthquakes based on survey responses. The major data collection obstacle this research had to deal with was the unwillingness of many organisations to share data. So an

opportunity to compile extensive data for rigorous analyses of the insurance market pre-quakes had been lost which would have otherwise informed this study of the major trends and market dynamics post-catastrophe.

3.2. Research Strategy on Demand-side

Two chapters, chapter five and chapter six, of this work examine the demand-side of the insurance market in the aftermath of a major natural disaster. The research strategy adopted to study the demand-side aimed to develop a theoretical model on insurance demand responses post-loss and an empirical chapter based on survey data on insurance demander's responses post-loss. Both perspectives are geared towards investigation of how a major catastrophe affects insurance demand from policyholders' viewpoint.

3.2.1. Theory Methodology

The theoretic model utilises a methodology based on insurance in an intertemporal setting. This method is used to examine and give an in-depth analysis of how the demand for insurance changes in responses to loss incurred in the previous period. The underlying research question in this model is how demand for insurance changes post-catastrophe, and how to model it theoretically. The intertemporal dynamic model investigates insurance consumption decisions in an intertemporal setting. In this model, an agent is allowed to update their insurance demand, initial wealth and a host of other risk and consumption decision parameters in the subsequent periods.

In this approach, insurance will be sought in two periods of time (sequential), and at the second period it is known whether or not a loss event happened in period one. Thus, it is possible to model the demand for insurance in period two conditional upon the loss event happening or not in period one. Above all, this methodology incorporates a

parameter on probability updating; so the consumer increases the probability belief for a loss event in period two, in an effort to explain why demand for coverage might increase after a loss event. Simulation results have been achieved using hypothetical values for all the parameter assumption. This result explains how the insurance demand changes post-loss.

3.2.2. Empirical Methodology

This section presents the research methodology used in the empirical study and how it has guided data collection and analysis of survey focusing on the demand-side aspect of residential property insurance coverage. The study gives an empirical analysis of pre- and post-Christchurch earthquakes insurance reactions using survey data. The key interest using this methodology on the demand-side is centered on the analysis of changes in the level of insurance coverage and other variables that contributes to change in insurance demand post-loss. The study further investigates how various insurance demand determinants variables affect the level of insurance coverage post-loss. In addition, this analysis method goes further to investigate how varying demographic attributes of the insurance demanders affect insurance demand post-catastrophe in New Zealand residential insurance market. Simple descriptive and visualization figures and tables are used to explain what happened after the earthquakes based on survey responses. Simple descriptive statistical analysis (Chi-square test and correlation analysis) have also been used to analyse the survey responses.

3.2.2.1. Data Source

This study uses data from an online survey conducted through random sampling of Christchurch dwellers. The sample respondents to the survey questionnaire composed of employees from four major public organisations. As a note of caution, the survey is

probably not representative, given that the data was gathered from only four institutions: University of Canterbury, ARA Institute, Christchurch Airport and Christchurch Women's Hospital. However, representation was not the primary intention; the researcher needed some data to show insurance market responses from demand-side. The sample of interest only consisted of homeowners insured prior to the 2010-11 earthquakes, and these four institutions provided easily accessible email contacts which could be used for an online survey. To this end then, the survey data is only intended to be illustrative, not necessarily representative of the entire population, but the survey participants in the sample were all affected by the earthquakes and they had some relationship with the insurance companies. In compiling this dataset, this study aimed to examine the influence and effect of each of these variables on insurance demand using a multinomial logistic model with an appropriate statistical test.

3.2.2.2. Pilot Study

One pilot study was conducted before the actual research survey was carried out. A focus group of 10 participants within the University of Canterbury was sent an email with the survey questionnaire. The main two aims of the pilot test were: first to examine the participants' response rate and factors that affect participation in the post-catastrophe survey or might hinder accurate completion of the survey, and second to ensure that the survey design and the technical aspect of the questionnaire would capture the data necessary to meet the survey objectives.

The focus group results were used to revise the survey questionnaire and other respondent materials prior to the full-scale study survey. Based on the pilot test results, improvements were made in the invitation email and minor text changes were made to the questionnaire title and few questions. The potential limitations of the pilot study

were considered and appreciated. The main limitation was primarily a small sample size within one organisation which could not provide sufficient representative results and the possibility of making inaccurate predictions or assumption based on the small size of the pilot data.

3.2.2.3. Questionnaire Design and Coding

The method of e-mail online survey is used in this study. This particular research instrument has been chosen due to the unique characteristics of the study population in Christchurch and the need for efficiency of data collection in the aftermath of the quakes. The survey consisted of closed-ended questions formulated to ensure in-depth information on insurance coverage is provided. The questions were formulated based on the objectives, hypotheses of this research and main research question. Using the guides in Sue and Ritter (2011), questions were developed following a logical progression starting with simple demographic profile questions, progressing to more specific natural disaster questions to sustain the interest of respondents and gradually stimulate question answering.

A survey cover letter was sent to the compiled email addresses to explain the purpose of this research and its relevance, and to seek respondents' consent to participate in the study. The letter also contained an online link where willing participants could complete the questionnaire. Contact information of the researcher had been provided in case a respondent raises questions relating to the survey. The questionnaire was made up of 24 questions designed to test the hypotheses of this research as well as investigate the post-earthquake reactions from insureds' viewpoint. The survey questionnaire was worded carefully to avoid long, ambiguous, leading and biased questions. More particular information on the survey question can be obtained in Appendix 1.

In the coding of the questionnaire responses, the survey used a mix of numerical rating, multiple choices and checklists where appropriate. The Likert scale of 1 to 8 was also used to scale most of the responses to the questionnaire. After sorting all the data set, it was necessary to transform them into ordinal and categorical dummy variables coding scheme to enable statistical analysis. This is in line with Walter, Feinstein, and Wells (1987).

3.2.2.4. Conception and Execution of the Survey and Ethical Consideration

The process of putting together a survey questionnaire began in the early months of 2015. After a series of refinement editing, and taking in to account all the comments from varying stakeholders, the first draft of the questionnaire was ready by May 2015. All data collection activities necessitated conformity to standard procedures for conducting household surveys. In this light, the process sought survey approval from the University of Canterbury ethics committee; this was cleared by June 2015. The request for permission to survey the university staff was also granted by the university survey policy group.

In the aftermaths of the quakes, many homeowners left their damaged homes to new suburbs or relocated to other cities. An online survey was hence considered as the most efficient survey method. The university's Qualtric survey tool, which is jointly administered by academic services group and the centre for evaluation and monitoring, was the preferred survey tool. The use of a number of survey tools such as survey monkey was strongly discouraged for official university research purposes.

The university communication office distributed the Qualtric survey link on 28th June 2015 via the university weekly e-newsletter on the researcher's behalf. The survey was directed only to insured homeowners and real-estate property owners and was

structured to take no more than 10 minutes to complete. However, this did not yield anticipated results, and we only got a paltry 7 responses from the university communications invitation. Next, the survey process took a more direct approach by emailing the respondents directly appealing to them for their support by taking time to complete the survey. The second survey invitations included the employees from four major public organisations: University of Canterbury, Christchurch Polytechnic Institute of Technology, Christchurch Airport and Christchurch Women's Hospital. In total, 1600 emails were sent between September and November 2015, but it was not possible to establish if all email address were still valid. A total of 254 of participants went on to complete the survey, representing a response rate of 16 percent. After sorting and cleaning the compiled data a total of 221 responses out of 254 met all the required information for analysis.

3.2.2.5. Data Analysis

Analysis of the survey data is done in two parts. The first part, which forms the main findings of this survey, entails simple descriptive analysis. In this descriptive analysis of the survey respondents' responses, clear summaries of results are presented in the figures and tables below. The main purpose of this analytical approach is to exhibit, in a simple manner, what actually happened to insurance demand-related variables after the earthquakes. A chi-square test of independence is also used to examine differences in participants' responses where appropriate.

3.2.2.6. Some Survey Limitations

The major reason why this study conducted an online survey was due to lack of funds to facilitate direct door-to-door interview or mailing paper-based questionnaire via the Christchurch suburbs addresses. Perhaps other survey approaches would have

improved the response rate. Another challenge was that many of the heavily affected homes in city East suburbs had been red-zoned as unfit for habitation and residents had moved to other suburbs or to other cities. So it was difficult to collect a broader dataset of those deeply affected by the earthquake. This particular survey method was chosen due to such unique characteristics of the study population in Christchurch and the need for efficiency of data collection in the aftermath of the quakes. The survey aims to provide a comprehensive reaction of home insurance buyers post-catastrophe. The resulting databases will be used to formulate and update insurance demand models for a natural disaster, as well as to inform the interested stakeholders on the lessons learned from insurance market experience in the aftermaths of catastrophic natural disasters.

3.3. Conclusions

The general goals of this research are centered towards investigating demand and supply market responses to the Christchurch earthquakes. In part, this is also to establish how the homeowners reacted in terms of their buying characteristics to their home insurance contracts in the aftermath of the Christchurch earthquakes. This study then documents a post-catastrophe response on both supply-side and demand-side and captures the perception towards risk in the period immediately after catastrophe as drivers of insurance decision.

This chapter outlined the methodology and justification for the chosen research design. Both empirical and theoretical research approach are described along with the datasets used in each case. The research instrumentation was discussed in detail and issues pertaining to validity, ethical consideration, coding, and transformation were presented. The interview and survey procedure were also described. Lastly, the statistical software used and data gathering procedures that were employed were described.

CHAPTER FOUR

4. AN EMPIRICAL ANALYSIS OF INSURABILITY OF NATURAL DISASTERS

4.0. Introduction

This chapter provides a comprehensive empirical analysis of the challenges faced in providing insurance coverage for natural disaster risks. The main objective of this chapter is to present a coherent discussion of the global challenge faced by the private insurance market to insure catastrophe risks and the possible solutions to address these challenges. The role played by the government insurance schemes is also illustrated and some examples of government insurance schemes worldwide are discussed.

The chapter is organised as follows: Section 4.1 describes the challenges faced in insuring natural disasters. Section 4.2 presents a probabilistic catastrophe loss model for natural disasters. This is an earthquake model which is used to reasonably determine the probability of losses occurring and likely severity when a disastrous earthquake event strikes. Section 4.3 demonstrates the need for government involvement in the provision of natural disaster insurance coverage. Sub-sections 4.3.1 - 4.3.4 present a discussion of important government-sponsored natural disaster schemes worldwide. Section 4.4 gives the discussion and conclusions of the study.

4.1. Challenges Faced in Insuring Natural Disasters

One of the essential characteristics of a risk is that it should meet some specific insurability prerequisites. These insurability conditions are essential for risk transfer as a risk treatment tool. To discuss the concept of insurability, consider a standard insurance policy under which premiums are paid at the inception of the contract to cover

losses which might occur within the contract time period. There are two conditions that must be met before an insurer can offer coverage against an uncertain event. The first is that the probability of the loss event occurring and the extent of losses likely to be incurred in monetary terms must be quantifiable, or estimated at least partially. The second condition is that the insurer should have the ability to set premiums for each potential policyholder. If a loss event satisfies these two conditions then, the event is considered to be insurable even though there are other generic insurability requirements.

Extreme catastrophic events, such as natural disasters, pose a set of challenges for insurers because they involve potentially high and spatially correlated losses that are extremely uncertain to predict when calculating the premiums. Besides not meeting the minimum insurability conditions, natural disaster events with extremely high insured losses have increased significantly in the last few decades (Kleindorfer & Kunreuther, 1999; Amendola et al., 2000; Aseervatham et al., 2013; Nguyen, 2013). The continual growth in losses from disasters is increasing the existing challenges faced by the private insurance market for catastrophe risk. To address the global challenge posed by natural disasters, some countries (Turkey, Japan, France, New Zealand, Norway, Spain, Taiwan, USA, Australia, and Mexico) have passed regulations to intervene in the provision of disaster insurance coverage. There are ways in which governments can create conditions for a private market to emerge; by acting as a reinsurer of last resort, providing subsidies to catastrophe insurance, and establishing government-sponsored mechanisms to directly provide coverage. A common rationale for disaster assistance and government intervention in disaster insurance markets is that private markets fail to provide socially adequate levels of insurance coverage. The challenge remains to make such disaster insurance programs actuarially viable like other forms of coverage

provision. To do so requires four conditions which are entirely different to the usual insurability conditions; (i) a wide coverage which sometimes might be through compulsory insurance, (ii) reasonably fair pricing which perhaps might not be actuarially fair so to speak, (iii) a keen attention to the political and economic realities inherent in the immediate post-disaster environment, and (iv) encouragement of active risk management in communities prone to disasters through appropriate incentives.

It is worth noting that catastrophic risks are characterised by two main features. First, many natural catastrophes, from earthquakes to hurricanes, have been shown to be fat-tailed (Muir-Wood, 2012; Newman, 2005; Schoenberg et al., 2003). Statistically, an event with a fat-tailed loss distribution implies that the probability of the event declines slowly relative to its severity. This implies that the premium for insurance of such an event must be relatively higher than the expected loss because the insurer has to provide a large amount of capital to cover catastrophic events. The second feature of catastrophic risks is that losses are spatially correlated. This means that a large number of buildings and other properties in close proximity are simultaneously affected by the occurrence of a given natural disaster. Owing to this high correlation between insured risks, there is insufficient risk diversification among the insurance pool. Due to these features (fat-tailed and spatially correlated losses), increases in the number of natural disaster events and the uncertainty surrounding their occurrence in the last few years compounds the non-insurability of natural disasters in a private insurance market. This is due to the high-risk of insolvency for the private insurers in the aftermath of catastrophe losses.

With these unique prerequisites, insurers must be able to develop reasonably accurate estimates of their future claims. This is helpful for setting appropriate premium rates

and for structuring investments to ensure efficient cash flow management, to build-up sufficient catastrophe reserves and to keep the probability of financial insolvency as low as possible. This is challenging given that low-frequency, high-severity events are affected by a wide range of factors and are subject to considerable ambiguity. To address these problems, actuaries normally utilise sophisticated modelling techniques to attempt to measure catastrophe risk and diversify risk exposure using risk-based efficient pricing methods. When efficient pricing and risk diversification mechanisms are employed with proper reinsurance arrangements in place, then insurers can potentially overcome the non-insurability problem. There are several ways by which insurers can manage and diversify catastrophe risk, including reducing concentration of exposures, modifying the terms of their insurance contracts, encouraging risk mitigation, purchasing reinsurance, utilising catastrophe-hedging financial instruments, holding more capital and establishing sufficient catastrophe reserves.

4.2. Probabilistic Catastrophe Loss Model for Natural Disaster (Earthquake Model)

There is limited natural disaster data available to reasonably determine the probability of losses occurring and likely severity when a disastrous event strikes. In the absence of historical data, insurers are cautious when they model anticipated future catastrophe risks. Catastrophe models serve this purpose by maximising the use of available information on the risk to estimate the potential losses from natural or man-made catastrophic events. This chapter does not aim to present a catastrophe modelling approach. Instead a brief conceptual discussion of the characteristics of the existing probabilistic catastrophe model is presented. The model used in this discussion is based on a progressive version of the initial catastrophe model proposed by previous

researchers (Grossi, Kunreuther, and Patel, 2005; Hochrainer, 2006), as is shown in Figure 4-1. This consists of five basic components: stochastic, hazard, a portfolio of the asset at risk, vulnerability, and loss. The model characterises the risk of natural disaster phenomena as underwritten by primary insurers. For example, in the case of earthquake cover, the catastrophe is characterised by its epicentre location and moment severity, along with other interrelated underwriting office parameters. The frequency of certain magnitudes or frequencies of events will also describe the hazard in question.

A probabilistic catastrophe loss model integrates detailed database and scientific understanding of the highly complex physical phenomena of natural disaster events. The specific exceedance probability curve is computed using a multi-collaboration of natural hazards expertise, like seismologic and engineering expertise. This makes the catastrophe loss model responsive and pragmatic in modelling events of a catastrophic nature. However, it should not be lost that the modelling of catastrophic risk is a complex process that depends on subjective and objective inputs related to the natural disaster and underwriter's office experience.

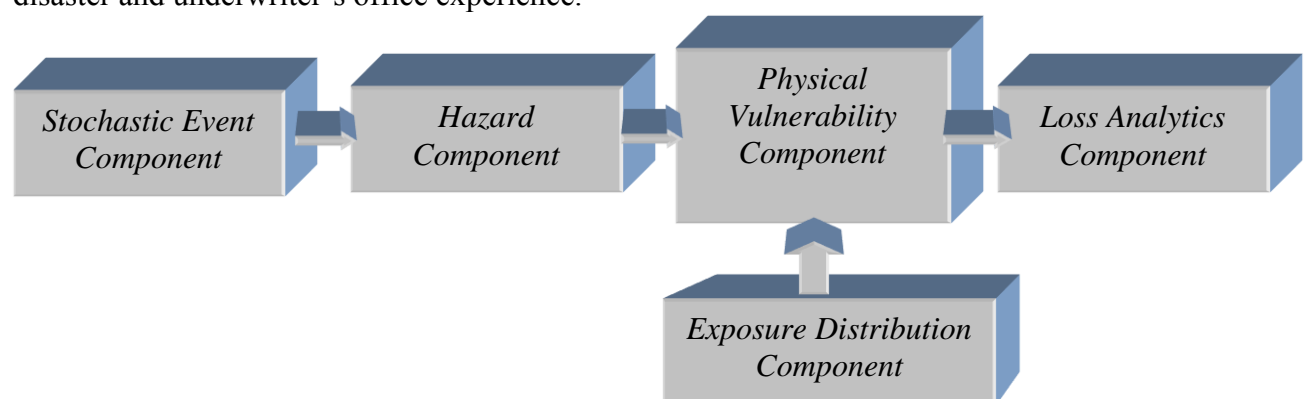


Figure 4-1: Structural Components of the Probabilistic Catastrophe Loss Model
(Initially Developed By: Grossi et al. (2005), Hochrainer (2006), and Mahdyiar and Porter (2005))

Typically, the stochastic component helps in stochastic simulations, a procedure that employs a range of engineering-based modelling and statistical techniques. This is

founded on the scientific understanding of the catastrophe in question, to generate a large randomised set of potential extreme events. The hazard component incorporates at least three variables regarding the source parameters of the disaster: the locations of future events, the frequency of occurrence, and severity. It also simulates the event across the affected region and calculates local intensity at each affected location. For example, using earthquake natural disaster as a conceptual illustration to determine the frequency and local intensity of an earthquake, various parameters are needed, depth, rupture length, seismic wave amplitude, dip angle, rupture mechanism, location, and magnitude. The spatial distribution of past earthquakes within the region is used to estimate the spatial distribution for future earthquakes. Historical data on earthquake magnitudes are usually fitted to an exponential distribution. The Gutenberg-Richter (G-R) relationship is used to model the occurrence rate of earthquakes and their magnitude. The G-R relationship states that the log of the cumulative annual frequency of an earthquake declines as the magnitude increases (Hochrainer, 2006; Muntendam-Bos and De Waal, 2013).

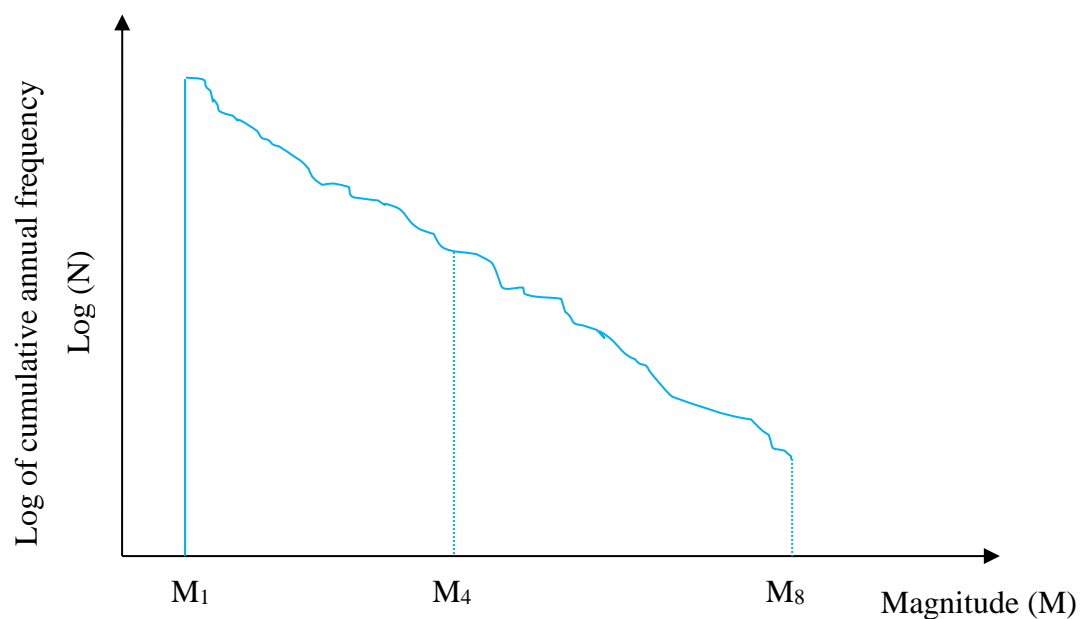


Figure 4-2: Frequency-Magnitude Relationship of a Seismic Zone

(Source: Mahdyiarand Porter, 2005)

The G-R relation has been the subject of extensive research by seismologists (Bird and Kagan, 2004; Cosentino et al., 1977; Kagan, 1991). The present situation can be summarised as follows; for small and moderate magnitudes of earthquakes, and for large space-time volumes, the G-R is valid to high accuracy. However, for the largest magnitudes, some more or less significant deviations have been documented by Pisarenko and Sornette (2004). From a statistical point of view, the study of such magnitudes is hampered by the insufficient number of large earthquakes. It is therefore inevitable that the existing models of the deviations from the G-R, and the numerous proposals to modify it for large magnitudes, suffer from a large statistical uncertainty. As a consequence, the problem of finding an adequate description of the tail property of the magnitude distribution cannot be considered as definitely settled.

Let x be a random variable that denotes an earthquake event happens at particular date and time, then a model of the probability distribution of x , $F(x)$, assumes that the G-R law holds as far as the maximum magnitude M , beyond which no earthquakes can occur (Cosentino et al., 1977; Pisarenko, Lyubushin, Lysenko, and Golubeva, 1996). This is represented by Equation 4.1;

$$F(x) = \begin{cases} 0; & x < m; \\ 10^{-\beta m} - 10^{-\beta x} / 10^{-\beta m} - 10^{-\beta M}; & m \leq x \leq M; \\ 1; & x > M. \end{cases} \quad (4.1)$$

Where the parameter M represents the maximum possible earthquake size, $M = M_{\max}$, and m denotes the magnitude of the earthquake when it occurs as described by Gutenberg-Richter law. For any given number of earthquakes occurring in a large seismic zone then, $M \geq m$. The parameter β is denotes the slope of the Gutenberg-Richter law at small values of x when the probability distribution $F(x)$, is plotted.

The parameter M plays a very important role in seismic risk assessment and in seismic hazard mitigation. The parameter is very useful for earthquake risk underwriters; having a reliable estimate of maximum magnitude, it is comparatively easy to make adequate decisions on the standard building code or about insurance policy pricing. The exposure distribution component includes details of the location and the characteristics of the property at risk of damage. For example, in the present case of modelling earthquake catastrophes for residential property, this model characterises the portfolio of properties at risk as precisely as possible. The underwriting factors include features such as construction type, the number of levels in the structure, and the property age. Others might include soil type, slopes of land, proximity to bodies of water or known fault lines. If the property is already insured, information on the nature of the policy, such as the deductible and sum insured or coverage limit, is also recorded.

When quantifying the physical impact of the catastrophe on the property at risk; the hazard and portfolio of residential properties components enable the calculation of the vulnerability or susceptibility to damage, or other forms of loss, as a result of the impact of the hazard on the property at risk. From this measure of vulnerability, the loss to the property is evaluated. In essence, this step in the model quantifies the physical impact of the natural hazard phenomenon on the property at risk. How this vulnerability is quantified may differ from model to model or from one underwriting insurer to another. In many cases, the vulnerability component would define the loss in terms of the percentage of the value expected to be lost for that property type at a defined hazard value, specific to the exposure category. For example, the exposure could be a wooden single storey house in a Christchurch suburb, built in 1984, for which the vulnerability would convert an earthquake measuring 6.5 on the Richter scale or a peak gust wind-speed of 248 km/h into a mean damage ratio of say 25 percent of the property's value.

In the loss component, physical damage is translated to total ground-up losses. Insured losses are calculated by applying policy conditions to the estimates of total loss. After the loss estimations have been completed, they can be analysed in ways of interest to the stakeholders and more particularly, they are used in premium rate computations. Ordinarily, the output includes probability distributions of total monetary loss, as well as net losses after the application of insurance policy conditions for both annual aggregate and annual occurrence losses.

Most theoretic research (Ermoliev and Flåm, 2001; Kesete et al., 2014; Smith and Matthews, 2015) is based on similar models of catastrophe risk that assumes a smooth aggregate total loss distribution or a distribution of a binary (that is, loss or no-loss) variable. While this is adequate for addressing many questions, an engineering model can provide a more accurate and detailed representation of the risk. Importantly, it can also capture the great variability that exists among individual property loss distributions, which is necessary to optimise the design of a portfolio of insured properties.

Use of an explicit loss model also allows joint optimisation of insurance purchasing and retrofit decisions since the effect of the latter on the distribution of insured losses can influence both optimal insurer and homeowner behaviour. Despite these benefits, loss models have rarely been integrated into the economic catastrophe risk literature. Some studies (Athavale and Avila, 2011; Grossi et al., 2005; Klein and Kleindorfer, 1999) used loss model results from engineering, modelling firms to investigate the impact of mitigation on insurer losses and insolvency probabilities, and on how losses are distributed among stakeholders. Grossi et al. (2005) offered a useful summary of how catastrophe modelling can be integrated with insurance management. Other studies

(Hayek and Ghanem, 2004; Kesete et al., 2014) created an insurance portfolio optimisation model that takes input from a catastrophe model, including disaggregation of insured properties by location and building type. They focus on the role of the primary insurer and run the model with 6 locations, 10 structural types, and 34 earthquake scenarios. Their results confirm that any pragmatic catastrophe model should be able to estimate (i) the probability of occurrence of a catastrophic event, (ii) the upper intensity limits of a particular occurrence, (iii) the financial loss that will result for a particular event, (iv) the cost of managing the exposure, and (v) the concentration and accumulation of risk.

4.3. Need for Government Participation in Natural Disaster Insurance

Governments may intervene in the provision of natural disaster insurance because there is no satisfactory solution available in the private market to achieve the specific role of compensation schemes which enhance higher disaster insurance penetration and political pressure for government intervention due to inherent natural disaster risk within the country.

Private insurance markets for catastrophe risks may fail for a variety of reasons, and governments may try to intervene to stimulate the insurability of catastrophic risks. To demonstrate how the challenge faced in the natural disaster insurance market works, it is necessary to describe the supply and demand curves of the participants in the market. In standard non-catastrophe insurance, the insurance market is made-up of only two types of participants; individuals who buy insurance and companies that sell it. An individual will purchase an insurance contract so as to alter the pattern of uncertainties when a loss event occurs in future.

This is illustrated in Figure 4-3 which shows a general equilibrium in an insurance market in a standard Edgeworth box diagram, based on the theory proposed by a number of studies (Diamond and Stiglitz, 1974; Mossin, 1968; Pauly, 1974).

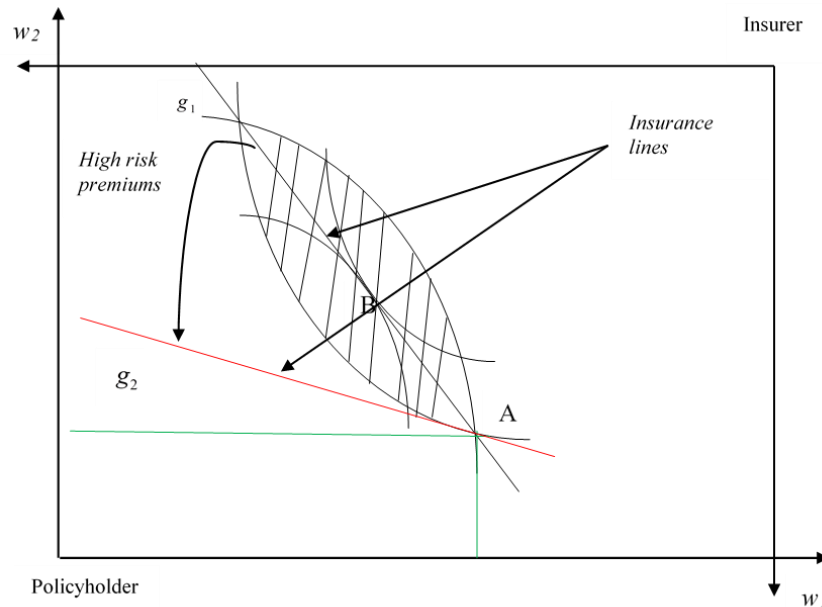


Figure 4-3: General Equilibrium in an Insurance Market

Note that, w_1 is used to denote wealth if there is no loss and w_2 denotes wealth if a loss event occurs. The convex indifference curves correspond to the policyholder, and the concave curves are the indifference curves of the insurer (who in this graph is assumed to be risk-averse). Point A is the initial point, where no insurance is transacted. A Pareto improvement is possible in the nested area since both policyholder and insurer reach a higher indifference curve compared to the initial situation at point A and are better off in terms of their wealth in this area than at the starting point A . The realisation of a point in this area depends on the market perception towards risk and the underwriting approach of the insurers. The slope of the insurance line gives an indication of the level of the insurance premiums: a flatter insurance line implies a higher insurance premium as is shown by insurance line g_2 . There is also a probable insurance line g_1 as clearly seen in Figure 4.3. The indifference curves of the policyholder and the insurance

company are tangent at point B in which both the policyholder and the insurer are better off. This, therefore, shows a Pareto improvement compared to the initial point A and in general point B can be regarded as a possible insurance equilibrium based on (Mossin, 1968). However, the uncertainties surrounding natural disasters make it difficult for the insurers to estimate the frequency and severity associated with a given catastrophe risk. In most cases, a risk-based underwriting will generate unaffordable premiums as shown by the high-risk premium flatter insurance line g_2 . It is clear that the new insurance line g_2 has no other intersection points with the nested area. In such a scenario, demand for catastrophe insurance may be too low since it is not optimal for the policyholder to buy insurance coverage at such a high premium. At all points on g_2 the policyholder would be on a lower indifference curve than at the initial point A . In order to avoid the insurance market inefficiency due to extremely high premiums, government interventions will be necessary. The private insurance markets would find it uncompetitive to offer coverage in an extreme catastrophic exposure without some sort of government intervention.

Section 4.1 has described and listed some nations where government participates in catastrophe insurance solutions in a variety of forms. These schemes are normally designed to offer insurance to individuals, mostly homeowners, who would otherwise find it unaffordable to buy policies in the private insurance market. In designing a public insurance program to avoid the difficulty faced by private market, the government-sponsored schemes should be guided by two design principles. First, government programs should support, not replace, private markets and direct participation by the private markets should be encouraged as much as possible. Second, the program must be priced at actuarially fair rates and sufficient capital reserves based on standard

insurance principles must be maintained. In essence, the government insurance scheme must require premiums which reflect the underlying risks and must operate with a capital reserving strategy. Likewise, the program should not operate with subsidies that have the effect of encouraging individuals to develop adverse selection behaviour.

4.3.1. Natural Disaster Insurance; the Case of Flood Insurance in the USA

In the USA, the standard homeowner's insurance program covers flooding and associated natural hazard perils. It is therefore important for property owners to have protection from the floods associated with hurricanes, tropical storms, heavy rains and other conditions that heavily impact some states in the USA. The history of flood insurance goes back to the aftermath of the Great Mississippi Flood of 1927, when private insurers decided to leave the flood insurance market. The following decades marked a period through which hazard-prone communities relied heavily on government disaster relief. The federal government established the National Flood Insurance Program (NFIP) in 1968 (Dacy and Kunreuther, 1969; Michel-Kerjan and Kousky, 2010). NFIP was created to help provide a means for property owners to protect themselves financially. Managed by the Federal Emergency Management Agency (FEMA) which maps flood risks and sets flood insurance premiums, the programme is designed as a voluntary partnership between the federal government and local communities. The FEMA creates flood maps in participating communities, designating the risks in different flood zones. Property owners in participating communities are eligible to buy federal flood insurance. This is achieved by providing affordable flood insurance coverage for property owners and by encouraging communities to adopt minimum floodplain management policies and enforce floodplain management regulations. These efforts help mitigate the effects of flooding

on new and improved structures. Overall, the program reduces the socio-economic impact of natural disasters by promoting the purchase and retention of risk insurance in general, and national flood insurance in particular.

The NFIP provides insurance up to a maximum limit for residential property damage, now set at US\$250,000 for building coverage and US\$100,000 on contents coverage. The underlying principle of the program is to subsidise the cost of flood insurance on existing homes, in order to maintain property values, while charging actuarially fair rates for new constructions. Since the enactment of the NFIP, flood insurance in the USA has been provided mainly by the government. However, private insurance companies have played a pivotal role as a distribution channel and servicing the policies. Also, there is some private flood insurance covering claim amounts above the NFIP residential cap for flood losses, and under certain special commercial insurance policies, even though this represents only a small portion of the market today.

As at 1st January 2014, there were over 5.4 million flood insurance policies in force in the USA managed through a federal program which generated US\$3.53 billion in premiums for a total of US\$1.28 trillion of assets under coverage (Atreya et al., 2015). The average annual premium per policy for residential cover stood at US\$645 nationwide. The three key important facts about the standard flood insurance policy are; (i) It is a single-peril (flood) policy that pays for direct physical damage to insured property up to the replacement cost value (Replacement Cost Value - RCV - is the cost to replace that part of a building that is damaged without depreciation) or Actual Cash Value (Actual Cash Value - ACV - is Replacement Cost Value at the time of loss, less the value of physical depreciation) of the actual damages or the policy limit of liability, whichever is less. The contents coverage must be purchased separately. (ii) It is not a

valued policy. A valued policy pays the limit of liability in the event of a total loss. For example, say a home is totally destroyed by a fire and it costs US\$350,000 to rebuild. If the homeowner's insurance policy is a valued policy with a US\$400,000 limit of liability on the building, the insured would receive US\$400,000. Flood insurance pays just the replacement cost or actual cost of real damages, up to the policy limit, in essence this avoid over-insurance. (c) It is not a guaranteed replacement cost policy. A guaranteed replacement cost policy pays the cost to rebuild the home regardless of the limit of liability. For example, a property is totally destroyed by a fire and it costs US\$400,000 to rebuild. If the homeowner's insurance policy is a guaranteed replacement cost policy with a US\$350,000 limit of liability on the building, the insured would still receive US\$400,000. Flood insurance does not pay more than the policy limit.

Although the program has been in operation for over 45 years, academic research on its operation and the demand for flood insurance through the NFIP is fairly recent. Browne and Hoyt (2000) provide the first empirical analyses of homeowners' demand for flood insurance through a state-level analysis across the USA. Their empirical analysis suggests that both price and income are influential factors in one's decision to purchase flood insurance, and flood insurance purchases at the state level are found to be highly correlated with the losses in the state during the prior year. Kriesel and Landry (2004) used household-level data from coastal zones in the USA to examine participation in NFIP for nine south-eastern counties. They find participation responsiveness to price to be inelastic while respondents with higher incomes were more likely to have flood insurance, with an elasticity. This implies that higher income households are more likely to purchase flood insurance, a finding that suggests that flood insurance is viewed as a normal good. Three studies have looked at specific states or cities. Zahran et al.

(2009) showed that household flood insurance purchases in Florida correlate strongly with local government mitigation activities. Additionally, they also showed that NFIP policy take-up correlates positively with prior flood experience, local hazard proximity conditions such as a land area in a floodplain, and the educational attainment levels of individuals in a locality. Michel-Kerjan and Kousky (2010) reported that the majority of policies in Florida are located within the FEMA-defined high-risk floodplains. Kousky (2010) examined the demand for flood insurance in St. Louis, Missouri, and noted that the take-up rates increase with more land in the high-risk floodplains and the rates decline with levee protection along major rivers. However, most of these papers have not examined the supply and demand for insurance contracts post major catastrophic event holistically at the primary level where the direct insurers, individual insureds, and reinsurers interact. Grace et al. (2003) point out that, analysing the supply and demand for residential property insurance after a mega-disaster and integrating this analysis with research on risk diversification and mitigation is critically essential in order to formulate a complete picture of the catastrophe risk problem and to evaluate viable solutions.

4.3.2. Natural Disaster Insurance; the Case of Earthquake Insurance in the USA

The California Earthquake Authority (CEA) was established by the California legislature in 1995 following the 1994 Northridge earthquake, which cost US\$12.5 billion in insured losses and triggered an insurance availability crisis (Marlett and Pacini, 1999; Roth Jr, 1998). Designed to preserve the state-mandated offer of earthquake coverage, the CEA required the participation of 70 percent of California homeowner insurers before it could begin operation. Insurers choosing not to

participate are required to offer a similar brand of earthquake coverage to residential policyholders. The CEA commenced operation in late 1996 and allowed the policyholders of all participating insurers to purchase earthquake coverage directly from it. As of September 2004, the program insured approximately 724,000 policyholders, generating approximately US\$393 million of written premium annually (Jaffee, 2015). The CEA offers a scaled-down policy covering homes and certain apartment buildings, but not other structures such as swimming pools and garages. Contents coverage is limited to US\$5,000; additional living expenses are capped at US\$1,500. The standard deductible on the home and its contents is 15 percent and is applied to the total loss. The CEA also offers supplemental coverage that decreases the deductible to 10 percent and increases contents coverage to as much as US\$100,000. Factors used to determine premiums include the location of the dwelling, the year it was built, and the type of construction. The pricing model takes information from every CEA earthquake policy and simulates earthquakes of varying magnitudes in various locations throughout the state. The model accounts for; (i) type of home (house, condominium), (ii) construction method (wood-frame, masonry), (iii) age of the construction, (iv) soil types, and (v) proximity to fault lines. To determine the earthquake risk for an area, scientists and engineers at the CEA's computer modelling firm take data from a variety of highly respected sources. The computer model scientifically estimates the average annual loss to the CEA by estimating losses within each postal (ZIP) code. In other words, given its book of insurance policies, on average, how much insured earthquake loss is expected to occur? The combined losses of all ZIP codes produces the appropriate state-wide rate. Regional differences in rates are established by comparing expected losses from one ZIP code to another. Those who live in a ZIP code close to an earthquake fault line or with predominantly poor soil can

expect to pay more than those on firm soil, away from fault lines. The resulting rate determines the premium for a CEA policy. Depending on its date of construction, a house that has been retrofitted may be entitled to a 5 percent premium discount. The CEA's actuaries place ZIP codes that present similar seismic risk into rating zones. Although the risk is not exactly the same for each ZIP code in a rating zone, the risks are similar enough to justify the zone groupings. This method of establishing rating zones produces rates that are more affordable. Affordable rates, in turn, permit the CEA to meet its goal of offering sound earthquake insurance to all Californians. More importantly, the CEA sells its policy through its participating insurers, who offer coverage to homeowners, condominium owners, and renters throughout California. It also provides retrofit assistance to help people protect their houses against earthquakes. The CEA funding plan totals approximately US\$6.73 billion, which should enable the fund to survive a 1-in-800 year event (McAneney et al., 2016). Structured in layers, the fund is made up of monies from premiums, contributions from an assessment on member insurance companies, borrowed funds, reinsurance, and returns on invested funds. Unlike the New Zealand's EQC, no public funds are pledged or available to cover CEA-insured losses. If an earthquake causes damage greater than the CEA's claims-paying capacity, a very unlikely possibility, policyholders will be paid on a prorated basis. The prorated claims would be calculated on the basis of the total amount of expected claims compared to the remaining available funds.

4.3.3. Natural Disaster Insurance; the Case of Earthquake Insurance in Japan

The 1966 Earthquake Insurance Law (enacted after the Niigata earthquake of 1964) established the Japanese earthquake reinsurance (JER), to whom private nonlife insurers were obliged to offer earthquake insurance and cede 100 percent of the

earthquake premium and liabilities (Tsubokawa, 2004). The JER thus acts as the sole earthquake reinsurer for the private insurance market. The JER can be looked at as an earthquake reinsurance pool, retaining a portion of the liability and ceding the rest back to private insurers based on their underwriting capacity and to the Japanese government through reinsurance treaties. The reinsurance program is designed such that the liability of private insurers and the JER itself does not exceed the accumulated reserves from earthquake insurance premiums. The JER program was revised in May 2011 after the Great East Japan earthquake (GEJE). The total claims-paying capacity of the program is currently ¥5,500 billion (US\$45 billion), which is estimated to correspond to the scenario of the 1923 Great Kanto earthquake with a return period of 220 years. Should insured earthquake losses exceed this amount, claims would be prorated accordingly.

The role of the Japanese government is central to the program. The maximum liability of the government of Japan, JER, and private insurers is 87%, 10%, and 3%, respectively. It should be noted that under the previous reinsurance program (before May 2011), the government's liability was only 78 percent, and the rest was shared equally between the JER and private insurers. The revision of the reinsurance program, leading to an increase of the government's liability share, is the direct consequence of a depletion of the earthquake reserves of both the JER and private insurers after the GEJE (Mahul and White, 2012).

Earthquake insurance offered by private non-life insurance companies is available as an optional endorsement to fire insurance policies. Earthquake coverage is available at policy limits of 30%-50% of the fire insurance limit, with maximum limits of ¥50 million (US\$400,000) per dwelling and ¥10 million (US\$80,000) for personal property (Benfield, 2011). A three-step claims settlement allows for rapid damage assessment

and claims settlement. Payouts are not proportional to damage, but based on a three-step system; total loss, half loss, and partial loss which allow for 100%, 50%, and 5% of the earthquake insurance policy limit, respectively.

The premium rates are risk-based and vary according to the prefecture where the dwelling is located (divided into eight risk zones) and type of construction (wooden or non-wooden). For an insured amount of ¥10 million (US\$80,000), the annual premium varies between ¥5,000 (US\$45) for a non-wooden structure in Nagasaki Prefecture, and ¥31,300 (US\$255) for a wooden structure in Tokyo. Discount rates of up to 30 percent apply when the building is earthquake resistant, according to the Japanese Housing Performance Designation Standards, including a 10 percent discount for buildings constructed after 1981. The premium rates, calculated by the Non-Life Insurance Rating Organization, consist of the pure premium rate and a loading factor. The rates do not include any loading for profit since the program is not for profit. Despite this rating and because of Japan's considerable earthquake exposure, rates are still considered high (Mahul and White, 2012).

Residential earthquake insurance is also available through cooperative mutual insurers. These insurers conduct insurance operations on behalf of Japan's cooperative societies. The largest of these cooperatives is JA Kyosai, which holds an estimated 85 percent market share of all the homeowners' insurance written through cooperative mutual insurers. Like any cooperative, JA Kyosai operates on a non-profit basis. Its insurance products are different from those of private insurers. Cooperative mutual insurers offer building endowment policies: these policies offer more comprehensive coverage than the policies available through the private insurers and can be seen as a savings mechanism that provides funding for home repairs, whether caused by natural disasters

or other adverse events. The five-year (or longer) term policy automatically covers residential dwellings and personal property from damage caused by fire, flood, earthquakes, and other natural disasters. Unique to co-operative insurance is that, if the policy expires and the policyholder has not claimed a total loss, he or she is entitled to a partial refund of the premium.

Earthquake insurance is automatically included in the building endowment policies offered by JA Kyosai. The policy limit is 50 percent of the fire insurance limit, up to ¥250 million (US\$2 million). The average fire insurance amount is ¥30 million (US\$245,000), hence the average earthquake insurance limit is ¥15 million (US\$123,000) (Hikichi et al., 2016). Under the building endowment policy available through JA Kyosai, the claims settlement process in case of an earthquake is proportional; a loss assessor estimates the damage percentage of the house, and this rate is applied to the earthquake policy limit. The premium rate is flat; the same wherever the dwelling is located. It only differs according to the structural material whether the building is a wooden or non-wooden structure. Co-operative mutual insurers are not subject to the Earthquake Insurance Law and do not participate in the JER but cede a significant portion of their liabilities to the international reinsurance market. They work outside the nonlife insurance regulatory framework and are instead accountable to the respective ministries; for example, JA Kyosai reports to the Ministry of Agriculture, Forestry, and Fisheries. Penetration under the private nonlife insurance program is estimated at about 25 percent of Japanese households, with slightly less than 13 million residential earthquake insurance policies in force: an estimated 48 percent of all fire insurance policies in force include earthquake coverage. Co-operative mutual insurance programs cover about 14 percent of Japanese households so that total penetration is estimated at 39 percent (Mahul and White, 2012).

4.3.4. Natural Disaster Insurance; the Case of Earthquake Insurance in Turkey

In Turkey, the state is legally obliged to finance the costs of recovery and reconstruction of buildings after an earthquake. This responsibility of the state naturally brings an unplanned burden upon the Turkish economy with very limited central budget allocation in the occasions of a natural disaster. In the aftermath of the two major earthquakes in 1999, the Government of Turkey decided to enforce the earthquake insurance on the nationwide basis with the sole purpose of privatising the potential risk by offering insurance via the Turkish Catastrophic Insurance Pool (TCIP) and then exporting the major part of this risk to the international reinsurance and capital markets (Bommer et al., 2002). While this measure was aimed at reducing government's fiscal exposure in the event of a major catastrophic earthquake, it was also intended to encourage risk mitigation and safer construction practices. To achieve these goals all registered residential dwellings in Turkey (the total number currently is about 19 million) are required to be in the compulsory earthquake insurance coverage.

Initially funded by the World Bank, the TCIP program became effective as of March 2001 and is currently one of the most renowned insurance brands in the Turkish insurance market. High brand recognition and increasing earthquake insurance awareness among homeowners gives leverage to the take-up rate in earthquake insurance (TCIP policy count was about two million as of September 2004, increasing to 7 million by the end of 2014).

The aim of TCIP is to provide an adequate level of protection with affordable premiums. Therefore, the maximum coverage of compulsory insurance is currently at approximately US\$62,500 as of 1st February 2006. The sum insured is calculated by multiplying the size of the dwelling in square meters by construction prices per square

meter, which vary for different classes of construction. Construction prices for all classes of construction are adjusted periodically in line with changes in the construction cost index published periodically by the government. If the value of a dwelling exceeds this amount, policyholders can buy additional coverage from private insurance companies. To keep premium rates affordable, the TCIP does not cover dwelling contents, debris removal, and temporary living expenses. The California Earthquake Authority in the USA and the EQC in New Zealand, to a certain extent, do not always cover these items. The TCIP policy offers coverage on a first-loss basis, meaning that it does not impose underinsurance penalties when the value of a dwelling is significantly higher than the limit of coverage obtained from the TCIP. Unlike the CEA, which imposes a deductible of 10 percent, the TCIP applies a minimum 2 percent deductible to the sum insured to avoid small claims, reduce moral hazard and reduce the pools' administrative and reinsurance cost.

4.4. Discussion and Conclusions

The USA disaster insurance system has received the most research attention because of regular catastrophic losses that have seen the insurance industry face liabilities far beyond the solvency position. The same challenges are faced by insurance firms operating in other disaster-prone territories. The global challenge faced by private insurance markets to insure catastrophe risk, and the possible solutions to address these challenges, have been comprehensively discussed in this chapter. Extreme catastrophic events, such as natural disasters, pose a set of challenges for insurers because they involve potentially high and spatially correlated losses that are extremely uncertain to predict when calculating the premiums. It has been shown that the insurance premium of such an event must be relatively higher than the expected loss because the insurer

has to provide a large amount of capital in case of catastrophic events. The demand for catastrophe insurance would then be too low since it is not optimal for the policyholder to buy insurance coverage at such a high premium. The private insurance markets would therefore find it uncompetitive to offer coverage in an extreme catastrophe exposure without some sort of government intervention. In order to avoid the insurance market inefficiency due to extremely high premiums, government interventions are necessary. In designing a public insurance program to avoid the difficulty faced by private insurance market for a natural disaster, the government-sponsored schemes should be guided by two design principles. First, government program should support, rather than replace the private insurance markets and direct participation by the private insurance markets should be encouraged as much as possible. Second, the program must generate actuarially fair rates and sufficient capital and reserves based on standard insurance principles must be maintained.

But despite the uncertainty due to changes in insurance, risk-based pricing is an important step in encouraging individuals and organisations to put risk mitigation in place and to improve disaster resilience. From another perspective risk-based actuarial pricing alleviates the moral hazard problem of insurance consumers who think that they do not need to mitigate risks on the grounds of being insured, as is suggested in Brown et al. (2016), and Schuster (2013). However, due to increased occurrence of catastrophes and the changing nature of disasters, risk-based pricing could mean that those who cannot afford mitigation measures also cannot afford insurance and the private insurance industry cannot effectively meet two of the most important objective besides indemnifications. They ought to provide information to those residing in hazard-prone areas as to the nature of risks they face and incentivising those at risk to undertake loss reduction measures in anticipation of future disasters. Therefore, there

is a need for both private insurers and public disaster managers to develop a strategy on how to reduce losses from future natural disasters as well as to appreciate the limitations of individuals and organisations in dealing with low-probability, high-magnitude events and the challenges the insurance industry faces in providing coverage against these risks.

CHAPTER FIVE

5. OPTIMAL INSURANCE DEMAND BASED ON AN INTERTEMPORAL MODEL

5.0. Introduction

In the aftermath of 2010-11 Christchurch earthquakes, a number of fundamental market shifts occurred in the New Zealand insurance industry. This alludes to the fact that, post-disaster insurance market changes are not exceptional within the insurance market context. It is globally observed that a unique type of market adjustment effect occurs when a major disaster event occurs (Auffret, 2003). This affects both demand and supply sides of the insurance market. The focus of this chapter is to examine the effects generated by post-loss experience from an insurance demand side standpoint. The influence of post-loss experience on insurance demand decisions appears in particular on insurance markets for catastrophic risk. For example in California, before the 1989 San Francisco earthquake, 34 percent of the individuals considered insurance against an earthquake as an unimportant undertaking. But after the earthquake, only 5 percent held this opinion. Likewise, the earthquake occurrence increased insurance demand with 11 percent of the previously non-insured individuals subscribing an insurance contract Kunreuther (1996).

This chapter presents a basic theoretical model that examines insurance demand post-loss based on a two-period intertemporal approach. The chapter gives an in-depth analysis and discussion of the performance of the proposed insurance model that examines insurance demand response after a loss event has happened.

The chapter is organised as follows: Section 5.1 reviews and discusses the background of previous insurance demand models. Section 5.2 sets an introduction to the theory on

intertemporal insurance demand. This section also discusses the underlying research question in this chapter: That is, how demand for insurance changes post-catastrophe and how to model it theoretically. Section 5.3 presents both analytical and numerical illustrations of the proposed insurance model. Sub-section 5.3.1 gives the analytical framework and the properties of the intertemporal model. Sub-section 5.3.2 presents an illustrative example of intertemporal modelling using hypothetical datasets. Section 5.4 gives a discussion of several findings that can be drawn from the simulation results and conclusions.

5.1. Previous Insurance Demand Models and Where the Present Study Stands

Most of the previous analysis on the demand for insurance focuses on insurance in isolation within a single period time horizon. Using static models, most of the literature assumes there is only one area of uncertainty in the insurance analysis. Some studies (Arrow, 1963, 1965; Dreze, 1981; Mossin, 1968; Raviv, 1979; Smith, 1968) are credited for their enormous contributions to the analysis of insurance demand in a static setting. With such models, the question of the choice of the level of insurance coverage is not a simple one. Mossin (1968) shows that it is not optimal to purchase full insurance when insurance policies are not actuarially fairly priced. These classical models of insurance demand as described in a number of studies (Arrow, 1965, 1974; Dreze, 1981; Mossin, 1968) have an important deficiency arising from their static features. One clear deficiency is that, in single period models, wealth and consumption are exactly the same variables. A second deficiency lies in the fact that these models do not consider the post-loss implication for insurance demand in a multi-period model with updated wealth.

Briys, Kahane, and Kroll (1988) and Mayers and Smith (1983) introduced multiple sources of uncertainty in the analysis of the demand for insurance. More specifically, Mayers and Smith (1983) examined the interrelationship between insurance holdings and other portfolio decisions and found that the combined analysis leads to different predictions about insurance demand. Extending some of the results obtained by these studies and using the notion of prudence as first introduced in Kimball (1991), Eeckhoudt and Kimball (1992) documents a detailed impact of background risk on the optimal coverage.

Building on this new dynamic approach to insurance analyses, Gollier (2003) examined a simple consumption lifecycle model where the representative consumer faces a sequence of independent risks over his lifetime. The implicit assumption made in this study is that the policyholders must transform immediately the retained loss into a corresponding reduction in demand. This assumption implies that utility for wealth, and the attitude towards risk, are constant over time. But in the real world, people mostly compensate for losses to their wealth by reducing their saving or by borrowing money rather than just reducing their demand over several periods. In Gollier (2002) it is shown that a time-consistent cooperative multiplicity strategy provokes consumers to be much more risk susceptible than in the static version of the model. Because of time multiplicity, the attitude towards risk on wealth and towards risk on consumption is not the same, specifically the aversion to risk on wealth should be smaller than the aversion to risk on consumption. Meyer and Meyer (2004) suggested that a lower degree of risk aversion for wealth in a multi-period setting translates to depressed demand and welfare gains from insurance. Two reasons are given for these results. First, consumers are keen to consume immediately rather than to perfectly smooth their consumption over time, which implies that they do not adopt a perfect dynamic strategy. Second, they usually

face cash constraints, and when funds are needed, policyholders cannot withdraw to compensate for the loss, hence they are obliged to absorb incurred losses immediately. Gollier (2003) concluded that the ability of consumers to self-insure by accumulating wealth induces them to significantly reduce their demand for insurance relative to what the classical model suggests. However, consumers have a positive insurance demand when they have been unlucky enough to incur a sequence of accidents in the recent past, which reduce their accumulated wealth.

The model that this research proposes is in close agreement with Cohen et al. (2008) which examines the implications of a model for multi-period demand decisions on the insurance market. Cohen et al. (2008) looked at the optimal insurance demand strategy of a consumer for a three-year period when the consumer faces a risk of loss in each period. Assuming that the estimated probability of incurring a loss is known and those losses in successive periods are independent; they looked at a perfectly competitive insurance market proposing insurance contracts at actuarially fair premia corresponding to the estimated expected loss. In this case, insurance contracts are subscribed for one period. Therefore, the consumer has to choose an amount of coverage characterised by the indemnity and premium at each period. Their study revealed that an individual is optimistic in the initial period and modifies his risk perception with respect to damages occurring or not. The occurrence of damage modifies the individual's risk perception and he becomes less optimistic, while if no damage occurs, his risk perception does not change. To better isolate the risk perception arguments, the researchers assumed that preferences at the final period are represented by a linear utility function under certainty, and the individual chooses not to buy any insurance contract in the first period. In the second period, one chooses not to be covered only if he had no damage. Finally, in the third period, if one had never had loss, he/she chooses not to buy

insurance. If he/she had two consecutive loss events, he/she decides to buy a full coverage contract and in the intermediate cases, he is indifferent. This interesting example underscores the fact that what is important for the agent is not only the event occurring in the period directly preceding the moment of the decision but all sequence of events. In the end, the insurance demand example of Cohen et al. (2008) explains the modifications in insurance demand behaviour over time observed for catastrophic risk. Based on their findings, it appears that past experiences have cumulative effects on insurance decisions in the sense that an individual can maintain constant insurance demand after one occurrence of the loss and modify it only after two or more consecutive loss events. In this case, it is assumed that at any period, observing a loss renders the individual more pessimistic. This explains a behaviour in accordance with the availability bias which shows that individuals become more and more optimistic after experiencing losses.

The present study looks into a slightly different but related literature. A standard model of precautionary saving has an agent in period one with no risk; facing a risk in period two. The agent can, therefore, save some wealth in period one in order to offset the negative effects of the risk in period two. This is called “precautionary saving”. Kimball (1991) refers to the precautionary saving motive as “prudence” which can cause an agent to respond to risk by accumulating more wealth; essentially this is similar to insurance that can be bought. The distinction is that precautionary saving adds to the resources one would have in the subsequent future periods, while insurance increases the resources available after a loss event occurs and reduces the available resources under good conditions. The concept of prudence is more useful for analysing the demand for insurance in the presence of background risk, since insurance as mentioned above, like precautionary saving, is a way of increasing the resources available in the

event of a bad outcome. The premium, in this case, is the loss of consumption in period one, and the expected indemnity is the reduction in risk or reduction in the effect of risk in period two because of the saving indemnity. The current study suggests that prudence and the intertemporal literature would be interesting if looked at together because there are two innovations in such demand model. One of the innovations is the dynamic intertemporal setting in it and the other is the separation between the risk and the indemnity.

This analysis combines different literature results and sets up a dynamic intertemporal model, however, this is not the first study to do so. Other studies have already considered insurance demand in a dynamic setting (Cooper & Hayes, 1987; Schlesinger 2000; Cohen et al., 2008; Volkman-Wise 2015). Most of these studies do not allow agents to transfer wealth between different periods and only consider situations where consumers only differ in their accident probability. When considering the proposed model, there are new contributions to the insurance dynamic aspects. First, the model incorporates a parameter on probability updating in an effort to explain why demand for coverage might increase after a loss event in the previous period. Secondly, since there is no consumption decision, the only effect of the first period decision on the second period decision is through wealth, and all of the standard parameters in period two like the probability of loss, premium price etc. Finally, the model provides a unique way to study the effects of increases in risk aversion, increases in the premium, and increases in the perceived probability of loss to the demand for insurance in different periods. This is an important extension to the literature of dynamic insurance models.

5.2. Methodology

5.2.1. The Theory of the Intertemporal Model

The underlying research question in this chapter is how the demand for insurance changes post-catastrophe, and how to model it theoretically. To address this question, this chapter proposes an intertemporal dynamic model which significantly departs from the popular models in the economic theory of insurance but utilises much of the existing literature findings. The intertemporal dynamic model investigates the insurance consumption decision in an intertemporal setting where an agent is allowed to update their insurance demand, initial wealth and a host of other risk and consumption decision parameters in the subsequent periods.

In this intertemporal model, insurance can be sought in two sequential periods of time, and at the second period, it is known whether or not a loss event happened in period one. Thus, it is possible to model the demand for insurance in period two conditional upon the loss event happening or not in period one. Above all, the model incorporates a parameter on probability updating (that is, when a loss event happens in period one, the consumer increases the probability belief for a loss event in period two) in an effort to explain why demand for coverage might increase after a loss event. The model assumes that for the first period and in successive periods the estimated probability of incurring losses are independent. In essence, then, the intertemporal model of insurance is restricted to only two periods, with an identical insurable risk in each period and identical insurance supply characteristics in each period.

In period one, a decision is made on insurance, and then the period one risk is allowed to play out. Any wealth that is not lost as uninsured losses or premium payments in period one is passed to period two. Then, a decision is made on insurance in period two.

It should be noted that the period two decision is made with full information on both the amount of insurance contracted in period one and the outcome of the period one contract, that is, if a loss occurs or not. Since the inherited wealth in period two depends upon the insurance decision in period one, it happens that the insurance decision in period two is expressible as a function of the decision in period one.

Therefore in this model, it is easy to consider the comparison between (i) period two insurance conditional upon a loss in period one and conditional upon no loss in period one, and (ii) period two insurance (either with or without loss event in period one) and the period one insurance demand.

The pure theoretical results are derived in the next section. It turns out that the model is an interesting extension to the standard model of demand for insurance, which is based on a single period. So, in the end, the model generates results that can be compared to and contrasted with, those of the standard environment. More innovatively, this model provides unique contributions to the theory of insurance demand. In particular, then, the first novelty is the fact that the model provides a natural theoretical way to establish how the demand for insurance is affected by the size of the loss suffered in the previous period, that is the post-loss insurance demand. Second, the model provides a unique way to study the effects of increases in risk aversion, increases in the premium, and increases in the perceived probability of loss to the demand for insurance especially when this occurs in a different period. Therefore, an agent is able to make a decision on the model's variables using an intertemporal approach, which is not in the existing literature.

5.2.2. Analytical Framework

Take an intertemporal perspective, with two consecutive periods. This analysis studies the insurance demand strategy of an individual for the two consecutive periods of time. In each period, a loss can occur, and insurance coverage can be sought in both periods. Assume there exists an insurer willing to offer insurance contracts that provide positive expected profit⁵. Assume the same loss in each period and that the individual faces a risk of loss of amount L at each period. An insurance contract C_t , where $t = 1, 2$, is proposed for one period. Thus, individuals have to make a decision on the choice of the amount of coverage at each period. The insurance contract offers indemnity I_t in return of premium Π_t . Assume further that for each decision (insurance) period the estimated probability of incurring a loss is p and that losses in the consecutive periods are independent such that:

$$P(\text{loss at period } t / \text{loss in period } t-1) = p.$$

The outcome of the first-period, a situation which is governed by chance, will impact upon the choice to be made in period two. In the same way, the choice made in period one will impact upon the choice made in period two. For instance, in a simple two-dimensional loss situation, in period one a level of insurance coverage C_1 is purchased against a loss amount L that happens with probability p . If $C_1 < L$, that is partial coverage was purchased, and if the loss happens, then in period two wealth is lower than it would otherwise have been by the amount of uninsured losses. This will impact upon the decision made in period two.

⁵ If the contracts were actuarially fair, the insured would only purchase full coverage always. We need, therefore, that the contracts be actuarially unfair, or in other words, that they offer positive expected profit to the insurer.

Thus, in period two, the optimal insurance choice, C_2 , will be a function of (i) the size of loss in period one (at this point, either loss or no loss), (ii) the amount of coverage in period one, and (iii) all of the standard parameters in period two (probability of loss, premium price, etc.). The size of period one's loss and the level of period one's coverage will impact upon the level of initial wealth in period two.

It is also assumed that w_1 denotes the amount of initial wealth in period one. w_2^1 is the level of initial period two wealth conditional upon a loss occurring in period one, and w_2^2 is the level of initial period two wealth conditional upon no loss occurring in period one. Insurance is priced linearly, such that an indemnity of C costs qC , where $p < q < 1$. The model also introduces an intertemporal preference parameter β , which is used to measure period two utility in period one utility units.

Now, the consumer's problem is to choose C_1 to maximise the function (Equation 5.1);

$$p[u(w_1 - L + C_1(1 - q)) + \beta(pu(w_2^1 - L + C_2^1(1 - q)) + (1 - p)u(w_2^1 - qC_2^1))] + (1 - p)[u(w_1 - qC_1) + \beta(pu(w_2^2 - L + C_2^2(1 - q)) + (1 - p)u(w_2^2 - qC_2^2))] \quad (5.1)$$

$$\text{Where } C_2^i \text{ maximises } pu(w_2^i - L + C_2^i(1 - q)) + (1 - p)u(w_2^i - qC_2^i) \quad (5.2)$$

Since w_2^i will be a function of C_1 for $i = 1, 2$, this is a problem that needs to be solved recursively using backward induction. Starting then with the two optimisation problems in period two, this gives optimal choice functions $C_2^i(C_1)$. If a loss in period one leads to greater insurance in period two than if no loss happened in period one, then $C_2^1(C_1) > C_2^2(C_1)$. Moreover, if a loss in period one leads to more insurance in period two than what was purchased in period one, then it would see that $C_2^1(C_1) > C_1$. Once

the two functions $C_2^i(C_1)$ have been found, it is then possible to do the first period optimisation problem and find the optimal choice for C_1 .

Observation 1. *If the consumer is only partially insured in period one, and a loss event does happen, then initial wealth in period two would be lower by the amount of uninsured loss. So by under-insuring, the consumer causes a larger decrease in period two wealth when a loss happens in period one, but a higher period two wealth if a loss does not happen in period one (since the period one premium would be lower).*

Standard Result: Under decreasing absolute risk aversion, Observation 1 would also imply a greater demand for coverage in period two. But this is conditional on a loss happening in period one, and partial coverage.

As an example, use $u(x) = \frac{x^{1-R} - 1}{1-R}$, which is constant relative risk aversion (CRRA), and

for which $u'(x) = x^{-R}$. Start with the period two choices; we need to choose C_2^i to maximise $pu(w_2^i - L + C_2^i(1-q)) + (1-p)u(w_2^i - qC_2^i)$.

The first-order condition is expressed in Equation 5.3;

$$\begin{aligned}
 \frac{p(1-q)}{q(1-p)} &= \frac{u'(w_2^i - qC_2^i)}{u'(w_2^i - L + C_2^i(1-q))} \\
 &= \frac{(w_2^i - qC_2^i)^{-R}}{(w_2^i - L + C_2^i(1-q))^{-R}} \\
 &= \left(\frac{(w_2^i - qC_2^i)}{(w_2^i - L + C_2^i(1-q))} \right)^{-R}
 \end{aligned} \tag{5.3}$$

Thus, in this case, we get the expression presented in Equation 5.4;

$$\begin{aligned}
\left(\frac{p(1-q)}{q(1-p)} \right)^{-\frac{1}{R}} &= \frac{(w_2^i - qC_2^i)}{(w_2^i - L + C_2^i(1-q))} \\
\left(\frac{p(1-q)}{q(1-p)} \right)^{-\frac{1}{R}} (w_2^i - L + C_2^i(1-q)) &= (w_2^i - qC_2^i) \\
\left(\frac{p(1-q)}{q(1-p)} \right)^{-\frac{1}{R}} C_2^i(1-q) + qC_2^i &= w_2^i - \left(\frac{p(1-q)}{q(1-p)} \right)^{-\frac{1}{R}} (w_2^i - L) \\
C_2^i \left[\left(\frac{p(1-q)}{q(1-p)} \right)^{-\frac{1}{R}} (1-q) + q \right] &= w_2^i - \left(\frac{p(1-q)}{q(1-p)} \right)^{-\frac{1}{R}} (w_2^i - L) \\
C_2^i &= \frac{w_2^i - \left(\frac{p(1-q)}{q(1-p)} \right)^{-\frac{1}{R}} (w_2^i - L)}{\left(\frac{p(1-q)}{q(1-p)} \right)^{-\frac{1}{R}} (1-q) + q}
\end{aligned} \tag{5.4}$$

If we set $\left(\frac{p(1-q)}{q(1-p)} \right)^{-\frac{1}{R}} \equiv k$, then the optimal insurance purchase in period two is expressed as shown in Equation 5.5;

$$C_2^i = \frac{w_2^i - k(w_2^i - L)}{k(1-q) + q} \tag{5.5}$$

It can be noted that the only difference between the two options is the size of initial wealth, w_2^i . Thus, we now have Equation 5.6;

$$\frac{\partial C_2^i}{\partial w_2^i} = \frac{1-k}{k(1-q) + q} \tag{5.6}$$

Since the denominator of this is positive, the effect of larger initial wealth upon the optimal insurance purchase is positive if $k < 1$, and negative if $k > 1$. But $k > 1$ if $p(1-q) < q(1-p)$, in other words that is, if $p < q$. This is the condition for positive insurer profits, so it should be assumed to be so, in which case C_2^i is greater the smaller

is w_2^i . Assuming partial insurance in period one, it is expected that $w_2^1 < w_2^2$, that is smaller initial period two wealth if a loss is suffered in period one than if not. In this case, then, the period two insurance purchase is greater after a period one loss has happened than when a period one loss did not happen.

The indirect utility function for period two can thus be written as in Equation 5.7;

$$\begin{aligned} pu(w_2^i - L + C_2^i(1-q)) + (1-p)u(w_2^i - qC_2^i) &= p \frac{(w_2^i - L + C_2^i(1-q))^{1-R} - 1}{1-R} + (1-p) \frac{(w_2^i - qC_2^i)^{1-R} - 1}{1-R} \\ &= Eu(w_2^i) \end{aligned} \quad (5.7)$$

In order to continue, an assumption is made on how the period one outcome affects period two initial wealth.

Assumption 1: In both periods, wealth is simply the level of inherited wealth from the previous period plus an intertemporally constant wage of amount, w . That means, savings are rewarded with an interest rate of zero, and that there is no consumption outside of insurance in period one.

This assumption now gives Equations 5.8 and 5.9;

$$w_2^1 = w_1 + C_1(1-q) - L + w \quad (5.8)$$

$$w_2^2 = w_1 + qC_1 + w \quad (5.9)$$

When the period one insurance choice is made, the consumer now maximises as per equation 5.10;

$$p[u(w_1 - L + C_1(1-q)) + \beta Eu(w_2^1)] + (1-p)[u(w_1 - qC_1) + \beta Eu(w_2^2)] \quad (5.10)$$

The first-order condition is can be simplified as given in Equation 5.11;

$$p \left(u'(w_1 - L + C_1(1-q))(1-q) + \beta \frac{\partial Eu(w_2^1)}{\partial w_2^1} \frac{\partial w_2^1}{\partial C_1} \right) + (1-p) \left(u'(w_1 - qC_1)(-q) + \beta \frac{\partial Eu(w_2^2)}{\partial w_2^2} \frac{\partial w_2^2}{\partial C_1} \right) = 0$$

Using the specific utility function, this is equal to

$$\begin{aligned}
& p \left(\frac{(w_1 - L + C_1(1-q))^{1-R} - 1}{1-R} + \beta \left(p \frac{(w_2^1 - L + C_2^1(1-q))^{1-R} - 1}{1-R} + (1-p) \frac{(w_2^1 - qC_1)^{1-R} - 1}{1-R} \right) \right) \\
& + (1-p) \left(\frac{(w_1 - qC_1)^{1-R} - 1}{1-R} + \beta \left(p \frac{(w_2^2 - L + C_2^2(1-q))^{1-R} - 1}{1-R} + (1-p) \frac{(w_2^2 - qC_2^2)^{1-R} - 1}{1-R} \right) \right) \\
& p \{ (w_1 - L + C_1(1-q))^{-R} (1-q) \\
& + \beta \left(p (w_2^1 - L + C_2^1(1-q))^{-R} \left(1 + (1-q) \frac{\partial C_2^1}{\partial w_2^1} \right) + (1-p) (w_2^1 - qC_1)^{-R} \left(1 - q \frac{\partial C_2^1}{\partial w_2^1} \right) \right) (1-q) \} \\
& + (1-p) \{ (w_1 - qC_1)^{-R} (-q) \\
& + \beta \left(p (w_2^2 - L + C_2^2(1-q))^{-R} \left(1 + (1-q) \frac{\partial C_2^2}{\partial w_2^2} \right) + (1-p) (w_2^2 - qC_2^2)^{-R} \left(1 - q \frac{\partial C_2^2}{\partial w_2^2} \right) \right) (-q) \} = 0
\end{aligned}$$

with:

$$\begin{aligned}
C_2^i &= \frac{w_2^i - k(w_2^i - L)}{k(1-q) + q} \\
C_2^1 &= \frac{w_2^1 - k(w_2^1 - L)}{k(1-q) + q} \\
C_2^2 &= \frac{w_2^2 - k(w_2^2 - L)}{k(1-q) + q}
\end{aligned}$$

and

$$k = \left(\left(\frac{p(1-q)}{q(1-p)} \right)^{-\frac{1}{R}} \right)$$

also

$$\begin{aligned}
w_2^1 &= w_1 + C_1(1-q) - L + w \\
w_2^2 &= w_1 + qC_1 + w
\end{aligned}$$

On substitution, it can be shown that;

$$\begin{aligned}
C_2^1 &= \frac{(w_1 + C_1(1-q) - L + w) - \left(\left(\frac{p(1-q)}{q(1-p)} \right)^{1-R} \right) ((w_1 + C_1(1-q) - L + w) - L)}{\left(\left(\frac{p(1-q)}{q(1-p)} \right)^{1-R} \right) (1-q) + q} \\
C_2^2 &= \frac{w_1 - qC_1 + w - \left(\left(\frac{p(1-q)}{q(1-p)} \right)^{-\frac{1}{R}} \right) (w_1 - qC_1 + w - L)}{\left(\left(\frac{p(1-q)}{q(1-p)} \right)^{-\frac{1}{R}} \right) (1-q) + q}
\end{aligned} \tag{5.11}$$

Equations 5.8 - 5.11 are as a result of assumption one and its defining conditions (5.8) and (5.9). Equations 5.8 and 5.9 imply that there is no consumption. The wealth in the second period is simply the wealth of the first period minus loss plus income. However, there is still utility derived from this wealth, but the model doesn't expound on what this utility is derived from. It cannot be consumption as that would reduce the transferred wealth. In most cases, models of insurance in an intertemporal setting have to be solved both over insurance demand and consumption choices. As it stands, the model needs some improvement in the future more so on the effect of consumption decision and corresponding methodology to solve a bivariate optimization problem.

Next is an illustrative example of the model numerically. The properties of this model have been demonstrated both analytically then numerically that $C_2^1(C_1) > C_2^2(C_1)$ and how C_2^i relates to C_1 ; this is also supported by the assumption of a CRRA utility function. The two derivations are important because the numerical illustration alone can only be reduced to a single point in a graph.

5.2.3. Numerical Illustration of the Intertemporal Model

This section uses hypothetical values to demonstrate how insurance demand changes pre- and post-loss and how it compares with insurance demand based on empirical data from both the demand and the supply sides of the market. The insurance scenario described by the intertemporal framework model using hypothetical values is simulated and results are shown in the following scenario.

Given the parameters;

w_1	w	L	P	q	R	β
100	10	40	0.4	0.5	2	0.9

Then;

$$\begin{aligned}
 C_2^1 &= \frac{(100 + C_1(1 - 0.5) - 40 + 10) - \left(\left(\frac{0.4(1 - 0.5)}{0.5(1 - 0.4)} \right)^{-\frac{1}{2}} \right) ((100 + C_1(1 - 0.5) - 40 + 10) - 40)}{\left(\left(\frac{0.4(1 - 0.5)}{0.5(1 - 0.4)} \right)^{-\frac{1}{2}} \right) (1 - 0.5) + .05} \\
 &= 29.898 - 0.10102C_1 \\
 C_2^2 &= \frac{100 - 0.5C_1 + 10 - \left(\left(\frac{0.4(1 - 0.5)}{0.5(1 - 0.4)} \right)^{-\frac{1}{2}} \right) (100 - 0.5C_1 + 10 - 40)}{\left(\left(\frac{0.4(1 - 0.5)}{0.5(1 - 0.4)} \right)^{-\frac{1}{2}} \right) (1 - 0.5) + 0.5} \\
 &= 0.10102C_1 + 21.816
 \end{aligned}$$

Candidate(s) for extrema value for period one coverage are:

$$\{-13.864, 1.807, 1.875, 1.900, 1.964 - 0.130i, 1.964 + 0.130i, 1.887 - 7.530 \cdot 10^{-2}i, 1.887 + 7.530 \cdot 10^{-2}i\}$$

At

$$[C = -109.23 - 9.9402i], [C = -109.23 + 9.9402i], [C = 168.50]$$

$$[C = 195.77 - 7.2971i], [C = 195.77 + 7.2971i], [C = 179.95]$$

$$[C = -1456.0], [C = 25.070]$$

So the optimum is at 25.070.

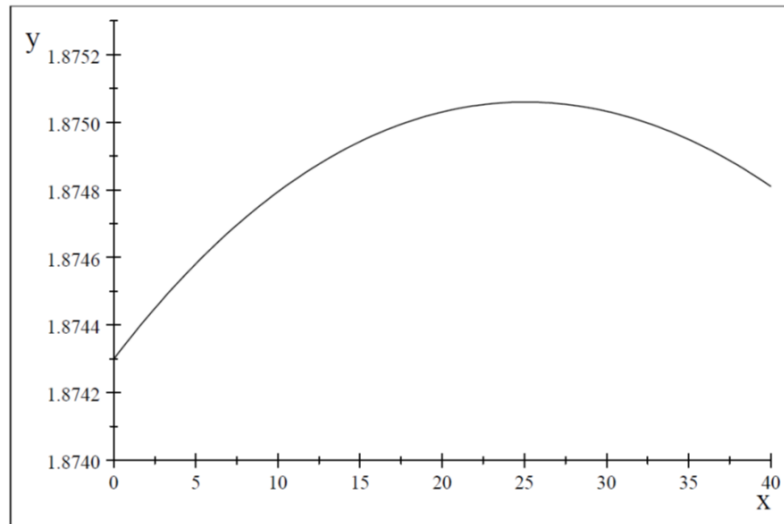


Figure 5-1: Optimal insurance coverage with intertemporal consideration

Comparing this to the solution for the case without intertemporal consideration,

$$0.4 \left(\frac{(100 - 40 + C(1 - 0.5))^{1-2} - 1}{1-2} \right) + (1 - 0.4) \left(\frac{(100 - 0.5C)^{1-2} - 1}{1-2} \right)$$

Candidate(s) for extrema: $\{0.98763, 0.99987\}$, at $\{[C = 23.837], [C = -1543.8]\}$.

Therefore optimum is at 23.837.

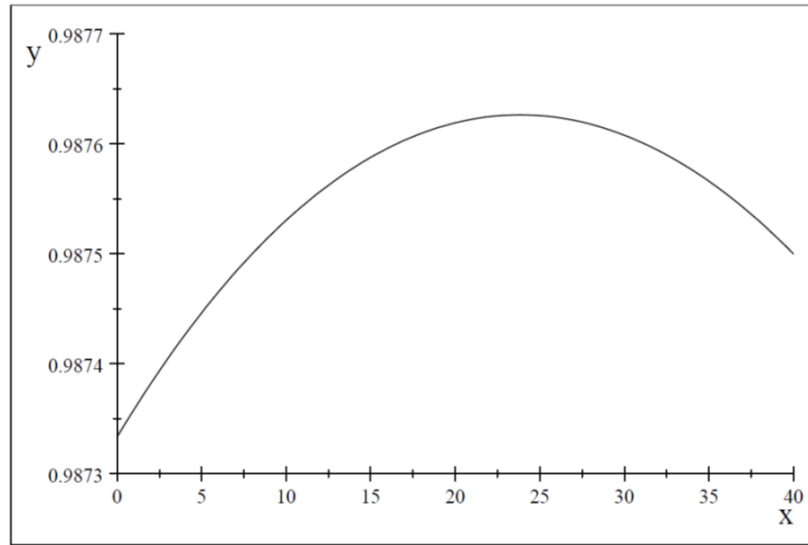


Figure 5-2: Optimal insurance coverage without intertemporal consideration

Results of the numerical simulation are plotted in Figure 1 and Figure 2. It can be clearly seen that the optimal insurance demand when there is an intertemporal consideration is at 25.070 whereas when there is not the intertemporal consideration, the optimal insurance demand is at 23.837.

So, for this example at least, taking into account the intertemporal nature increases insurance demand, finally;

$$C_2^1 = 29.898 - 0.10102 \times 25.070 = 27.365$$

$$C_2^2 = 0.10102 \times 25.070 + 21.816 = 24.349$$

So, insurance demand after loss increases by 9.2 percent (that is, from 25.070 to 27.365), and the demand if no loss falls by 2.9 percent (that is, from 25.070 to 24.349).

The principal findings in this analysis indicate that insurance demand increases immediately after the loss event. This is in line with the availability bias which corresponds to an overestimation of the probability of an event that recently occurred and implies an increase in insurance demand after a natural disaster, this demand being low after a long period without a catastrophe. However, the result found does not rely in any way on probability estimation bias or errors.

5.3. Discussion and Conclusions

This chapter provides a theoretical explanation for the observation on insurance demand post-loss. Several findings can be drawn from the model's results. First, it is notable that using the theoretical intertemporal model proposed in this analysis; (i) period one demand for insurance increases relative to the standard single period model, when the period two is taken into consideration, (ii) period two insurance demand is higher post-loss, higher than both the period one demand, and the period two demand without a period one loss.

Second, when the intertemporal model results are compared to the findings from previous studies on the insurance demand, it can be inferred that insurers will tighten the underwriting criteria when the insurance demand increases post-loss. Positive changes in the insurance demand will increase the cost of insurance cover in the short-run. Two major policy implication outcomes of increases in insurance demand post-loss based on Christchurch earthquakes is that; (i) deductibles changing from a percentage of the claim to a percentage of the insured value, and (ii) stringent risk-based underwriting measures in attempt to address any adverse selection behaviour that may emerge from the high-risk individuals.

Lastly, this analysis is still incomplete in a number of important ways. The model has restricted the analytical analysis by requiring certain assumptions. The critical limitation of model analysis is the Assumption 1 and its defining conditions (5.7) and (5.8) implying no consumption. The wealth in the second period is simply the wealth of the first period minus loss plus income. However, there is still utility derived from this wealth in both period one and two. What is this utility derived from? It cannot be consumption as that would reduce the transferred wealth, but if we allow the free choice of the amount of wealth the agents are allowed to keep and/or transfer, then savings and loans are essentially the same as consumption. However, since the wealth is evaluated through two utility functions, it is ambiguous how the results translate to known comparative statics results. In previous studies (Cooper and Hayes, 1987; Schlesinger 2000; Volkman-Wise 2015) models of insurance in an intertemporal setting have been solved both over insurance demand and consumption choices. Future work will need to relax this assumption then compare results presented in this chapter with evidence from the insurance market post-loss.

CHAPTER SIX

6. AN INVESTIGATION OF RESIDENTIAL INSURANCE DEMAND-SIDE REACTIONS AFTER A NATURAL CATASTROPHE: THE CASE OF THE 2010-11 CHRISTCHURCH EARTHQUAKES

6.0. Introduction

In September 2010 and February 2011, Christchurch city and its surrounding regions of the Canterbury plains experienced devastating earthquakes with an estimated economic cost of over NZ\$40 billion (Timar, Grimes & Fabling, 2014; Doyle & Noy, 2015; Chang-Richards & Wilkinson, 2016). The insurance sector played a very important role in re-building the Canterbury region after these devastating earthquakes.

There is varying evidence of how post-catastrophe experiences affect the demand for insurance. A study by Slovic et al. (1974) was the first to postulate over-reaction by economic agents in the aftermath of a new disaster. Since then, natural disasters have gained attention with various studies observing that insurance consumers over-react to the occurrence of a new disaster (Aseervatham et al., 2015; Dumm et al., 2015). Seog (2008) theoretically demonstrated that catastrophic events lead to increases in insurance demand when there is an increase in public information regarding a disaster. Browne & Hoyt (2000) looked at effects of catastrophic events on the demand for insurance using state-level data from the USA for a period of 10 years. The authors found that higher premium rates post-disaster lead to depressed demand when considering flood insurance. However, their study pointed out that this pattern is consistent with the lower demand noted prior to a disaster, but does not support the increased demand post-disaster, when premium rates are higher.

Working on the same USA National Flood Insurance Program, Michel-Kerjan & Kousky (2010) observed that policy limits associated with flood insurance programs are increased and more policies are purchased after a flood event. This signals that once there is an extreme catastrophic event like heavy floods, individuals overweigh the probability of a future flood and demand more insurance. In a recent study, Gallagher (2010) estimated the change in probability that occurs in the aftermath of floods using a panel dataset of floods and the uptake of flood insurance in the USA. The author provides new evidence on how individuals update their beliefs over uncertain rare events. Most importantly, he found that the consumption of insurance is completely flat in the years before a flood; it picks up immediately following a flood, and then steadily diminishes to pre-flood level. Other studies (Kirsch, 1986; Camerer & Kunreuther, 1989; Shanteau & Hall, 1992; McClelland et al., 1993; Palm, 1995; Ganderton et al., 2000; Cohen et al., 2008) analysed insurance demand reactions in the aftermath of a catastrophe, suggesting that the insureds have the belief that the probability of an event is lowered when that event has already occurred. Timar et al. (2014) estimated how the pricing of earthquake-related risks changed following the Christchurch earthquakes. Their study finds strong evidence that a liquefaction risk discount emerged in the high seismic area immediately after the Christchurch earthquakes, but disappeared entirely within three years of the disaster event. The findings could not rule out a time-varying risk premium as a result of a rational response to risk, similar to responses identified in a number of other studies (Jackson, 1981; Keller, Siegrist & Gutscher, 2006). Papon (2008) also suggested that prior risk occurrences influence subsequent insurance choices. Although several works make the case for risk perceptions affecting natural disaster insurance decisions (Kunreuther, 1984; Kunreuther et al., 1995; Braun & Muermann, 2004; Kousky et al., 2006; Manson, 2006; Michel-Kerjan & Kousky, 2010)

there is very little empirical work on how insurance demanders use their heuristic probability rule to update their past insurance coverage. Born & Viscusi (2006) found that major catastrophes may reduce the quantity of insurance written because of higher rates and insurance rationing, as well as exit of firms from the market. Similarly, West & Lenze (1994) argued that heavily flooding hurricanes are exemplified by relatively low insurance coverage.

The existing studies give several clues as to how some economic factors may influence insurance demand. According to Joskow (1973), Browne & Hoyt (2000) and Kousky (2010) those with higher incomes are more able to afford insurance and have accumulated more assets that they want to protect. However, Cleeton & Zellner (1993) showed that the only role that income can play in affecting the amount of insurance demanded at actuarially fair prices is to affect the size of the potential loss independent of the demander's degrees of risk aversion and how this varies with income. This chapter presents analysis involving the relationship between risk aversion, the level of income, the insured asset and the maximum premium the insurance demanders would be willing to pay for full insurance.

In the analysis of determinants of insurance demand, Browne & Kim (1993) explained that education is a good proxy for measuring risk aversion. Specifically, more risk-averse individuals due to higher educational attainment would have a higher demand for non-life products. Outreville (1996) also supported the view expressed by Browne & Kim (1993). In the same line, Dzaja (2013) suggested that education increases individuals' risk aversion and encourages people to demand insurance. Treerattanapun (2011) pointed out that high level of education increases the understanding of risk and threats to financial stability, helping the understanding of insurance benefits. An

analysis by Park & Lemaire (2012) on 82 countries for a period of 10 years also found a positive relationship between education and non-life insurance demand levels. Ofoghi & Farsangi (2013) demonstrated a significant and positive relationship between risk aversion and auto insurance demand, in which those with insurance knowledge are more risk-averse.

This study is a result of investigations that began in 2014 to examine post-disaster reactions of the insurance market after Christchurch earthquakes. The study gives an empirical analysis of pre- and post-Christchurch earthquakes insurance reactions using survey data. The work focuses on the demand-side aspect of residential property insurance coverage. The key interest in the demand-side reaction centres on an analysis of the change in the level of insurance coverage, and variables that contribute to such changes. Changes in the level of insurance coverage are used to proxy the insurance demand response post-Christchurch earthquakes. In this analysis of residential property insurance demand, the study does not seek to calculate and/or estimate the insurance demand function post-loss. The study instead examines the change in level of insurance coverage by conducting a demand-side survey to tease out, purely, the insurance market response from the demand-side perspective. The study further investigates how various insurance demand determinant variables influence the change in the level of insurance coverage post-catastrophe using simple descriptive analysis and correlation analysis. The output of this study is crucial to the understanding of how insurance demanders have adjusted their level of insurance as a result of the contract modifications and the effects of insurance demand determinant variables post-disaster.

The rest of the chapter is organised as follows: Section 6.1 presents the hypothesis and research question studied in this chapter. Section 6.2 presents data and methods used in

this study. Sub-section 6.2.1 describes the data sources and data collection techniques used in the study. Sub-section 6.2.2 presents a detailed profile of the survey respondents. Sub-section 6.2.3 describes the data analysis process used in the analysis of the survey questionnaire. Section 6.3 presents the main results and discussions. Simple descriptive results to illustrate what happened after the earthquakes are presented in sub-section 6.3.1; while some simple statistical analysis results are presented in sub-section 6.3.2. Section 6.4 gives the conclusions and recommendations of the study.

6.1. Hypothesis and Research Question

This research presents a novel area of investigation from New Zealand residential insurance standpoint after the 2010-11 earthquakes. The study proposes a set of hypotheses and research questions to be investigated. The hypotheses are discussed from an economic analysis and simple descriptive perspective with appropriate statistical tests to explain how insurance demand determinants respond to catastrophe losses.

Hypothesis I. Insured assets and annual household income are positively associated with the annual premium insurance demanders are willing to pay for full residential property protection, and these have a positive influence on the change in the level of insurance coverage.

The objective of this hypothesis is to test if household income and property value affect the insurance premium the demander is prepared to pay for protection of residential property. In general, the test will show whether there is an association between these three variables by carrying out a descriptive analysis. This hypothesis draws from the findings in the prior literature. For example, in Tooth (2015), the implied income

elasticity for the take-up of house insurance is around 0.02, suggesting that after controlling other factors, a 1 percent increase in income would only result in a 0.01 to 0.02 percent increase in the likelihood a household buys house insurance cover. A similar study by Showers & Shotick (1994) used USA consumer expenditure survey to assess the effects of age, income and household characteristics on total insurance expenditure. They found insurance expenditure to be positively related to income, age and size of household and that the marginal importance of income is greater for small households.

Hypothesis II. Demographic characteristics of households are associated with and influence the change in the level of insurance coverage for residential property insurance in the aftermath of a major disaster.

Insurance consumer risk aversion is strongly affected by demographic characteristics like the value of insured assets, income, age, and education amongst other features. The degree of risk aversion is a key determinant of insurance demand. Here we use the demographic characteristics of survey participants to deduce a proxy for risk aversion. The main demographic characteristics of households of interest for this hypothesis include; age, gender, education, incomes, and property value.

In the insurance literature, the level of risk aversion is hypothesised to be positively correlated with the insurance consumption of an individual. Numerous empirical studies (Browne & Kim, 1993; Beck & Webb, 2003; Hwang & Gao, 2003) demonstrate a positive and significant relationship between insurance demand and the level of education which would imply that a higher level of education leads to a greater degree of risk aversion and greater awareness of the need for insurance coverage. However, in macroeconomic and cross-section studies, this hypothesis does not always hold and it

cannot be concluded that there is a positive correlation between risk aversion and the level of education. For instance, a survey by Outreville (2014) on the relationship between risk aversion and education shows a negative relationship. This implies that higher education leads to lower risk aversion, which in turn leads to more risk-taking by highly-educated individuals. Aliagha et al. (2014) examine the role of income level and education level while purchasing flood insurance for residential properties. Their study found that the propensity to purchase flood insurance increases significantly with income levels while education level does not make much difference. They suggest that the increase is likely a result of property owners suffering greater losses of wealth, accumulated savings from income, and from the previous catastrophic floods than increases their risk aversion. According to Guiso & Paiella (2008), households that face income uncertainty or that suffered losses of income from severe natural disasters show evidence of a greater degree of risk aversion.

Hypothesis III. Increases in both risk aversion and risk perception have a positive influence on the change in the level of insurance coverage for residential property owners in the aftermath of a major disaster.

Insurers assess risk by making best estimates of the frequency and severity of a hazard using statistical techniques or catastrophe models. However, an expert's generated risk perception information often has a minimal influence on decision making under risk by a layperson (Kunreuther et al., 2001). Some studies (Viscusi, 1985; Papon, 2008; Dumm et al., 2015) suggest that individuals often use heuristics and simple rules when they are assessing risk. Thus, individuals may judge an event as risky if it is easy to imagine or recall; for example, individuals who have had an experience of the Christchurch earthquakes may find it easier to imagine that a similar disaster could

happen again in the future and therefore report a higher perceived risk than individuals without this experience. An analysis of hypothesis III can be used to infer on the level of risks; whether individuals located in the epicentre of a disaster have a higher risk perception. It is postulated that properties in the epicentre of a disaster event are more likely to have higher levels of insurance coverage post-loss than properties that are far from the epicentre. However, if insurers use a risk-based underwriting approach, then it is expected that there would be a positive relationship between the perception of risk and the cost of insurance coverage, and a change in risk aversion and perception would have a positive influence on the demand for insurance by property owners in the aftermath of a major disaster. Thus, at higher levels of risk perception, both the price of coverage and the demand for insurance coverage would be higher.

The underlying research question examined in this chapter is, “What is the demand-side insurance market response after the Christchurch earthquakes?” A simple description of the survey responses is used to illustrate what actually happened to insurance demand-side related variables as a response to the Christchurch earthquakes.

6.2. Data and Methods

6.2.1. Data Source and Data Collection

Following the Christchurch earthquakes, many households left their damaged properties and moved to new suburbs or relocated to other cities. An online survey was considered as the most effective data gathering method for these households. An online survey questionnaire link was distributed through a random sampling of Christchurch dwellers using publicly available emails. The process of survey design began in February 2015. After a series of editing refinements, and taking into account all the comments and suggestions from varying stakeholders, the first draft of the

questionnaire was ready in May 2015. The University of Canterbury research code of practice requires that all data collection activities conform to the standard procedures for conducting household surveys. In this light, the process required survey approval from the University of Canterbury Ethics Committee which was cleared in June 2015.

A total of 1,600 individuals were surveyed through emails which were sent to them between September and November 2015. However, it was not possible to establish if all email addresses were still in use. A total of 254 survey participants completed the survey, representing a response rate of 16 percent. Sorting and cleaning of the completed questionnaires produced a total of 221 responses which could be meaningfully analysed. As a note of caution, the survey is probably not representative, given that the data was gathered from only four institutions (University of Canterbury, ARA Institute, Christchurch Airport and Christchurch Women's Hospital). However, representation was not the primary intention; the researcher needed some data to show insurance market responses from demand-side. The sample of interest only consisted of homeowners insured prior to the 2010-11 earthquakes, and these four institutions provided easily accessible email contacts which could be used for an online survey. Thus, the survey data is only intended to be illustrative, not necessarily representative of the entire population, but the survey participants in the sample were all affected by the earthquakes and they had some relationship with the insurance companies.

An initial pilot test was also conducted to ensure that the survey design and materials would capture the necessary data to meet the survey objectives. A focus group made up of 10 respondents was contacted to examine the response rate and to identify factors that affect participation and that might hinder accurate completion of the survey. The focus group results were used to revise the survey questionnaire and other respondent

materials prior to the full survey. Based on the pilot test results, improvements were made in the invitation email and minor text changes were made to the questionnaire wording.

6.2.2. Sample Profile

Table 6-1: Respondents by age group

Age group (Years)	%	Count
18 - 30	1.81%	4
31 - 40	6.33%	14
41 - 50	26.70%	59
51 - 60	38.01%	84
61 - 70	21.27%	47
Over 71	5.88%	13
Total	100%	221

Table 6-2: Respondents by gender

Gender	%	Count
Male	47.51%	105
Female	52.49%	116
Total	100%	221

Table 6-3: Respondents by level of education

Education level	%	Count
High school graduate	6.82%	15
Technical/University graduate	38.64%	85
Postgraduate degree	52.73%	116
Other	1.82%	4
Total	100%	220

Table 6-4: Respondents by annual income

Income (\$)	%	Count
Below 14,000	0.00%	0
14,001 - 48,000	5.88%	13
48,001 - 70,000	35.29%	78
Above 70,000	58.82%	130
Total	100%	221

Table 6-5: Respondents by property value

Value (\$)	%	Count
Below 300,000	6.36%	14
300,000 - 400,000	12.27%	27
400,000 - 500,000	16.36%	36
500,000 - 600,000	22.73%	50
600,000 - 700,000	12.73%	28
Above 700,000	29.55%	65
Total	100%	220

Table 6-6: Respondents by the maximum premium insured are willing to pay per annum

Premium (\$)	%	Count
Below 600	3.50%	7
600 – 900	14.50%	29
900 - 1,200	47.50%	95
Above 1,200	34.50%	69
Total	100%	200

6.2.3. Data Analysis

Analysis of the survey data is done in two parts. The first part, which forms the main findings of this survey, entails simple descriptive analysis. In this descriptive analysis of the survey respondents' responses, clear summaries of results are presented in the figures and tables below. The main purpose of this analytical approach is to exhibit, in a simple manner, what actually happened to insurance demand-related variables after the earthquakes. A chi-square test of independence is also used to examine differences in participants' responses where appropriate.

In most survey analyses, there are key explanatory variables of investigation that are often covariant. For example, in this survey response, an insurance demander's decision to change the level of insurance coverage is closely related to the value of the insured asset and supply-side policy conditions; which in turn may be a function of property value, age, gender, income education or risk perception that vary together with other insurance demand determinant variables. So, to isolate and investigate the effect of an individual variable, a robust statistical approach is normally preferred. However, due to the nature of the survey questions, and possible interactions of demand and supply determinant variables, the present study acknowledges the inherent statistical shortcomings that emerge when regression analysis is used on this data-set, and in particular, the problem of endogeneity has already been identified. Consequently, part two of this survey analysis presents a simple tractable statistical analysis: Correlation analysis of the demand determinants and associated variables is carried out.

6.3. Results and Discussions

6.3.1. Simple Descriptive Results

6.3.1.1. Change in the level of insurance coverage after the earthquakes

Respondents were asked whether they had changed their level of insurance coverage after the earthquakes. A summary of the results is shown in Figure 6-1. Of note, 41.7% of the respondents reported that they had increased their level of insurance coverage. However, the percentage of the respondents who indicated no change in the level of insurance coverage after earthquakes were much higher, 55.5 percent, whereas only a mere 2.8 percent of the survey respondents indicated they had decreased the level of insurance coverage after the earthquakes.

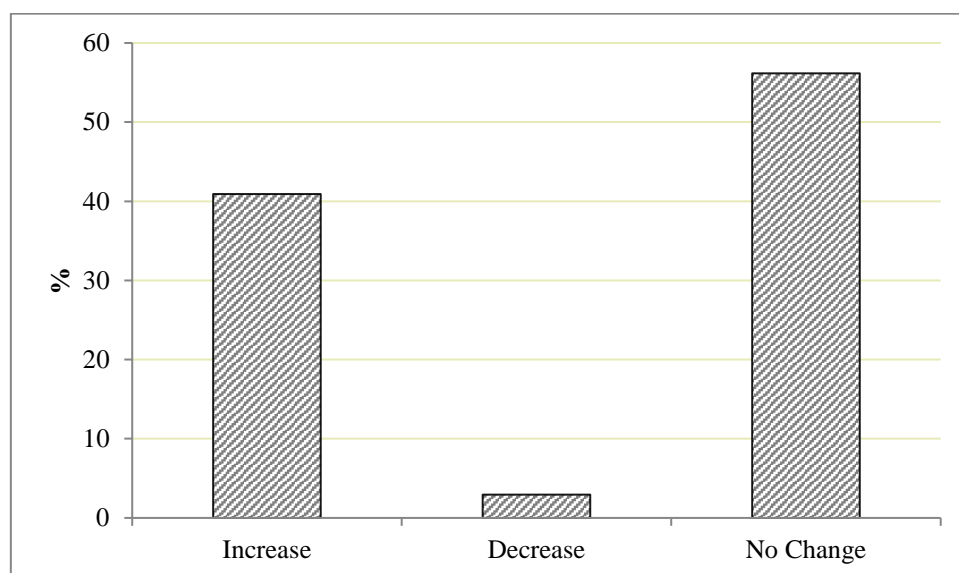


Figure 6-1: Change in the level of insurance coverage after the earthquakes.

Source: Q15-In the aftermath of the 2010 and 2011 Canterbury earthquakes how have you voluntarily changed the level of your past insurance coverage?

Base: 221 Survey respondents

A further assessment is inferred from the participants' response to the question about the reasons for the change of the level of insurance coverage. Respondents who had increased the level of insurance coverage were asked to indicate reasons for doing so. A summary of responses for both male and female participants are provided in Figure 6-2. Of note is that more female, 50.88 percent, survey participants reported an increase

in their level of insurance coverage when compared to male participants at 30.93 percent, who reported an increase in their level of insurance coverage. Figure 6-2 shows the percentage distribution of the specific reasons provided for the increase in the level of insurance coverage. “To cover a more valuable asset”, was most commonly nominated as a reason in both genders. A chi-square test of independence showed that there was a significant difference in the reasons both gender survey participants provided for an increase in the level of insurance coverage, $\chi^2(4) = 12.37, p < 0.01$. However, there was little variation of results across all the different demographic groups when variation across age, income, and level of education is examined.

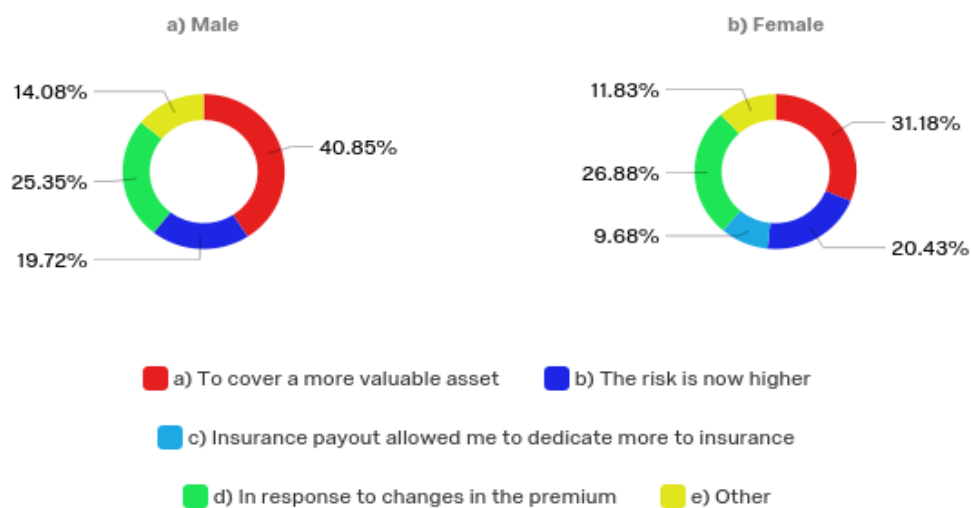


Figure 6-2: Reasons for increase in level of insurance coverage post-earthquakes by gender distribution.

Source: Q1-Which age group do you belong to?; and Q16-If increase, in response to Question 15 above; why?

Base: 88 Survey respondents

The respondents could choose multiple reasons and so the specific reasons provided add to more than 100 percent. A further analysis was undertaken on the comments provided by the survey participants who selected “Other” as a reason for an increase in the level of insurance coverage.

Some of the interesting comments provided by the respondents are:

- 1) Risk aversion (higher dollar coverage costs little extra on premium).

- 2) *This is tricky to answer because the insurance contract has changed form to a fixed dollar amount of cover versus full replacement previously.*
- 3) *Because I was required to set the value by the insurance company. Before that the value was not defined.*
- 4) *Total replacement policy not now applicable.*
- 5) *Insurance company changed to "total sum insured" basis.*
- 6) *Cover at previous level was insufficient for property.*
- 7) *I was forced to change type of cover, not voluntary at all.*
- 8) *We had to value the property ourselves - so the insurance concept has changed - it is no longer replacement value but the value we assessed was needed to replace it.*
- 9) *Being clear about definition of full replacement.*
- 10) *Full replacement cover is not available for natural disasters any longer.*
- 11) *The earthquakes highlighted the plight of those who were underinsured and I don't want that to happen to me.*

The examination of the change in the level of insurance coverage indicates that:

- The majority of the households in Christchurch marginally changed the level of insurance coverage as reported by the survey participants.
- The households' demographic features did not influence the decision to change level of insurance coverage as reported by the survey participants.
- The main reason for the change in the level of insurance coverage was changes in the format of supply, so the insurance demanders had to adjust coverage as supplied in the insurance market in order to reflect the new policy requirements.

These results also indicate that the change from a full replacement value type policy to a nominated replacement value type policy is clearly the key determinant of the direction of change in the level of insurance coverage after the Christchurch earthquakes. The comments provided by the survey participants focus mainly on the issues of changes in the policy format.

6.3.1.2. Change in the perception of probability of loss after the earthquakes

The survey participants were asked to identify their perception, in relation to their current residential property and contents insurance policy, of how the probability of loss from the occurrence of another earthquake had changed. Figure 6-3 shows that 44.1 percent of the respondents perceive the probability of loss from another earthquake had increased, whereas 23.7 percent of the sample perceives the probability had decreased, and 32.2 percent were neutral on neither increase nor decrease in their perception on the probability of loss from another earthquake. In support of these results, previous studies infer that many insurance demanders do not mathematically compute the level of risk, but rather they use heuristic rules to reduce the complex tasks of assessing probabilities and predicting values to simpler judgmental operations (Slovic et al., 1977; Rothschild & Stiglitz, 1992; Raschky & Weck-Hannemann, 2007). An assessment by Mileti & O'Brien (1992) found that survey participants who suffered damage in a natural disaster perceived the future risk as higher than those who did not.

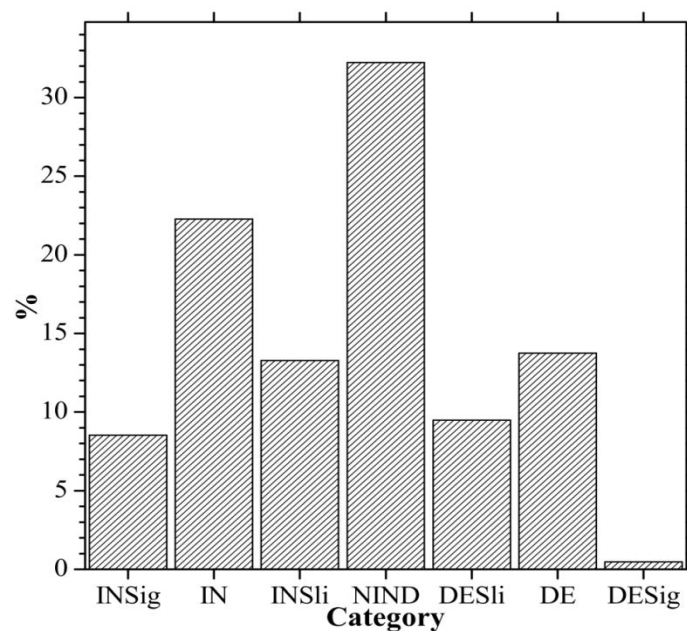


Figure 6-3: Probability of loss from another earthquake

(INSig– Increased significantly, IN – Increased, INSli – Increased slightly, NIND –Neither increased nor decreased, DESli–Decreased slightly, DE – Decreased, DESig– Decreased significantly)

Source: Q19-Based on your perception, in relation to your current residential property and contents insurance policy in the aftermath of 2010 and 2011 Canterbury earthquakes, how would you rate the overall changes in the following items?-Probability of loss from another earthquake.

Base: 221 Survey respondents

Previous research findings (Eeckhoudt & Kimball, 1992; Showers & Shotick, 1994) show that demand would increase with an increase in risk. Thus, the perception of risk helps the researcher to assess how past catastrophes impact insurance demand.

This research went further to cross-tabulate the data for these respondents based on gender to compare if there is any meaningful difference in how each gender perceives the risk of another earthquake. The gender distribution of male and female participants shows a significant association between gender and change in the perception of the probability of loss in the aftermath of the earthquakes, $\chi^2(6) = 2.83$, $p < 0.03$.

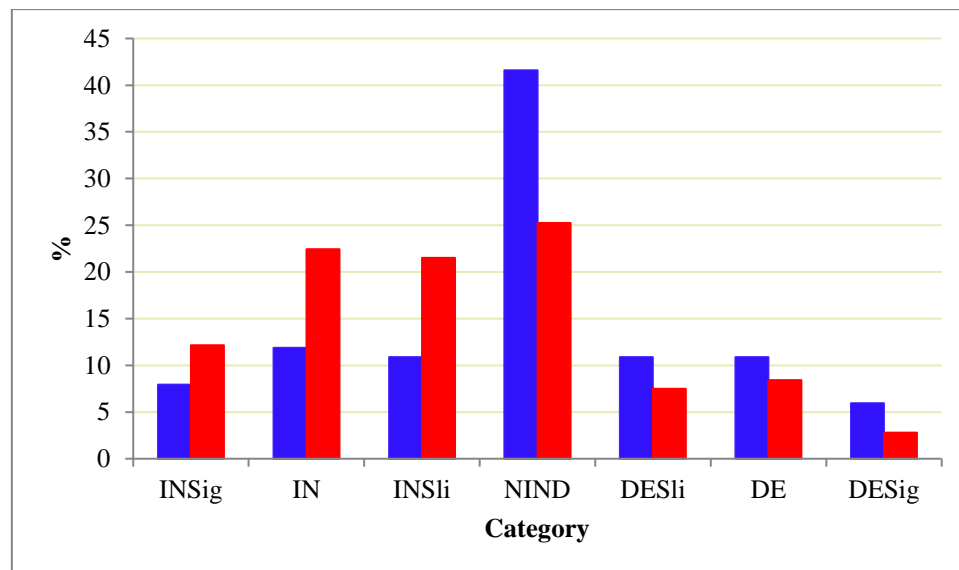


Figure 6-4: Probability of loss from another earthquake by gender (Male-blue, Female-red) distribution

(INSig– Increased significantly, IN – Increased, INSli – Increased slightly, NIND –Neither increased nor decreased, DESli–Decreased slightly, DE – Decreased, DESig– Decreased significantly)

Source: Q1-Which age group do you belong to?; and Q19-Based on your perception, in relation to your current residential property and contents insurance policy in the aftermath of 2010 and 2011 Canterbury earthquakes, how would you rate the overall changes in the following items?-Probability of loss from another earthquake.

Base: 221 Survey respondents

The results are presented in Figure 6-4 which shows that over half of the female, 56.07 percent, of the survey participants believed that the probability of loss from another earthquake was higher than before, whereas the percentage of those with a neutral point of view on the issue (i.e. probability neither increased nor decreased) was at 25.23 percent. The percentage was much lower for male; 30.69 percent of survey participants believed the probability of loss from another earthquake was increased, and a much higher percentage, 41.58 percent, were neutral (neither increase nor decrease). The main objective here is to illustrate the effects of insurance demand determinants in the response to the earthquakes. However, it is interesting to note that female participants reported a greater perceived likelihood of catastrophe loss from earthquakes in future. This is supported by previous studies on the existence of gender differences in the propensity to take risks and has been reported in a large number of the questionnaire and experimental studies. Byrnes et al. (1999) reviewed numerous studies on gender differences in risk perception. They concluded that the literature indicated that male participants are more likely to take risks than female participants.

6.3.1.3.Satisfaction rate with the policy modification after the earthquakes

In light of the findings on Question 15 and Question 16; the researcher examined the responses provided on both questions to assess how the survey participants viewed the policy modification. Respondents were asked about their satisfaction with the change in residential insurance contracts from a full replacement value type policy to a nominated replacement value type policy. The results show that the majority of the survey participants, 60.34 percent, reported that they were less satisfied with the policy modification. The percentage that was indifferent was much lower, 29.61 percent, while

a slight minority, 10.06 percent, reported being more satisfied with the policy modifications (Figure 6-5).

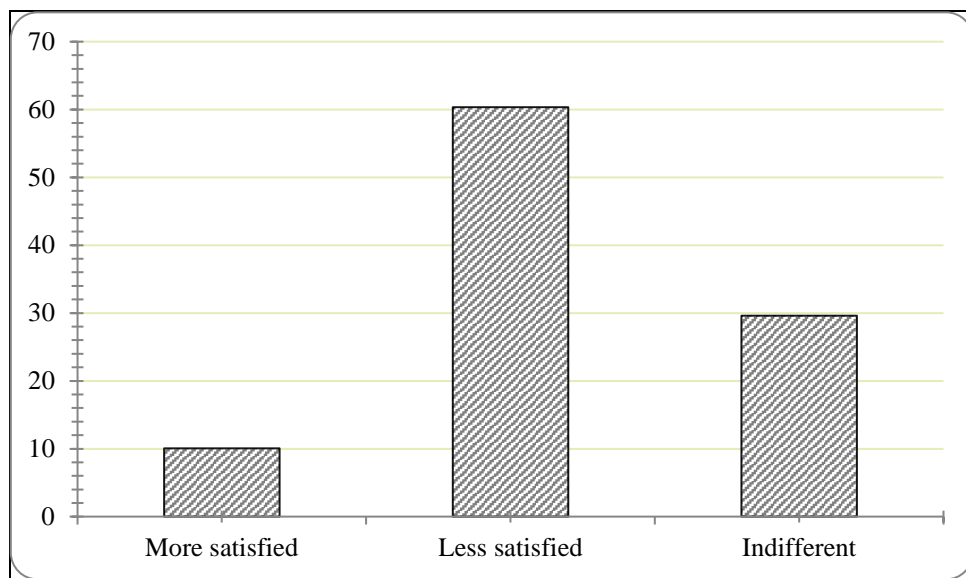


Figure 6-5: Satisfaction rate for the policy modification

Source: Q18-Comparing the new post-earthquake “sum insured” insurance coverage to the pre-earthquake “full replacement value” insurance coverage, how do you rate your satisfaction?

Base: 221 Survey respondents

These results suggest that many policyholders, as reported by survey participants, were generally negative about their own policy modification and the new requirement to value their property themselves. While it might not be surprising that policyholders have a high dissatisfaction rate with the policy modification, a low satisfaction rate within the insurance industry cannot be inferred generally. The insurance industry has, since 2012, reported an incremental increase in the gross written premiums across residential insurance cover, however, the amount of coverage written may not accurately represent satisfaction. It’s already known from the survey that many people increased coverage while being less satisfied.

Further examination revealed that older male respondents were more likely to be less satisfied with the changes. However, there was no evidence to suggest that the satisfaction rate would significantly vary with age, income, and/or level of education.

Figure 6-6 shows the participants' response to their satisfaction rate when examined across the gender distribution. These results demonstrate that in general, male participants were less satisfied when compared to female participants.

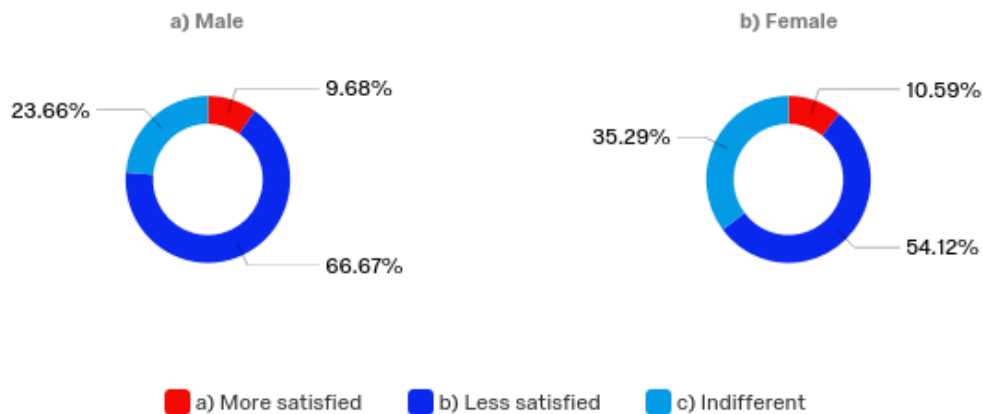


Figure 6-6: Satisfaction rate by gender distribution of the policy modification after the earthquakes

Source: Q1-Which age group do you belong to?; and Q18-Comparing the new post-earthquake “sum insured” insurance coverage to the pre-earthquake “full replacement value” insurance coverage, how do you rate your satisfaction?

Base: 221 Survey respondents

It is imperative to report that this survey demonstrates the opportunities provided by the changes introduced in the insurance market after the Christchurch earthquakes, and as such, some respondents reported that “the earthquakes highlighted the plight of those who were under-insured and I don’t want that to happen to me”. However, the findings reaffirm that under-insurance continues to be a problem, especially with the new changes in which the policyholders nominate their sum insured.

6.3.1.4.The availability of insurance coverage after the earthquakes

The survey asked two questions with regard to the availability of insurance coverage after the Christchurch earthquakes.

The two main concerns of the researcher are that:

- Insurance firms might have exited the New Zealand residential insurance market following the Christchurch earthquakes. In reference to other insurance markets,

numerous studies have documented insurance firms' withdrawal from markets prone to catastrophes in the aftermath of disasters (Klein, 2013; Born & Viscusi, 2006, and Aseervatham et al., 2015).

- Insurance demanders were most likely to have been denied insurance coverage following the Christchurch earthquakes. This is in line with previous studies that demonstrate that most insurance companies refused to offer coverage and/or retreated from markets prone to catastrophe losses because it is unprofitable to offer insurance cover against catastrophes in these high-risk markets (Raschky & Weck-Hannemann, 2007; Michel-Kerjan & Kunreuther, 2012; Kunreuther, 2015).

Survey participants were asked to comment on the availability of insurance coverage for their property after the Christchurch earthquakes. The results indicate that the majority of survey participants, 70.6 percent, felt that availability of insurance coverage had decreased in general. A smaller percentage, 25.6 percent, of the survey participants were neutral as to whether the availability of insurance coverage had increased or decreased, while only a minority, 3.8 percent, observed that insurance availability had increased post-earthquakes. Participants' response to this question raised curiosity, so the researcher sent a few emails to follow-up and/or to understand why so many participants reported a decrease in availability of insurance coverage, whereas the insurance industry statistics showed incremental growth in gross written premiums since 2012.

An analysis was undertaken to establish the reasons behind the higher percentage of responses that indicate insurance availability has decreased. It became clear that the availability of insurance policies did not change, but there was a change in the insurers' underwriting requirements, which pointed in the direction of dissatisfaction. From an underwriting perspective, post-earthquakes the insurers were seeking more

information, including the age of buildings, the spread of risk, construction, land and/or soil structure, the extent of strengthening work, and seismic reports. This array of new stringent underwriting requirements did not sit well with policyholders. To this end, the participants reported this dissatisfaction as if it were a reduction in the availability of insurance coverage. However, earlier on during the recovery period immediately after the Christchurch earthquakes, insurers were not taking on additional risk in Christchurch and so continued to provide coverage only to existing customers. The survey participants indicated that this practise remained in place for a period of six months to one year. Figure 6.7 presents a plot of the survey participants' responses on the availability of insurance coverage post-earthquakes. The results can be fully appreciated when interpreted together with responses to the question about those who had been denied coverage after the Christchurch earthquakes.

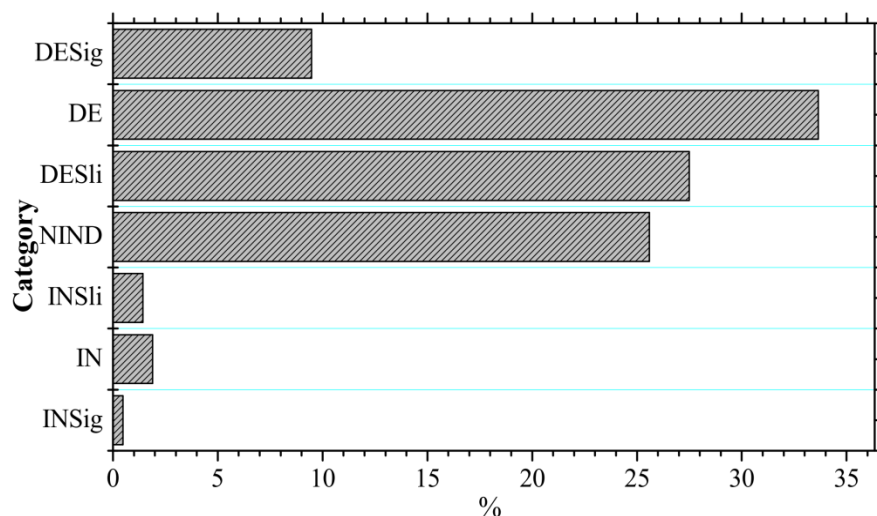


Figure 6-7: Availability of insurance coverage

(INSig– Increased significantly, IN – Increased, INSli – Increased slightly, NIND –Neither increased nor decreased, DESli–Decreased slightly, DE – Decreased, DESig– Decreased significantly)

Source: Q1-Which age group do you belong to?; and Q19 - Based on your perception, in relation to your current residential property and contents insurance policy in the aftermath of 2010 and 2011 Canterbury earthquakes, how would you rate the overall changes in the following items?-Availability of insurance coverage.

Base: 221 Survey respondents

Further analysis was undertaken to examine if there were cases when insurance demanders were denied coverage. Survey participants were asked if they had had a case

in which an insurer declined to offer coverage to protect their property. This survey question was very important to establish if there is any link between availability and accessibility of insurance coverage after the Christchurch earthquakes. The results are presented in Figure 6.8, which shows strong evidence that insurance demanders were not denied insurance coverage. The results show that a majority, 88 percent, of the respondents reported that they had never been denied insurance coverage, whereas only, 13 percent, had been denied insurance coverage.

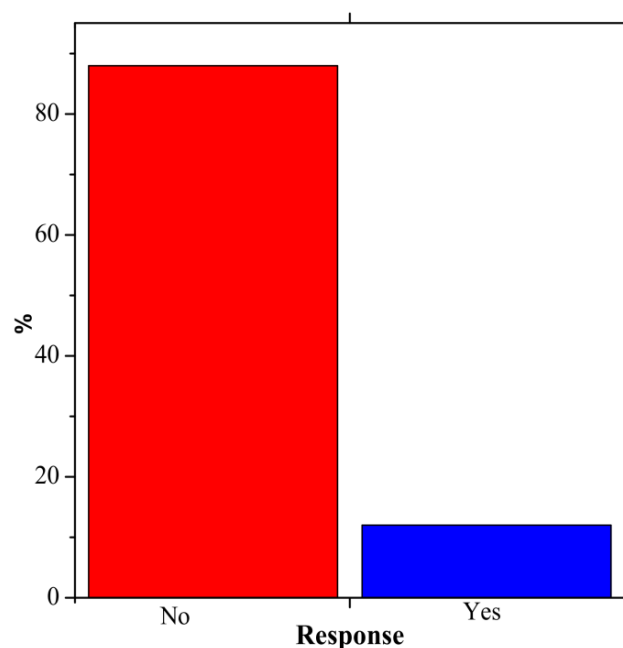


Figure 6-8: Cases where an insurance cover was declined

Source: Q23-*Have you had a case where an insurance provider declined to offer insurance coverage to protect your property against any potential risk?*

Base: 221 Survey respondents

Of particular interest is the extent to which the small percentage (13 percent) of respondents who were declined coverage went on to provide further comments stating the reasons for insurance coverage refusal. The response comments are: (i) Claimed on the driveway damage and now they will not cover the driveway to the same extent as before; (ii) Did not have a kitchen; (iii) Immediately after the February earthquake the company was not taking on any new insurance; (iv) New building - many companies would not undertake new policies; (v) No companies are taking on new customers; (vi)

No response to request for quote; (vii) Paid-out but not repaired therefore uninsurable except for public liability - yet fit to live in; (viii) Received payout - Company unwilling to offer 3rd party fire cover; (ix) Soon after the September 2010 earthquake and was not providing contents cover for Canterbury.

Following the earthquake, there was a lot of uncertainty on the extent to which the disaster would affect the insurance market from an underwriting perspective. The researcher observes that it is most likely that those who were denied coverage might have tried to seek cover within the period of moratorium when the insurers had placed a number of restrictions on undertaking new risks. The results are in line with the existing insurance studies suggesting catastrophes suppress insurance supply, but government intervention in disaster insurance provision improves the supply (Grace et al. 2004; Harrington & Niehaus, 2001; Doherty, 1997). In some markets, notably in catastrophe-prone states in the USA, price suppression depresses availability, inviting government intervention. Similarly, a study by Parker & Steenkamp (2012) immediately after the Christchurch earthquakes found that insurers had placed a moratorium on new residential insurance coverage in the affected regions in order to limit their exposure.

6.3.1.5.Change in insurance coverage per dollar and value of insured assets after the earthquakes

The survey also sought to investigate changes in the value of the insured assets. There is evidence that the value of insured assets is related to the perceived insurance coverage per dollar of property insured. This is premised on the fact that, following the Christchurch earthquakes, many property owners opted to re-build their structures to high earthquake standards in order to reduce the amount and cost of insurance. This

increased the value of the property, and also made the building more tenantable (Brown et al. 2013). A change in property values in disaster-prone areas is also reported clearly in Dumm et al. (2012). Two variables, the change in insurance coverage per dollar and the change in the value of insured assets, were examined to probe these effects after the earthquakes. For the first variable, survey participants were asked, “Do you perceive insurance coverage per dollar of property insured is greater now than before the earthquakes?” A summary of the results is presented in Figure 6-9. Approximately 58 percent of respondents believed that the insurance coverage per dollar of property insured was greater than before the earthquakes. The percentage of respondents who perceived that their insurance coverage per dollar of property insured was not greater than before the earthquakes were much less, 30.5 percent, whereas only 11.5 percent of the respondents were not aware of how their insurance coverage per dollar of property insured had changed.

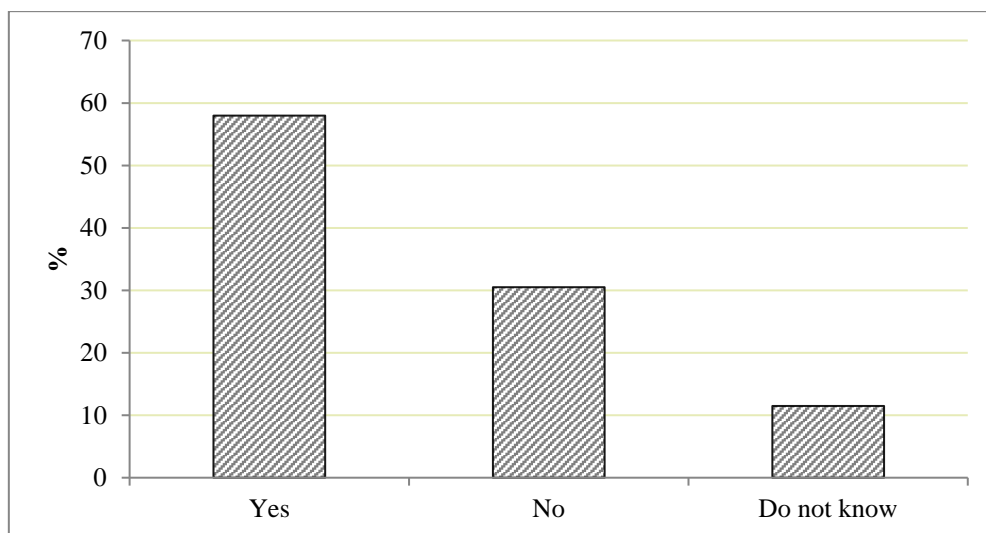


Figure 6-9: Change in the insurance coverage per dollar of property insured

Source: Q14-Do you perceive insurance coverage per dollar of property insured is greater now than before the earthquakes?

Base: 221 Survey respondents

For the second variable, survey participants were asked, “How would you rate the overall changes in your property value?” The results are presented in Figure 6-10. The

results observed indicate a sharp increase in property values after the earthquakes. In general, the majority, 70.7 percent, of respondents reported an upward change in property value. Only, 14.7 percent, reported no change in property value and a similar percentage reported a negative change.

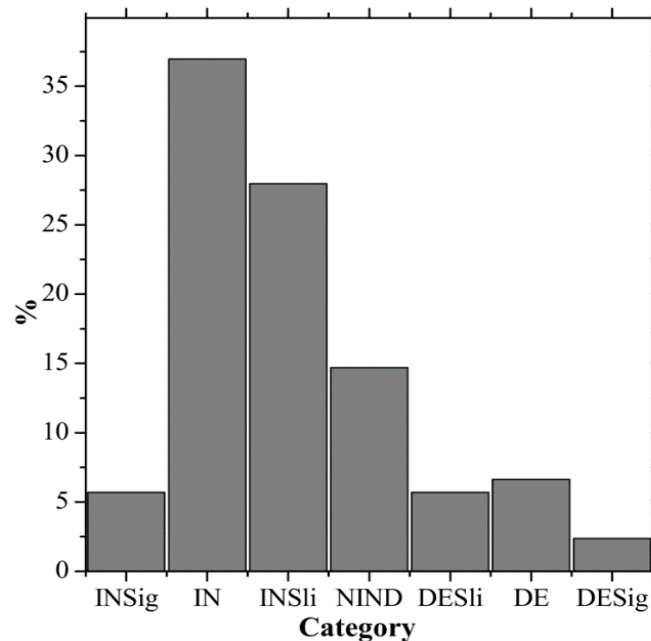


Figure 6-10: Insured property value post-earthquakes

(INSig– Increased significantly, IN – Increased, INSli – Increased slightly, NIND –Neither increased nor decreased, DESli–Decreased slightly, DE – Decreased, DESig– Decreased significantly)

Source: Q19- Based on your perception, in relation to your current residential property and contents insurance policy in the aftermath of 2010 and 2011 Canterbury earthquakes, how would you rate the overall changes in the following items?-Property Value.

Base: 221 Survey respondents

This result is consistent with observations from similar studies (Browne & Hoyt, 2000; Kelly & Kleffner, 2003; Powell & Harding, 2009) showing post-loss responses improves the coverage per dollar of insured asset. However, Parker & Steenkamp (2012) found that property prices suggested that the loss of residential properties outstripped the loss of population, generating some excess demand for housing around the Canterbury region. It can be inferred that rational property buyers' behaviour in regard to residential insurance should reflect price-efficient policies relative to disaster risk exposure. Thus, this survey highlights the possibility that, in general, higher

property values and greater insurance coverage per dollar of insured assets after the Christchurch earthquakes is a reflection of an increased level of insurance coverage and/or a higher insurance demand. This is also supported in past studies (Nelson, 1994; Kelly & Kleffner, 2003) which shows that consumers would choose an insurance policy that yields the highest benefit per additional dollar of insurance expenditure holding other factors constant.

6.3.1.6. Change in expenditure on insurance after the earthquakes

A further question of interest is to examine how household expenditure on insurance responded to the changes in the insurance market after the earthquakes. Respondents were asked, “How would you rate the overall changes in your money spent on insurance?” To this end, the question seeks to investigate how the policyholder generally changed their expenditure on insurance, in order to depict how the earthquakes affected households’ expenditure associated with insurance coverage.

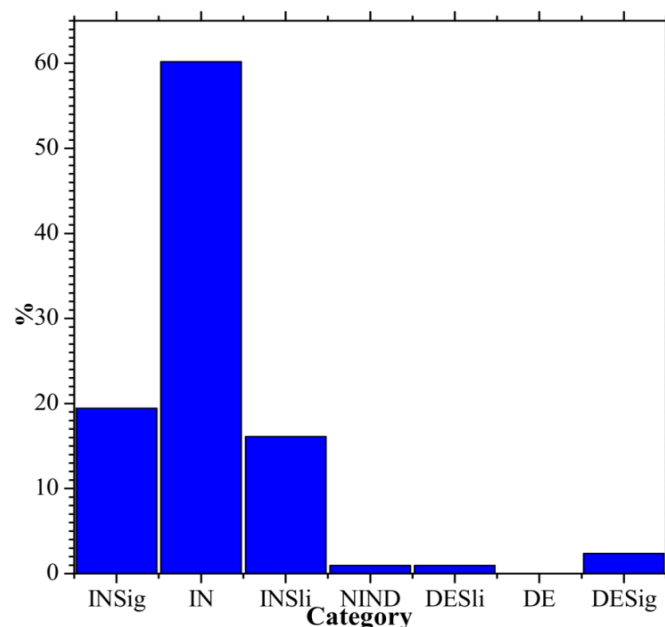


Figure 6-11: Expenditure on insurance

(INSig– Increased significantly, IN – Increased, INSli – Increased slightly, NIND –Neither increased nor decreased, DESli–Decreased slightly, DE – Decreased, DESig– Decreased significantly)

Source: Q19- Based on your perception, in relation to your current residential property and contents insurance policy in the aftermath of 2010 and 2011 Canterbury earthquakes, how would you rate the overall changes in the following items?-Money spent on insurance.

Base: 221 Survey respondents

Figure 6-11 presents a summary of the respondents' responses to the changes in the expenditure on insurance in the aftermath of the earthquakes. The results show that the vast majority, 95.7 percent, of the survey participants had increased the total amount of money they spent on insurance post-quakes, and only 3.3 percent indicated a decrease in money spent on insurance. The result of money spent on insurance when linked with the household profile indicates that expenditure on insurance increases with greater incomes and greater property value. Moreover, Figure 6-11 presents the relationship between the increase in premiums post-quakes and the increase in insurance expenditure; respondents were asked, "How has the total premium you pay for residential property insurance changed from pre-earthquake period to post-earthquake period?"

In Figure 6-12, 93.85 percent of respondents reported a premium increase after the earthquakes.

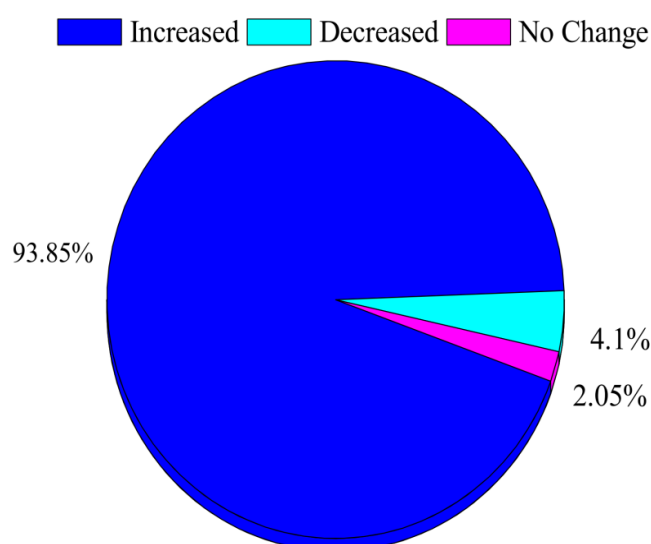


Figure 6-12: Change in premium rate

Source: Q13-How has the total premium you pay for residential property insurance changed from pre earthquake period to post-earthquake period.

Base: 221 Survey respondents

The results lead the researcher to postulate that the increase in insurance expenditure might be linked to increased premium rates rather than to a change in level of insurance coverage and/or insurance demand.

There are very few studies that have looked at household expenditure on residential insurance coverage post-loss. Dionne & Eeckhoudt (1985) showed that increases in risk aversion post-loss result in an increased household expenditure due to both loss-reduction measures and insurance activity. In a related article, Kleffner & Kelly (2001) noted that if post-loss premiums are not risk-based, then insureds will invest less in insurance or self-insurance. These results help to understand the effect of a disaster on the amount of household income to be spent or allocated for insurance.

6.3.2. Simple Statistical Analysis Results

This section starts by presenting the summary results and discussions of a descriptive analysis on Hypothesis I: Insured assets and annual household income are positively associated with the annual premium insurance demanders are willing to pay for full residential property protection, and these are postulated to have a positive influence on the change in the level of insurance coverage. The results of the test of Hypothesis I are reported in Table 6-7.

Table 6-7: Relationship between Variables to Test Hypothesis I

Relationship between variables to test Hypothesis I	Coefficient	p-value	No. of obs.
Premium versus Income	0.233*	0.001	221
Premium versus Property value	0.536*	0.000	221

*, Correlation is significant at the 0.01 level (2-tailed).

Source: Q4-Annual income; Q8-What is the approximate value of your property?; and Q11-What is the maximum premium you are willing to pay per annum to fully protect your residential property and contents from natural disasters through insurance coverage

Base: 221 Survey respondents

Referring to the first hypothesis, the computed correlation coefficient value for premium versus income is reported in Table 6-7 as 0.233 and the associated p-value is 0.001. The observed p-value is less than alpha value, $p\text{-value} = 0.001 < 0.05$, indicating that the results are statistically significant. While the data is significant at the 0.05 level, the computed coefficient value is closer to 0 than to +1. Based on the results, $R = 0.233$, $N = 221$, $p\text{-value} = 0.001$, it can be inferred that there is a weak positive linear relationship between the annual premium insurance demanders are willing to pay and their annual income. The weak relationship between premium and income is not surprising given that the analysis excludes other variables such as the value of contents, age, gender and education that are closely correlated to income. The results for income versus premium are consistent with the analysis on house insurance in that, controlling for other factors, income by itself should not be a major determinant of demand for insurance cover or the amount of premium demanders are willing to pay (Kriesel & Landry 2004; Kousky, 2010; Petrolia et al., 2013).

Similarly, the computed correlation coefficient value for premium versus property value is reported in Table 6-7. The correlation coefficient value is 0.536 and the associated p-value is 0.000. The observed p-value is less than alpha value, $p\text{-value} = 0.000 < 0.05$, and therefore, from the results ($R = 0.536$, $N = 221$, $p\text{-value} = 0.000$) it can be concluded that the study finds a statistically significant, strong positive linear correlation between the annual premium an insurance demander is willing to pay to fully protect property and contents, and the value of that property.

The results of the tests on research Hypothesis I show moderate relationships between the amounts of premium insurance demanders are willing to pay and annual household income. There is a strong positive linear association between the amounts of premium

insurance demanders are willing to pay and the property value. Although the hypothesis does not examine the influence of the property value on insurance take-up rates, it is observed that an increase in the value of property increases the average level of insurance coverage, holding all else constant. These results could thus imply that the level of insurance coverage and/or insurance demand is a function of wealth (as measured by property value) and income.

We also consider Hypotheses II; The demographic characteristics of household are positively associated with, and influence, the change in the level of insurance coverage for residential property in the aftermath of a major disaster (where the main demographic factors examined are: age, education, gender and income), and Hypotheses III; Increases in both risk aversion and risk perception have a positive influence on the change in the level of insurance coverage for residential property owners in the aftermath of a major disaster. The computed correlation coefficient value for a change in the level of insurance coverage versus household demographic features and the individual's risk perception are reported in Table 6-8. The coefficients and associated p-values of changes in the level of coverage versus risk perception, insured assets, income and gender are positively correlated and statistically significant. This observation is in agreement with most existing studies. For example, Lee et al. (2010), Showers & Shotick (1994), and Truett & Truett (1990) showed that income and insured assets were positively related to the demand for insurance in property insurance cover. Likewise, age, education and gender are shown to be positively related to insurance demand for both life insurance and auto-insurance as reported by Lee et al. (2010). This alone does not provide conclusive evidence that demographic features influence changes in the level of insurance coverage. However, the correlation coefficient offers

an opportunity to understand and further investigate how both the response variables and the explanatory variables are interrelated.

Table 6-8 shows no statistically significant differences in insurance coverage by age and education; the only demographic variables that have a significant association with change in the level of insurance coverage is gender. In reference to the second hypothesis on the demographic variables, only gender shows a relationship with changes in household insurance cover, and as far as the third hypothesis is concerned, a change in risk perception also influences the demand for residential insurance cover in the aftermath of a natural disaster.

Table 6-8: Relationship between Variables to Test Hypothesis II and III

Relationship between variables to test Hypothesis II & III	Coefficient	p-value	No. of obs.
Change in the level of insurance coverage versus Age	0.373	0.427	221
Change in the level of insurance coverage versus Education	0.469	0.118	221
Change in the level of insurance coverage versus Gender	0.301*	0.034	221
Change in the level of insurance coverage versus Income	0.207**	0.008	221
Change in the level of insurance coverage versus Property value	0.861**	0.000	221
Change in the level of insurance coverage versus Risk perception	0.526**	0.001	221

** . Correlation is significant at the 0.01 level (2-tailed).* . Correlation is significant at the 0.05 level (2-tailed).

Source: Q1-Which age group do you belong to?; Q3-Highest level of education; Q2-What is your gender?; Q4-Annual income; Q8-What is the approximate value of your property?; Q19-Based on your perception, in relation to your current residential property and contents insurance policy in the aftermath of 2010 and 2011 Canterbury earthquakes, how would you rate the overall changes in the following items?-Probability of loss from another earthquake; and Q15-In the aftermath of the 2010 and 2011 Canterbury earthquakes how have you voluntarily changed the level of your past insurance coverage?

Base: 221 Survey respondents

6.4. Conclusions and Recommendations

This survey has examined the fundamental insurance market responses after the Christchurch earthquakes from the demand-side perspective. The results of this analysis show that, the change from full replacement value type policy to nominated replacement value type policy is the key determinant of the direction of change in the level of insurance coverage. According to the outcome of the analysis, it is evident that most policyholders increased the level of insurance coverage so as to comply with the

new policy modification. However, other varying reasons for change in the level of insurance coverage are also observed. More essentially, the earthquakes highlighted the plight of those who were underinsured prompting policyholders to update their insurance coverage to reflect the estimated cost of re-building their property.

The survey has added further evidence to the existing literature that insurance policyholders update their risk perception immediately after major catastrophe losses. Those who have had a recent experience with disaster loss report increased risk perception that a similar event could happen in future with females reporting higher risk perception than males.

This analysis has also highlighted new results to the literature on the availability of insurance coverage after a major catastrophe event. While most studies have reported decreased insurance supply post disaster loss, this study presents new opportunities from an underwriting perspective. The findings show that a short period of moratorium immediately after the earthquake helps the insurance market to understand the new risk exposures and put in place stringent measures to provide insurance coverage for new risks. This is not always received well by the policyholder based on the comments of the survey respondents' responses. Post-earthquake property remedies are reported to be important tasks to improve the value of the insured asset as well as keeping the cost of coverage affordable under new stringent risk-based underwriting approaches.

There is a causality relationship between gender and the changes in household insurance cover. However, the exact direction of change is still ambiguous. The relationship would depend on insureds' degree of risk aversion and how it changes with changes in the level of income, the change in value of insured assets and the change in insurance premiums. Of interest is that, the sampling strategy adopted in this

investigation is helpful in that, the four institutions sampled with predominantly skilled and high-income individuals reduces variation that could otherwise be caused by genders holding very different roles. A proposition is that, the direction of the effect depends on whether an increase in income increases the value of insured asset, and on whether the insurance demander has increasing or decreasing absolute risk aversion. In this case, it would be implicitly assumed that the level of risk aversion has an impact on decisions made post-disaster and hypothesised that both risk aversion and perception will be positively correlated with change in the level of insurance coverage at all levels of income. Thus, if insurance demanders perceive a higher possibility of further natural disasters then they will always adjust their insurance coverage appropriately. A more comprehensive data set and robust econometric analysis is required to rigorously investigate this proposition.

As the composition of Christchurch dwellers evolves, and the city gets back to its pre-earthquake state, changes in households' demographic characteristics will affect the demand for property insurance cover. Those households who have had experience with the Christchurch earthquakes may find it easier to imagine that the disaster could happen again in the future; an indication of higher risk perception than for households who have not had this experience. Higher risk perception amongst risk averse property owners will lead to an increase in natural disaster insurance and other alternative natural disaster risk mitigation measures. Nevertheless, the results of this study comprise useful information about variables that have an influence on the change in the level of insurance coverage and/or insurance demand in the aftermath of a major catastrophe, and can have beneficial implications for insureds, insurers, policymakers and other stakeholders.

CHAPTER SEVEN

7. A RISK-BASED PRICING MODEL FOR NATURAL DISASTER RISK: AN ACTUARIAL PERSPECTIVE FOR RESIDENTIAL INSURANCE COVER

7.0. Introduction

This chapter presents a pragmatic approach that can be used in the rate-making of fire and general cover for residential property with natural disaster risk as a rider. This is an actuarial risk-based pricing perspective that takes into consideration the key features of New Zealand's natural disaster insurance as provided by the Earthquake Commission (EQC). This study uses 2010-11 Christchurch earthquake claims data for the red-zoned properties as an illustrative empirical example of how the model can be used. The posed pricing model will, in the end, generate a technical risk premium rate that can be used either as a benchmark for adjustment to generate an office premium, or as an appropriate theoretical guideline of where the office premium should gravitate to.

The rest of the chapter is organised as follows: Section 7.1 introduces the challenges faced in the provision of insurance for natural disaster risks, and how the New Zealand insurance market copes with these challenges. Section 7.2 describes the current paradigm in natural disaster insurance pricing and the opportunities provided by the proposed pricing model. Section 7.3 presents the model's framework. This section also gives a discussion of the actuary's role in insurance pricing and demonstrates how the model fits in New Zealand's residential insurance coverage using empirical claims data from earthquakes disasters. Section 7.4 gives the conclusions and recommendations.

7.1. Challenges Faced in the Provision of Natural Disaster Insurance

Insurance markets play a crucial role in managing global natural disaster risks. This happens by both spreading large catastrophic losses associated with natural disaster events, and by providing incentives to encourage risk reduction efforts as well as providing the necessary rebuilding funds in the aftermath of catastrophic losses. The biggest challenge to insurers as they provide catastrophe loss coverage is how to underwrite and produce competitive and fair office premiums for natural disaster risks. The uncertainties of natural disasters pose a different set of risks, responsibilities, and responses by insurance markets. This complicates the underwriting and rate-making process even for the most experienced underwriter. While most global insurers and reinsurers do provide natural disaster risk coverage, it is increasingly becoming unaffordable for most insureds (Kousky and Cooke, 2012). This implies that most of insurance-demanders find it difficult to access affordable coverage for their homes, leading to mass lack of insurance, or an under-insurance problem. The risk posed by many people living in disaster-prone areas being un-insured or under-insured and the economic externalities and social chaos that would occur is increasingly pushing the government to take an active role in the provision of natural disaster insurance coverage.

Despite the government interventions in natural disaster insurance, the ability to accurately calculate the probability of natural disaster events occurring, and the magnitude of the losses that may result is still undoubtedly a challenging task from an underwriter's perspective. To help address some of these challenges, this study presents a pragmatic risk-based premium pricing approach. When this model is adequately

adjusted to specific market characteristics, then it can be used for natural disaster rate-making in any catastrophe prone insurance market.

Besides stringent risk-based underwriting measures, other common rate-making requirements to address natural disaster loss include, first, the physical infrastructure of the built environment strengthening to high seismic or flood requirement standards to offset property damage and by extension, injury and death following an earthquake or floods. Second, the insurance industry infrastructure (both private and public) to put in place substantial capital to assist in recovery and re-build in the aftermath of major natural disaster (Ericson and Doyle, 2004). However, of the two extra measures both shock-resistant physical infrastructure and an insolvency-resistant insurance market entail additional uncertainties due to the uncertainty of the magnitude of disasters and related financial impacts when these events occur. A study by Ericson and Doyle (2004) demonstrates that there are several data limitations with respect to when and where a catastrophic such as an earthquake will occur and the probable maximum loss (PML) it will cause. Large magnitude earthquakes are rare and occur without warning. This makes data collection difficult especially from countries without appropriate automate seismic data monitoring centres. Fortunately, New Zealand has very advanced modern seismographs to measure the magnitude, location and characteristics of earthquakes in real time. Notwithstanding the sizable historical data on seismic events in New Zealand, accurate translation of the data into a specific contemporary setting for insurance underwriting remains scant. This implies that there is still a high prevalence of uncertainties associated with earthquake risk analysis and how this could be used in underwriting in New Zealand insurance market to generate risk-based premiums. Studies by Brown et al. (2013, 2016) show that, prior to the 2010-11 Christchurch earthquakes, there was very limited risk-based insurance premium pricing in New

Zealand. Some underwriters are now requesting for more information like the age of the property, spread of risk, nature of construction, land and/or soil structure, extent of strengthening work and seismic report where possible. Even with all this information, technical provisions on the frequency and severity of catastrophes are open to competing interpretations due to the subjective manner in which historical data are compiled and interpreted. It is therefore very crucial for catastrophe risk underwriters to create a sense of objective knowledge out of their incomplete subjective assessment and different interpretations of historical loss data. While the underwriting and rate-making of extreme disaster events should be risk-based, this should also be supplemented by a mixture of creative innovative skills in order to generate affordable premiums which when invested and accumulated can be used to offset major catastrophe loss claims.

To tackle the inherent nature of spatially concentrated natural disaster risk, New Zealand insurers participate in elaborate reinsurance arrangements. This also ensures that the huge capital that is required to fund catastrophic losses is available across all classes of business. The international reinsurers, in turn, spread the load amongst themselves by only taking a portion of the underwriters' risk. The reason why reinsurers take on less than 100 percent of the underwritten catastrophe risk themselves can be examined from the underwriting margin perspective. This can be done by comparing the insurer's underwriting margin over a range of loss ratios on the original un-reinsured portfolio to the reinsurer's underwriting margin over the same range of loss ratios. The insurer's underwriting margin can be defined as 100 percent less its un-reinsured loss ratio less its incurred expense ratio on the un-reinsured portfolio. Whereas the reinsurer's underwriting margin can be defined as 100 percent less its assumed loss ratio less the ceding commission. If the insurer's margin equals or exceeds the reinsurer's

margin for the loss ratios that imply an underwriting loss, then clearly the reinsurer has assumed substantially all of the insurer's catastrophe downside risk. Thus, to adequately determine how much reinsurance cover insurers require, insurers must make an appropriate estimate of the PML of their insurance portfolio or use the market experience to determine their retention limit.

In most cases, insured losses are equivalent to the insurance cover contracted, in which case the PML would equal the total cover. This is certainly the case with the new nominated value policy type now in place in New Zealand insurance market. Alternatively, insurers can still conservatively assume that the risk of a total loss of insured property can be discounted and so the PML can be set at a lower value. For catastrophe losses such as an earthquake, where there is a potential accumulation of losses, an inherent challenge is posed. In a diversified insurance portfolio, in which the degree of correlation between the individual risks has been controlled, the PML should reflect that diversification and be much less than the aggregate of the insured risks. Thus, the choice of appropriate retention level is mostly determined by the insurer of the insurance contract under consideration. Insurers will use their judgement and experience to decide the best and competitive retention level. To this end, the aim of the choice of particular limit is more likely to balance the relationship between profits and stability, rather than to reduce the risk that capital is exhausted, which indirectly enforces incentive compatibility on both the insurer and the reinsurer. The probability of ruin is not a concept which becomes of immediate concern to a pricing actuary at this stage. However, as the capital at risk approaches 100 percent of premium, then there is a rapid increase in the retention limit and a reduced need for reinsurance coverage.

To adequately arrange for reinsurance coverage, New Zealand private insurance companies and the EQC typically have treaties with several reinsurers which is in line with other disaster-prone insurance markets. The reinsurers in turn spread their risk load amongst themselves and through the large insurance syndicates that trade at Lloyd's of London. This points to the fact that New Zealand insurers participate in the global reinsurance market extensively. Even with the extreme natural disaster experiences in New Zealand, this network of insurance, reinsurance and retro-reinsurance mechanisms keeps the market afloat due to the extensive footprint in the global reinsurance market.

Another key area in which the government helps is in the provision of natural disaster provision is through construction regulation under a common building code. For example, in the aftermath of Christchurch earthquakes, the Christchurch City Council issued new 67 percent earthquake strengthening standards as a compulsory target for all earthquake-prone buildings (Galloway and Hare, 2012). While these measures may not exclusively be a key requirement for the residential insurance policy contract, they are vital in the underwriting process. Homeowners can also be offered lower premium rates as incentives and rewards in commensurate with mitigation measures put in place. These measures have made insurability of natural disasters affordable and available for residential property owners in New Zealand.

7.2. Current Paradigm in Natural Disaster Insurance Pricing

This study proposes a pragmatic risk-based pricing model which seeks to address some of the challenges highlighted above. The proposed model appreciates that the premium rate generated should be sufficient to fully indemnify the contracted policy liability, make a reasonable profit margin without subjecting the in-force business to unreasonable solvency constraints, and at the same time generate competitive rates in

the insurance market faced. This implies that the premium rate should be much higher than the expected loss because the insurer has to provide a large amount of capital in case of extreme catastrophic events. In highly uncertain situations like these, the previous trend has been that of insurers inflating premiums; this is clearly discussed in Kunreuther et al. (1995). A popular approach currently in many insurance markets is that insurers are pricing and/or underwriting natural disaster risk in terms of local market trends and reinsurance requirements, rather than in line with actuarial principles of PML and statistical loss models (Bin and Landry, 2013). When the insurance demand surges, the private insurance companies rely on the seller of reinsurance as the price setter more so for catastrophe risk. Spatially correlated losses from catastrophe events imply that there is very minimal or no risk diversification within the insurance portfolio. Thus, on the one hand, relying on reinsurance markets to set the premium rates due to their global capability and experience in diversification of risk seems a desirable measure, but on the other hand, this compromises the need to use an independent risk-based pricing approach to underwrite risks on their merits. The proposed pricing model deals with these challenges by providing an opportunity to incorporate the technical aspect of catastrophe risk to premium rates.

7.3. Model Framework and Discussions; an Actuarial Perspective

7.3.1. Actuary's Role in General Insurance Pricing

Actuarial pricing entails the determination of the technical basis necessary for the premium rate charged on the underwritten risks (Straub and Actuaries, 1988). Like any other business venture, an insurance company is a business that expects returns on investment. Therefore, the rate charged must be sufficient to pay for the expected claims payouts, office overheads and earn some profit margin as well. Adequate premiums

should also be able to withstand volatility associated with the insurance business. This implies that insurers will seek to maximize profits, preferably by setting an actuarially unfair premium. However, insurance regulators in each market have local policy guidelines and provisions on how the underwriting process should be done. In this case, the pricing actuary is restricted to the assumptions that can be used in the pricing model. For example, the comprehensive Solvency II directive regulates insurance markets in the EU region on pricing, valuations and reserving. In the presence of strict regulation, the actuary's pricing role reduces to a calculation of risk premium sufficient to keep the insurance portfolio solvent. The risk premium would constitute part of the premium necessary for anticipated claims payouts, and the proportionate cost associated with these claims. One major cost associated with claims includes the amount paid by the insurer to investigate and settle claims including loss adjustments effects when a loss event occurs. The claims payouts and the associated claims cost would heavily depend on the mean expected loss based on the assumption that future claims costs do not deviate much from historical claims data. The underwriting insurer can then decide on the loading adjustments component of the premium necessary to cover other expenses, particularly office expenses, reinsurance costs and a reasonable profit margin on the risk premium rate to generate the gross premium, which when multiplied with the exposure per unit generates the premium insureds pay on a particular policy. The pricing process can, therefore, be summarised into two stages. The first stage is the estimation of the loss distribution and the associated moments of the loss, and the second is incorporating all the rate-making factors, expenses and margin loading in the pricing model. Essentially, the second stage is a cost mark-up process as opposed to a profit maximising price setting given demand. In such a case, a hypothetical underwriter could set the price equal to mean expected loss plus some reasonable profit

margin that can be expressed as premium rate times a mark-up rate. In economic theory, there are different theoretical treatments of mark-up pricing, for example Bain (1956), Modigliani (1958) and Baron (1973) have long argued that price and mark-up function as barriers to market entry set up by incumbents who wish to deter potential competitors. In this limit-pricing process, prices are set above the costs but below prices at which potential competitors could enter the market and earn positive profits. From an economic theory perspective, pricing depends on many factors such as the degree of concentration, economies of scale, product differentiation, the absolute cost advantages of incumbents, and to some extent the elasticity of demand. This means the loading for an insurance contract will be reasonably similar to the standard loading of risky assets.

In practice, the loss distributions are selected based on past and current loss experience using the available data and/or through simulation process. This reiterates the need for cautious modelling using the historical loss data because systemic changes may have occurred such that prior catastrophes are no longer representative of the future. These systemic changes may involve both frequency and severity of the loss. For example, climatic and seismic changes may either increase and/or decrease the frequency and/or the severity of various catastrophe losses. Keen et al. (2003) gives clear reasons to believe that the coming years will see an increase in the frequency and severity of natural disasters. Similarly, economic and demographic changes may affect catastrophe losses in respect to the severity of the loss. This challenge can be overcome by adjustments for the main systemic changes involving the frequency and severity of catastrophes and better assumptions so that the predictive loss distribution is based on a statistically sound modelling framework.

7.3.2. How the Model Fits in New Zealand's Residential Insurance Coverage

7.3.2.1. Background of Residential Insurance Cover in New Zealand

This section examines the framework and formation of the natural disaster insurance in New Zealand which is offered as a rider on fire and general peril coverage. Residential property and contents insurance coverage in New Zealand is constituted of two layers of insurance contracts run in a dual-insurance system. The first contract layer is covered by EQC, while the second contract layer is covered by the private insurance market.

The EQC scheme currently provides EQC cover for insured residential property damaged by earthquake, volcanic eruption, hydrothermal activity, landslip, tsunami or fire caused by natural disaster. Maximum cover for each event is up to \$20,000 plus GST for personal property (contents) and \$100,000 plus GST for each dwelling. The government believes that without something like the EQC scheme, many homeowners would be under-insured or uninsured against catastrophe risks. Global reinsurers note that New Zealand has very high catastrophe insurance coverage rates (see Edwards & Davis, 2012). EQC insurance cover attracts a premium in the form of a statutory levy of 15 cents plus GST for every \$100 of private home or contents fire insurance. EQC revenue is collected by each homeowner's private insurer and passed on to EQC. Before the cost was tripled from five cents in 2012 it had been unchanged, per dollar of cover, since the scheme's inception in 1945.

In the aftermath of the 2010-11 Christchurch earthquakes, numerous questions emerged on the effectiveness of the insurance organisational dual model for natural disaster cover, and whether it worked as envisaged by EQC and the wider insurance industry (Brown et al., 2016). Due to the challenges experienced post-catastrophe, the government decided to review the EQC Act in light of the lessons learned from the

Christchurch earthquakes. From an actuarial standpoint, the current pricing arrangement, and the structure of the single-rate premium does not require EQC's premiums to reflect the costs and risks that the scheme imposes on the government. Since EQC has an unlimited government funding guarantee, then the risks of the EQC scheme are ultimately borne by the government. This highly subsidised dual-system with a flat rate levy irrespective of size or location of dwelling creates a positive distortion in the insurance market. On the one hand, it mutes the risk signal and potentially creates adverse selection behaviour, and on the other, it enables private insurance which has a higher degree of risk rating to be cheaper because private insurers do not have to meet the first loss and this, therefore, helps keep insurance in total more affordable. This insightful thought was motivated by the quantitative information and correspondence received from Tim Grafton CMInstD, the chief executive of Insurance Council of New Zealand.

However, it should not be lost that insurance is not the only approach for dealing with catastrophes. An alternative risk hedging mechanism in addition to the existing traditional reinsurance arrangements can also be explored. Future research work could investigate how these alternative measures can address the issues to do with a better treatment of natural disaster risk.

7.3.2.2. Theoretic Framework of Structure of the Residential Insurance Cover in New Zealand

Assume the proportion covered by the EQC scheme is up to a predetermined sum insured denoted by Q . The value of Q represents the maximum amount of claim paid EQC scheme due to natural disaster event. The second component of the contract is covered by the private insurer to a maximum nominated sum insured, denoted by M .

The primary insurer is responsible for any claim's cost associated with random natural disaster loss X in this case, if and only if the gross loss amount is between Q and the maximum nominated sum insured M subject to any other policy conditions within the contracted period denoted as T . Then, this analysis presents the EQC-private insurers' dual-system arrangement as follows;

- i). If $X < Q$ then the primary underwriter pays nothing;
- ii). If $Q \leq X \leq M$ then the primary underwriter pays $X - Q$; and
- iii). If $X > M$ it is expected that the underwriter pays out M then gets a rebate of Q from EQC, while the exceeding portion $X - M$ is borne by the homeowner as deductible.

This arrangement relates closely to the standard excess of loss layer in the traditional reinsurance contract. However, the novelty of this presented arrangement is that EQC is viewed as though it was the primary underwriter of this contract with the retention limit capped at Q ; whereas the private insurer is viewed as though it was the reinsurer capped at M .

Let's now relate this arrangement back to the standard theory of optimal insurance in Arrow (1970). Under Arrow's theorem, the optimal insurance indemnification for a risk-averse insured is a deductible contract. Thus, in the present New Zealand insurance structure, the EQC is the only one with a deductible deal while the policyholders have a non-deductible contract. In the current EQC dual model, the EQC first loss of \$100,000 is viewed as a deductible to the primary insurer, where to make the model tractable, the standard building claims excess of \$2,000 is ignored in this contract structure.

Now, for an insurance indemnity denoted by P , the insurance contract arrangement i) - iii) from the insurer's viewpoint is presented by Equation 7.1:

$$P = \begin{cases} \text{Min}(X - Q, M - Q) & \text{for } Q \leq X \\ 0 & X < Q \end{cases} \quad (7.1)$$

Equation 7.1 presents a formulation theoretic framework that forms the basis for pricing the risk undertaken by both EQC and private insurers.

When an alternative risk management process is considered as a way to deal with the catastrophe losses, Equation 7.1 can also be re-expressed as the difference between two call options with different exercise prices. This will represent a call-option spread, written on the loss exposure of the underlying event. Cummins et al. (1999) pose a call-option in pricing reinsurance contracts and transferring catastrophe risk from (re)insurance market to capital market.;

$$P = \text{Max}(0, X - Q) - \text{Max}(0, X - M) \quad (7.2)$$

The innovation in the proposition is that EQC will not only rely on reinsurance and government but also on the global derivative market to fund and/or minimise natural disaster losses.

Equation 7.2 gives a standard call-option, this presents an interesting opportunity to both the EQC and the private insurers to write hedging contracts in form of catastrophe derivatives in line with the existing derivative market. The EQC and private insurers can directly write and sell contingent claims against the upper cap of natural disaster losses on a per occurrence basis and trade this in a similar way to the well-known catastrophe bonds.

7.3.3. Modelling Catastrophe Claims with Pareto Model on Actuarial Premium

Principle

This section presents the basic insurance premium rate formula as expressed in Equation 7.3:

$$\text{Pure Premium} = \text{Mean Expected Loss} + \text{LAE} + \text{UW Expenses} + \text{UW Profit} \quad (7.3)$$

where, LAE: denotes the amounts paid by the insurance company to investigate and settle claims when a loss event occurs including loss adjustment consideration, and UW: denotes underwriting. The pure premium refers to that portion of that premium rate needed to pay losses, loss-adjustment expenses and both underwriting expenses and profits. When the pure premium is adjusted to allow for loading per exposure unit, this generates a gross premium rate. Lastly, to calculate the amount of premium paid by the insured, the gross premium rate is multiplied by the number of exposure units.

Normally, premium rates are fixed in advance, implying that the rates basis must be appropriate to match future uncertain payouts when an event triggers payments. A unique way to address this is to discount the solvency basis and incorporate a component of the probability of ruin into the pricing. This is a realistic assumption because insurers must adequately allow for extreme exposure, which can leave the insurer insolvent. This is a seemingly easy assumption but it is nowhere in the existing literature. The future equilibrium stability or solvency position is maintained by allowing for the probability of failure when pricing the contracts.

This analysis postulates that the relationship between the mean present cash-inflows and the mean present value of the cash-outflows should produce an equilibrium solvent

position to enable the insurer to pay-out catastrophe losses when disastrous events occur.

Assume R_0 represents the solvency capital requirement at the time of contract inception while the adjustment coefficient k is a ruin model parameter that describes the behaviour of the ruin probability. The standard notation in risk theory, defines the ruin probability as $\psi(\cdot)$ with $\psi(t) \leq e^{-kR_0}$ where;

$$\begin{aligned} \ln \psi(t) &\leq -kR_0 \\ k &\cong \frac{|\ln \psi(t)|}{R_0} \end{aligned} \quad (7.4)$$

Equation 7.4 stems from the fact that given an upper bound for the ruin probability, we would be interested to know whether k is the best possible exponent in an exponential upper bound. In this case, it is assumed that the adjustment coefficient $k > 0$ is a hypothetical value such that;

$$e^{-k(\text{Cash in-flows})} = E\left(e^{-k(\text{Cash out-flows})}\right) \quad (7.5)$$

Cash-inflow is a representation of the premium inflows while the cash-outflow is a representation of claims outgo.

In the standard ruin model, the adjustment coefficient k for a risk process describes the behaviour of the ruin probability and is used to characterise the risk tolerance of the underwriting insurer. Several results for both independent and dependent claims exist. Gerber (1979) gives exact formulas for finite time ruin probabilities involving the adjustment coefficient k , and Pitts et al. (1996) provide a consistent estimator of k , while Mammitzsch (1986) presents necessary and sufficient conditions for the existence of k .

To compute value for k , the pricing actuary must target the probability of ruin at a hypothetical level, say $\psi_t = 0.5\%$. The value of R_0 in the Equation 7.4 represents the solvency capital requirement at the time of contract inception as a proportion of insured risk. This value is mostly set by the regulatory regime in each insurance jurisdiction. For example, in the EU insurance market, the solvency capital requirement is set at a level to ensure that insurers and reinsurers can meet their obligations to policyholders and beneficiaries over the subsequent 12-month period with a 99.5 percent probability. This is set such that it can limit the likelihood of financial ruin to less than 1 in 200 cases within any given year

Section 7.3.1 describes the traditional role played by pricing actuary in general insurance rate-making. The actuarial professional bodies in each jurisdiction have guidelines that set out the assumptions and/or basis used in computation of each component of Equation 7.3. This implies different techniques can be adopted to estimate each component based on the pricing assumptions used. This work estimates the pure premium based on the standard variance premium principle. An appropriate loss distribution is used to model the expected catastrophe losses.

In theory, actuarial premium principles based on both economic principles and a generalised Markov inequality are used as the method for assigning an appropriate amount of indemnity for an insurance policy. The present model adopts the variance premium principle based on Bühlmann's economic principle, initially proposed in Booth et al. (2004) and Bühlmann (1985). Innovative modifications have been done on the variance principle to incorporate the novel assumption and pricing basis proposed in this analysis. This model as presented should not be seen as a step back from the current practice of simulating disasters through catastrophe models to generate

expected loss costs, and probability exceedance curves to compute appropriate premiums. Catastrophe models based on simulation output are very limited and require substantial amounts of data for model construction and validation. In addition, the reliability of such models depends heavily on an understanding of the underlying physical mechanisms that control the occurrence and behaviour of natural disasters (see Muir-Wood & Grossi, 2008; Phelan, 2011; Joyette, Nurse & Pulwarty, 2015). While no one disaster expert would claim to have a complete understanding of all the complexities of these physical systems, scientists and engineers, aided by increasingly sophisticated instrumentation and computing capabilities, have continuously built information and knowledge in these areas. The sophisticated theoretical and empirical models currently being developed can reasonably simulate these complex phenomena, but there is still a lack of inclusion of underwriters in the entire process of developing the models. Thus, there is limited understanding among most insurers on how to use catastrophe modelling in their rate filings to help determine how much premium their policyholders are charged in catastrophe-prone areas.

This study poses a pragmatic approach that can be easily understood amongst underwriters since it is based on the well-known variance principle. The proposed model deduces five fundamental components to price catastrophe risk. The novelty of these five components is that the concept of investigating, settlement and loss adjustment claims effects, and both underwriting profit margin and underwriting overheads and/or commissions are allowed for in the rate marking of catastrophe risk. This is fundamentally new in two perspectives; first, only life insurance contracts price policies on the basis of such assumptions. A certain form of certainty makes pricing life contracts interesting and safer to set premiums. This particular approach in the pricing

of life contracts is valuable when incorporated to the pricing of catastrophe risk with appropriate adjustments made to reflect the nature of general insurance business.

Second, the uncertainty actuarial basis mostly derogated to reserving and solvency calculations has been appropriately incorporated and allowed for at the inception of the policy contract. In essence then, this approach become superior to risk loading methods described in Bühlmann (1984), Feldblum (1990) and Kaluszka (2001).

On the first reflection, it might seem that using the variance principle of Bühlmann (1985) is not new as it has been incorporated by insurers for years in calculating risk loads, not just for catastrophe exposure, but in all exposures. Of note is that, when the ratio of the variance to the expected value is considered, this does not change when similar risks are added to a portfolio. In essence then, the proposed model approach of discounting the contingencies associated with catastrophes then loading this appropriate to the standard variance principle, is a unique approach which also reduces the process risk faced by the insurers when policies are issued. Process risk aggregates in pricing due to the ratio of the variance to the expected loss increasing when more risks are added to the pool, and due to the theoretical failure of the variance in that they determine only relative risk, not absolute risk. Furthermore, the application of the risk load methodology based on variance only results in fairly low-risk loads across various lines of business which may threaten the future solvency of the insurer. The volatility in catastrophe lines makes it more of an issue, since the variance component will add substantially to the overall premium charged, but again other loading needs to be allowed for appropriately.

Equation 7.6 gives a compact model made up of the five fundamental components as;

(i) mean expected value of the loss amount, (ii) a proportionate variance component to

accounts for the variability and the risk tolerance associated with the anticipated underwritten risk when a loss event occurs, (iii) a proportionate mean expected value to allow for the amounts paid by the insurance company to investigate, settle claims and loss adjustment effects when a loss event occurs, (iv) underwriting profit margins, and (v) underwriting overheads and commission. Now, using the variance principle and making the adjustment as proposed in the Equation 7.3 the pure premium rate is expressed as presented in Equation 7.6:

$$\begin{aligned}
 \pi_{X;Q,M} &= E(X;Q,M) + kVar(X;Q,M) + \theta_1 E(X;Q,M) + \theta_2 a_{t|i\%} [\pi_{X;Q,M}] + \theta_3 \ddot{a}_{t|i\%} [\pi_{X;Q,M}] \\
 &= (1 + \theta_1) E(X;Q,M) + \frac{|\ln \psi_t|}{R_0} Var(X;Q,M) + (\theta_2 a_{t|i\%} + \theta_3 \ddot{a}_{t|i\%}) [\pi_{X;Q,M}] \\
 &= \frac{(1 + \theta_1) E(X;Q,M) + \frac{|\ln \psi_t|}{R_0} Var(X;Q,M)}{1 - (\theta_2 a_{t|i\%} + \theta_3 \ddot{a}_{t|i\%})}
 \end{aligned} \tag{7.6}$$

The notation in the Equation 7.6 is defined as follows; $\theta_2 a_{t|i\%} [\pi_{X;Q,M}]$ denotes the present value of the underwriting profit margin proportional to the premium rate. Where $a_{t|i\%}$ is the present value component if this is made in-arrears and discounted for t period at an interest rate of $i\%$.

Of note is that, private insurance companies may have an internal policy guide on what variables should the underwriting expert put into consideration when allowing for the underwriting profit margin. For example, a typical approach is to use accounting variables to generate the profit model as:

$$\text{UW Profit} = \left(\frac{\text{ROE} - \text{IY}_s}{\text{P/S}} - \text{IY}_{\text{op}} \right) / (1 - \text{tax rate})$$

Where:

ROE = target return on equity

IY_s = investment income on surplus

P/S =premium to surplus ratio
 IY_{op} =investment income on operations

This profit loading is widely accepted, but for simplicity, this work uses the mean present value of the premium rate to estimate profit loading component. The term $\theta_3 \ddot{a}_{t|i\%} [\pi_{X;Q,M}]$ is used to denote the present value of the amount of commissions and overheads associated with the underwritten risk as a proportion of the premium rate. Whereas, $\ddot{a}_{t|i\%}$ is the present value component if this is made in-advance and discounted for t period at an interest rate of $i\%$. For $i\%$, the base rate or risk-free interest rate is used and t denotes the contracted period such that $t = t_1, t_2, \dots, t_N \mid \forall t < \infty$. The proportions θ_1 , θ_2 and θ_3 are hypothetical values randomly selected; empirical data and local regulatory guidelines can be used to calculate particular values of the proportion. This can reduce any bias created when the proportions are determined judgementally. The variance component $kVar(X;Q,M)$ is used to represent the variability and the risk tolerance associated with the anticipated underwritten risk. The value k (a factor associated with ruin probability) is incorporated into the variance to expresses risk as a dynamic process. This factor relates ruin concept to the counteracting factors of premium rate and severity distributions (Ohlsson and Johansson, 2010). Lastly, $E(X;Q,M)$ denotes the mean expected value of the loss amount whereas $\theta_1 E(X;Q,M)$ represents a proportionate mean expected value to allow for the amounts paid by the insurance company to investigate, settle claims and loss adjustment effects when a loss event occurs.

The characteristic of the mean expected loss and variance components depend heavily on the choice of the loss distribution to fit the historical claims data. The loss model must represent a reasonable fit of the data. When modelling loss frequency and severity,

it is important to fit a probability distribution to the observed data as well as to evaluate the observed data directly to have a clear understanding of the tail behaviour of the data. In this light then, when the data is fitted on the probability distribution, it is possible to model loss expectations in the tail end of the loss distribution for ranges of losses larger than those contained in the data set. This is very important, especially when the sample size is small and/or contains very large catastrophe losses.

It is typical for most catastrophe losses to have a heavy long-tail, which makes the Pareto model the distributional family of choice to model catastrophe losses in a variety of actuarial and finance applications. Normally, the standard two parameter Pareto distribution is the best choice when the random loss variables have values greater than a fixed positive number, say β . In this instance, β is used to indicate the minimum claim amount and α gives the shape of the density function. This means that the Pareto model covers the behaviour of large losses well, but fails to cover the behaviour of very small losses making it unfit for non-catastrophic losses (Cooray & Ananda, 2005). In this case, the random loss variables X have a continuous cumulative distribution function of the form;

$$F(x) = \begin{cases} 0 & \text{if } x < \beta \\ 1 - \left(\frac{\beta}{x}\right)^\alpha & \text{if } \beta \leq x \end{cases} \quad (\alpha > 0, \beta > 0) \quad (7.7)$$

and the corresponding density function is of the form

$$f(x) = \begin{cases} 0 & \text{if } x < \beta \\ \frac{\alpha\beta^\alpha}{x^{\alpha+1}} & \text{if } \beta \leq x. \end{cases} \quad (7.8)$$

The moments of Pareto random variable X exist only a finite number of times. The existence of the Pareto higher moments $E[X^m]$ is capped by the shape parameter α .

In particular, the improper integral in Equation 7.9 converges, and $E[X^m]$ exists, whenever $m < \alpha$:

$$E[X^m] = \alpha\beta^\alpha \int_{\beta}^{\infty} x^{m-\alpha-1} dx = \frac{\alpha\beta^m}{\alpha-m} \quad (m=1,2,3,\dots, m < \alpha). \quad (7.9)$$

Thus, the mean $E[X]$ does not exist for $\alpha \leq 1$. Similarly, when $\alpha = 2$, the Pareto variance does not exist. Equation 7.9 can now be simplified to obtain Equation 7.10 for the mean and variance respectively;

$$E[X] = \frac{\alpha\beta}{\alpha-1} \quad (\alpha > 1),$$

$$Var[X] = \frac{\alpha\beta^2}{(\alpha-1)^2(\alpha-2)} \quad (\alpha > 2). \quad (7.10)$$

Note that, the variance of X denoted by $Var[X]$, defined by $E\{|X - E(x)|^2\}$, and can be computed via $Var[X] = E(X^2) - E^2(X)$: the second moment minus the square of the first moment. When the Pareto distribution is used to model a random catastrophic loss, and if the mean is infinite when $\alpha = 1$, then the catastrophe risk is uninsurable. As a continuous distribution to model claim severity, the standard Pareto distribution models only those catastrophe claims in excess of a specified positive amount (Rytgaard, 1990; Klugman et al., 2012). The subsequent section uses empirical data to illustrate how the distribution is used to model catastrophe claims for losses greater than a set minimum limit or the over-capped loss amount from the EQC viewpoint.

7.3.4. Illustrative Example of the Modelling Framework

This section uses insurance claims data for Christchurch red-zone properties to fit the selected Pareto loss distribution. The loss distribution is used to estimate expected indemnity assuming that the data is an ideal illustrative of the cost of a catastrophe

event in a highly seismic region. This illustrative example demonstrates how actuarial risk-based rate-making techniques could be used to price residential insurance coverage.

Table 7-1: Average Claims Payout per Suburb for Christchurch Red-zone Properties

Suburb	Property Under Red-zone	Average Claims Payout \$ (NZD)
Aranui	19	160560.90
Avondale	777	260825.00
Avonside	635	233852.08
Bexley	869	204430.54
Brooklands	510	333219.59
Burwood	1449	258885.63
Cashmere	17	552038.36
Cass bay	1	575005.00
Central Christchurch	77	334656.60
Clifton	48	687555.11
Dallington	761	255179.16
Ferrymead	28	363750.00
Governor's Bay	8	576219.07
Heathcote Valley	73	887816.62
Hillsborough	29	397375.44
Kaiapoi	893	232069.09
Kairaki	71	229160.54
Linwood	34	288355.77
Lyttelton	32	449962.30
Moncks bay	15	770909.63
Mount Pleasant	12	311700.00
New Brighton	554	303391.08
Rapaki	9	399414.34
Redcliffs	66	462333.42
Richmond	347	270692.00
Richmond Hill	19	463793.50
Somerfield	1	164131.77
SouthNew Brighton	50	482277.40
Southshore	145	321399.10
Sumner	154	522642.43
The Pines Beach	84	204073.31
Wainoni	71	258810.84
Total for 32 Observations	7858	12,216,485.62

Let's assume that an insurer anticipates selling a portfolio of policies in New Zealand to cover residential buildings against the risk of fire and general risk with a natural disaster endorsement. It is assumed that the mean claim payout for the 32 suburbs is a

good representation of the portfolio of residential insurance policies. For simplicity, it is also assumed that the high-definition New Zealand Earthquake model estimates that the catastrophe claims from insurers' portfolio of policies is modelled by the selected Pareto model. Table 7-1 displays the Christchurch red-zone properties claims data from 32 suburbs that were declared unfit for habitation in the aftermath of Christchurch earthquake. It also shows average claims payout per suburb for the red-zoned properties. This illustrative of the pricing model looks at the data of each suburb as a single observation so, in total, the modelling framework is based on 32 observations with a total mean claim amount of NZ\$12,216,485.62.

To provide useful interpretation and modelling of the data, the first step is to present the results of well known plots such as the histogram and the quantiles plot. Figure 7-1 presents the histogram and Pareto density function of the data. The plot shows that the histogram is highly skewed right. This is common to most catastrophe loss claims that are typically highly positively skewed and distributed with a larger upper tail (Klugman et al., 2012). In particular, it is observed that most of the claims are below NZ\$480,000. In general, it can be observed that the claims data presents few claim amounts with very high values while most of the claims amounts were of low values.

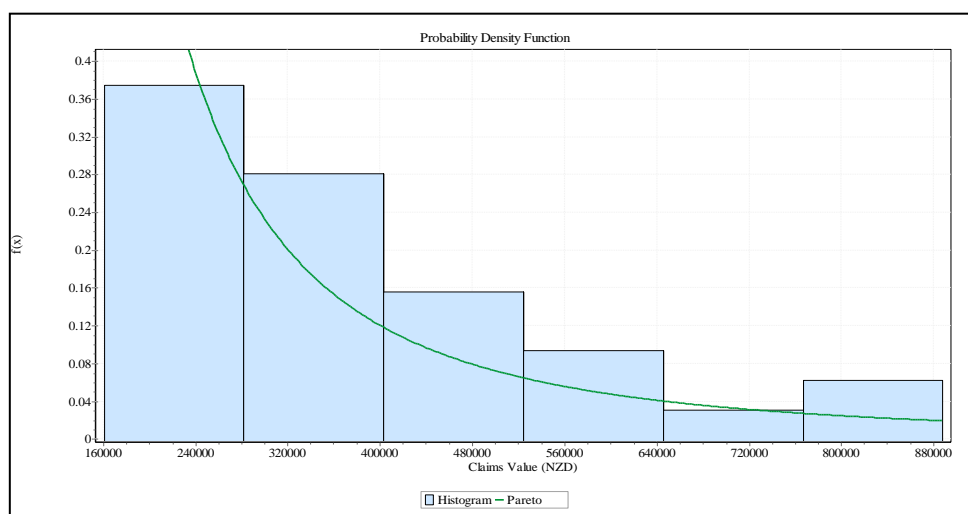


Figure 7-1: Histogram and Pareto Density for the Christchurch Red-zone Claims

This model illustration also uses Q-Q plot to give a graphical presentation for the goodness-of-fit of the Pareto model to the observed claims data. In general, the Q-Q plot is normally used to show if two data sets come from the same distribution.

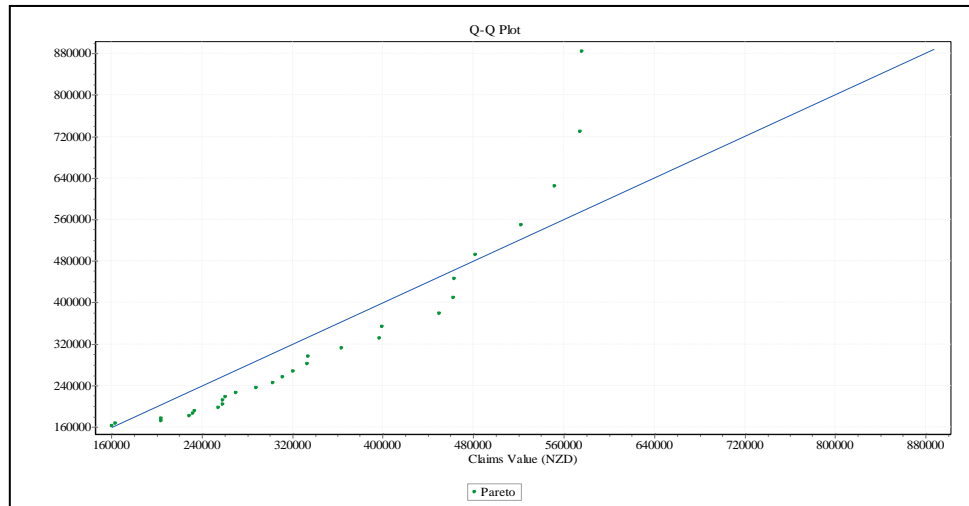


Figure 7-2: Q-Q Plot of Christchurch Red-zone Claims to the Pareto Model

Figure 7-2 presents the Q-Q plot which is plotted against the observed loss data.

According to the Q-Q plot, it can be clearly seen that the Pareto is a reasonable model to fit this data.

Of note is that the Q-Q plot, as shown in Figure7-2, tends to be sensitive to variations of the claim values in the tail end of the distribution. The slope of the curve at the upper end of the claims values gives cause for concern as it is fairly easy to see that the model is increasingly off the slope. However, it is noted that the most useful property of the Pareto tail model is that, when going upwards to model larger losses the model forgets the original threshold β , which is not needed any further, instead the new threshold comes in dictated by the nature of the data being modelled. So if the model encounters few fairly large claim values, it is not necessary to know exactly where that tail starts or ends. As long as we are in the tail, which is the Pareto area, we always have the same parameter α , whatever the threshold. More importantly, a loss distribution with desirable properties only helps if it provides a good fit of the data in practice. From

many (re)insurance data it is clear that not all tails in the world of insurance are Pareto distributed (Embrechts & Schmidli 1994; McNeil 1997; Cummins et al. 1999), in particular the model often seems to be somewhat too heavy-tailed at the very large end. Nevertheless Pareto is the best model to use on claims with characteristics similar to the present data. If it fits well between – in the case of our data, say 160,000 to 560,000 – one can use it for claims in that area independently of whether beyond 600,000 one needs a different model or not.

Figure 7-3 plots Christchurch red-zone property claims against the Pareto density function. The Pareto distribution parameters based on the data are $\alpha = 1.2977$ and $\beta = 160560$.

This plot reiterates the desirable properties of the Pareto loss distribution to model (re)insurance data, but also it illustrates the limitation of the Pareto model in that it has monotonically decreasing shape of the density. Thus, it does not provide a reasonable fit for smaller valued loss claims. It can be seen from Figure 7-3 that the shape of the Pareto curve changes slowly with alpha, but the tail of the distribution increases dramatically with decreasing alpha.

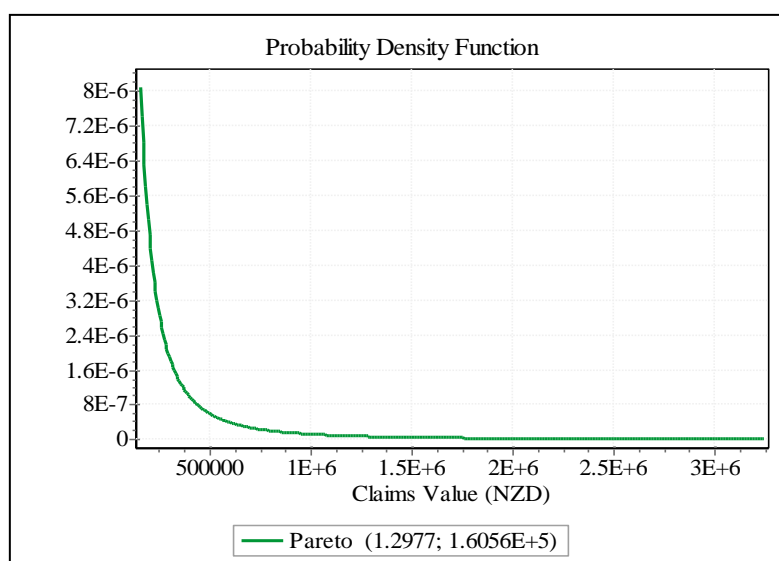


Figure 7-3: Christchurch Red-zone Suburbs Property Claims against Pareto Density

To further compare the performance of the Pareto model in describing the claims data, the 32 suburbs are considered as the cells, then a goodness of fit test is done. The goodness of fit test represents the measures of the compatibility of the empirical data with a theoretical probability distribution function. The most often used goodness of fits tests are Kolmogorov-Smirnov, Anderson-Darling, and Chi-Square (Plackett, 1983; Choulakian & Stephens, 2001).

The results are summarised in Table 7-2 which gives $\chi^2 = 8.1966$. Since $d.f. = 32 - 1 = 31$, the rejection limit is $\chi_{0.95}^2(31) = 44.98$. The fitted Pareto distribution is therefore, at the 5 percent level of significance, a reasonable fit to the data.

Table 7-2: Goodness of Fit – Summary

Distribution	Kolmogorov-Smirnov	Anderson-Darling	Chi-Squared
	Value	Value	Value
Pareto	0.24476	4.3192	8.1966

Now, recall that for any natural disaster claims to be payable by the private insurer in New Zealand, it must be greater than NZ\$120,000 for both property and content, this represents the upper limit of EQC. Next, assume that catastrophic claims are capped at the mean loss generated by the loss distribution in addition to the EQC cap-limit. Using the Pareto distribution with parameters $\alpha = 1.2977$ and $\beta = 160560$, the mean of the claims payouts is 699940. The mean expected loss can then be computed conditional on the claims being greater than NZ\$120,000.

Denote by Z the indemnity amount paid by the insurer.

Then; $P(Z > 0) = P(X > 120,000)$

$$\begin{aligned}
 &= 1 - F(120,000) \\
 &= \left(\frac{160560}{120000 + 699940} \right)^{1.2977} \\
 &= 0.48467719
 \end{aligned}$$

$$E[Z] = \int_{120000}^{819940} (X-120000)f(X)dx + 699940 \times (1 - \text{cdf}(819940))$$

$$= 40544.5935059407$$

Working in Matlab:

$$\int_{120000}^{819940} (X-120000)f(X)dx = 40543.2159841015$$

$$9940(1 - \text{cdf}(819940)) = 1.3775218393$$

Matlab	
	<pre> % tail index k, % scale parameter sigma % threshold, theta, sigma=1.2977; theta=160560; k=1; n=100000000; x = linspace(120000,819940,n); grid=(819940-120000)/n; first=sum(grid*(x-120000).*gppdf(x,k,sigma,theta)); latter = 699940*(1-gpcdf(819940,k,sigma,theta)); fprintf('E[z] = %.10f\n',first+latter) </pre>

The conditional expectation for the indemnity paid by the insurer is then obtained as follows:

$$E[Z/z > 0] = \frac{40544.5935}{0.48467719}.$$

Thus, we now have $E[Z/z > 0] = \text{NZ\$}83,652.77826$.

Note that: when Pareto with parameters $\alpha = 1.2977$ and $\beta = 160560$, is used to model this data, the variance is undetermined since $\alpha > 2$. In this case $\text{Var}[Z/z > 0]$ is not observed.

Next, choose the probability of ruin such that $\psi_t = 0.5\%$ and a solvency margin $R_0 = 200\%$. This gives $|\psi_t| = 5.298317367$. To illustrate how the proposed risk-based model incorporates the five components of the pure premium from Equation 7.6 assume the following; (i) both mean expected loss and LAE can be modelled using a known loss distribution and that the LAE is set at 1 percent of the mean expected loss, (ii) each time the insurer writes a residential insurance contract, the insurer incurs underwriting expenses set at, say 15 percent of each dollar of pure premium rate, and (iii) targeted profit margin provision at 5 percent of pure premium rate. This model does not use the dividend income component proposed by Bühlmann (1985) and ignores the reinsurance costs. The mean expected pure premium rate can therefore be calculated as presented in Equation 7.11:

$$\pi_{X;Q,M} = \frac{(1 + \theta_1)E[Z/z > 0] + \frac{|\ln \psi_t|}{R_0} \text{Var}[Z/z > 0]}{1 - \left(\theta_2 a_{\overline{t}|i\%} + \theta_3 \ddot{a}_{\overline{t}|i\%} \right)} \quad (7.11)$$

When the empirical data is fitted into the Pareto model it does not have finite variance, therefore the premium variability component $\frac{|\ln \psi_t|}{R_0} \text{Var}[Z/z > 0]$ is zero or the effect of the variance is undetermined.

The pure premium formula is reduced to Equation 7.12:

$$\pi_{X;Q,M} = \frac{(1 + \theta_1)E[Z/z > 0]}{1 - \left(\theta_2 a_{\overline{t}|i\%} + \theta_3 \ddot{a}_{\overline{t}|i\%} \right)} \quad (7.12)$$

$$\text{with } \ddot{a}_{\overline{t}|i\%} = (1 + i)a_{\overline{t}|i\%}$$

Since the rates are determined per contract period, let's assume $t = 1$ so at $i = 2.5\%$;
 $a_{\overline{1}|2.5\%} = 0.9756$. When all the values are replaced in Equation 7.12; the pure premium
for the portfolio of policies gives;

$$\pi_{x:Q,M} = \frac{(1+0.01) \times 83652.77826}{1 - (0.05 \times 0.9756 + 0.15 \times (1.025 \times 0.9756))}$$

$$= \text{NZ\$}105,450.6226$$

The total Christchurch red-zone claims data is made-up of 32 suburbs with an average claims total of NZ\$12,216,485.65; this is a grand total of average payout in each suburb. This gives the estimated pure premium for each suburb at approximately NZ\$3,295. If the private insurers take into consideration the first loss cover provided by the EQC, then the pure premium can be significantly reduced to a more competitive value.

It is also common to adjust catastrophe claims in modelling data as they can have a disproportional impact on the pure premium rate. To deal with the disproportionality, the insurer can look into the composition of the insurance portfolio to establish the extent to which further pricing assumptions can be made for appropriate adjustments. This can further be compared to the actual office expenses, unforeseen losses, reinsurance cost, regulatory restrictions and exposure units. The standard procedure is to multiply the pure premium rate determined by an actuary by the number of exposure units and then adjusting the premium by appropriate rating factors in accordance with the insurer's underwriting policy as well as allowing for the law of large numbers to apply (Schofield, 1998). If the actuary is estimating pure premium rates for a new insurer or new risk, there will be no internal historical data to which a loss distribution can apply. In such a scenario, the actuary can still determine the indicative pure premium rate by estimating the expected pure premium, expense provisions and a target

profit provision based on external data or judgmentally based individual pricing experience.

7.3.5. The Choice of Appropriate Premium Principles

The choice of the most appropriate premium principles is always a challenging task: actuaries rely on ad hoc approaches in choosing premium principles in some cases. The most important rule of thumb is that the premium principle should assign a non-negative value to an insurable risk as defined by its loss distribution function. Notwithstanding, there are some desirable properties all premium principles should adhere to and satisfy (Booth et al., 2004).

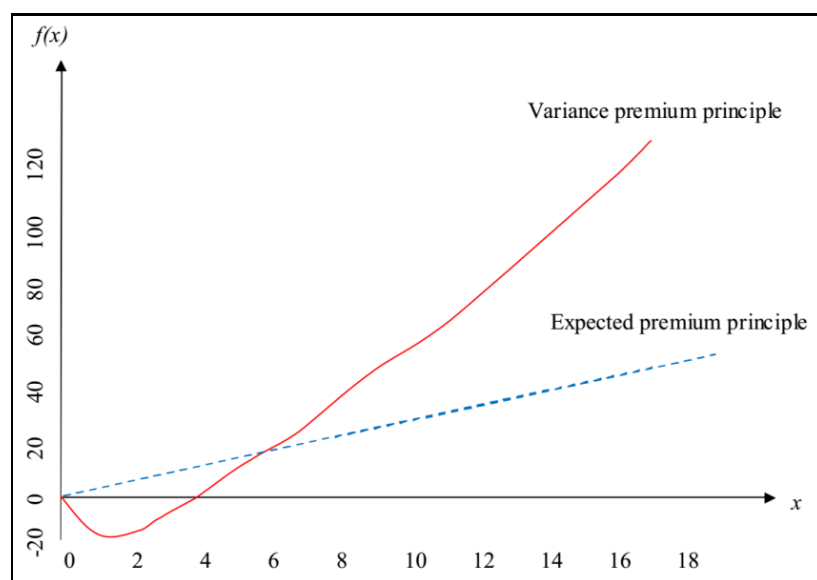


Figure 7-4: A Comparison of Variance and Expected Premium Principles

A common observation is that, if the distributions of the losses are highly positively skewed with fat-tails, features that define catastrophic losses (Schoenberg et al., 2003), then the variance premium principle is preferred because; (i) this gives higher premiums than the expected premium principle, and (ii) this gives a better consideration of risk when working with larger data with lower frequencies. However, in a competitive business environment, insurers strive to offer lower premiums for their products to

remain competitive. Thus, there is a residual risk of insolvency even when the best underwriting measures are in place in calculating the premium rates.

To minimise this risk, the insurer must continually look into the extent to which the law of large numbers is applicable in the insured pool. When pricing residential property cover against natural catastrophes, the law of large numbers may provide a rationale for the economies of scale. This makes it possible for insurance companies to produce gross premiums that are significantly lower than the computed risk premiums. This law in the simplest terms provides a justification for the existence of the insurance industry because the main role of the insurance industry is the transfer of risks and/or pooling and redistribution of risks (Seog, 2010). However, it should be appreciated that only a small component of catastrophe risk can be diversified using pooling and redistribution of risk. This implies that risk-based pricing models are the best approach that an insurance business can use to quantify technical provisions in rate-making. Many studies (Eling and Pankoke, 2014; Munroe et al., 2015; Theis and Wolgast, 2012) propose the use of the principle of proportionality proxy in the standard formula commonly used in Europe insurance pricing.

7.4. Conclusions and Recommendations

This study has built a risk-based pricing model suitable to generate competitive premium rates for natural disaster insurance cover. Using illustrative data from Christchurch Red-zone suburbs, the model has been able to provide competitive premium rates for catastrophe risk. The novelty of this model is that, it presents a new simple approach for risk-based rate-marking. This is an insightful contribution to the literature of catastrophe insurance, especially with respect to premium loading. This model can also play an important role to set internal benchmark rates in pricing of

natural disaster insurance coverage. However, it is crucial to study some models on market behaviour to find out the expected tendencies from market conditions; and how the consumer reacts to the premium rates proposed.

An emerging question is the applicability and practicability of the proposed model in the private insurance market, where insurers' rates are influenced global reinsurance firms and/or through catastrophe simulation. When the proposed model incorporates the new RMS high-definition New Zealand Earthquake Model, for example, insurers can find the model useful to identify losses at a granular level so as to calculate the competitive premium.

This modelling framework can provide a structure with which to examine the complex natural disaster risk pricing. This model could also help in addressing the complexities and challenges posed by the integration of compulsory EQC cover to the private insurance cover. The existence of the EQC scheme taking the first loss for dwellings based on a flat levy irrespective of size or location of dwelling mutes the risk signal and potentially creates adverse selection behaviour from the insureds' perspective, and on the other side it enables private insurance which has a higher degree of risk rating to be cheaper because it doesn't have to meet the first loss and this, therefore, helps keep insurance in total more affordable. It should also be noted that EQC pricing arrangements and the structure of the flat rate premium creates two main concerns. First, the EQC does not require premiums to reflect the costs and risks as EQC has an unlimited government funding guarantee. Second, EQC premiums are almost never changed. The premium rate first established in 1945 remained unchanged, per dollar of cover, for over 65 years. In 2012, it was then tripled in response to the losses generated by the Canterbury earthquakes.

CHAPTER EIGHT

8. THE DUAL INSURANCE MODEL AND ITS IMPLICATIONS FOR INSURANCE DEMAND AND SUPPLY POST-CHRISTCHURCH EARTHQUAKES IN NEW ZEALAND

8.0. Introduction

This chapter looks at the empirical implications of earthquakes for insurance markets. The study is centered on the supply-side of the insurance market post-Christchurch earthquakes. The analysis starts with an introduction of the events leading to the Christchurch catastrophes. The study then looks at how catastrophe risks are insured in New Zealand by giving a diagnostic analysis of the natural disaster insurance market for residential property and contents. Third, the role played by the governments in the provision of natural disaster insurance and how this has helped both private insurance and reinsurance providers to meet the reasonable expectations of customers is described. Lastly, an empirical analysis is carried out using datasets sourced from the Insurance Council of New Zealand and one confidential private insurer. In summary, then, the most interesting contribution in this chapter is the description of what happened in the supply-side of New Zealand insurance market post-Christchurch earthquakes. That is; (i) the change in contracts from full replacement cost to sum insured and the effect of this change on the insurance market, (ii) the rise in the premium rate and why the premium changed, (iii) the increase in the total amount of premiums written showing business growth; to what extent this depended on the increase in premium rates, changes in contract formation or changes in property value, and (iv) the values of the loss ratio pre- and post-quakes. A coherent review and discussion of the

roles played by both government and reinsurance system in the catastrophe insurance market is also an important contribution to the literature of disaster insurance.

The rest of the chapter is organised as follows: Section 8.1 gives an introductory background and economic impact of the 2010-11 Christchurch earthquakes. Section 8.2 gives a broad discussion of natural disaster insurance. Sub-section 8.2.1 discusses the need for government participation in natural disaster insurance. Subsection 8.2.2 discusses the New Zealand natural disaster insurance through the Earthquake Commission and subsection 8.2.3 gives a description of some natural disaster insurance programs worldwide with government involvement. Section 8.3 gives a description of reinsurance of the dual insurance model framework in New Zealand. Section 8.4 presents results for various empirical analyses of New Zealand insurance industry reaction post-Christchurch earthquakes. Section 8.5 gives the conclusions

8.1. Background and Economic Impact of the 2010-11 Christchurch Earthquakes

Over 20,000 earthquakes are recorded by New Zealand's geological hazard monitoring system every year, with approximately 200 of them being strong enough to be felt. In the years 2010 and 2011, two major earthquakes occurred in Christchurch. In particular, the first strong quake at a magnitude 7.1 on the Richter scale occurred at 4.35 am on 4th September 2010. The epicenter was 40 km west of Christchurch City and the depth of the quake was at 10 km (Potter et al., 2015; Wu et al., 2014). In the aftermath of the first earthquake, dozens of its aftershocks followed causing moderate damage. The first earthquake sequence initiated three other significant earthquakes close to the city of Christchurch culminating in an aftershock which was the second major earthquake which struck at 12:51 pm on 22nd February 2011, measuring 6.3 on the Richter scale.

The location of the second major quake was within 5 km south-east of Christchurch, at a shallow focal depth of 5 km (Potter et al., 2015; Wu et al., 2014). This quake produced damage labeled as destructive by GeoNet; the builder and operator of modern geological hazard monitoring systems in New Zealand. Unreinforced masonry buildings were severely damaged with liquefaction occurring in many parts of the eastern suburbs rendering entire neighborhoods completely uninhabitable (Buchanan et al., 2011; Bull, 2013).

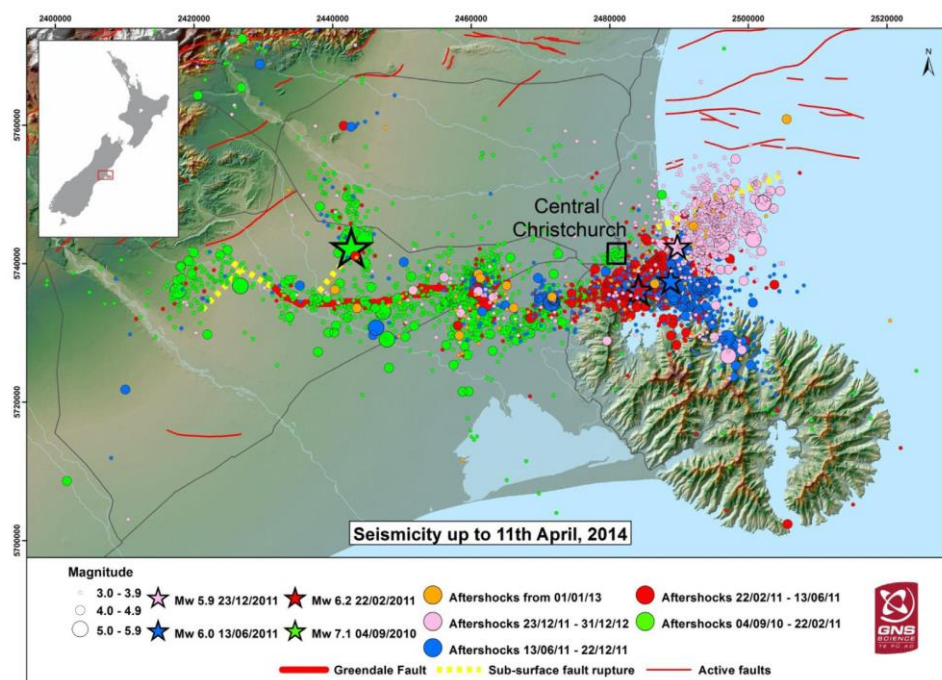


Figure 8-1: Location of Epicentres during the Canterbury Earthquake Sequence
(Source: Robert Langridge, GNS Science)

Estimates of the total economic cost of the two earthquakes vary and are subject to considerable uncertainty. The biggest challenge was the ongoing nature of the earthquake sequence, and the need to treat separately each of the 5 major events (Table 8-1) identified by the Earthquake Commission (EQC) as being independent events that could be claimed for individually.

Table 8-1: Five Major Canterbury Earthquakes for the Period 2010-11

Time	Location	Magnitude	Intensity
4:35am, 4 th September 2010	840M from Ansons Road, Charing Cross	7.10	X
10:30am, 26 th December 2010	40M from Brougham Street, Sydenham	4.91	V
12:51pm, February 22, 2011	340M from Rapiki Road, Hillsborough	6.34	VIII
2:20pm, 13 th June 2011	690M from Barnett Park Track, Redcliffs	6.41	VIII
3:18pm, 23 rd December 2011	250M from 466-68 Marine Parade South New Brighton, Christchurch	6	VII

(Source: GeoNet, 2014)

Until the full payment of all claims and complete recovery is done, it remains a difficult task to give an exact figure for the total economic cost and insured losses paid out. There have been differences between the market value of assets and all infrastructures destroyed, the cost of replacing those assets over time and the additional value of rebuilding properties to a higher risk resilient standard or other discretionary improvements. In addition, disruption of businesses and of lives following a natural disaster can be substantial, but it is difficult, if not impossible, to measure the financial implications of all of these effects accurately.

The Christchurch earthquakes provided an unprecedented challenge for the insurance industry and indeed to the entire New Zealand economy. The New Zealand Treasury estimated the total cost of insurance claims for the earthquakes at a value above NZ\$40 billion, approximately 18% - 22% of the country's Gross Domestic Product (GDP) (Kachali et al., 2015; Parker and Steenkamp, 2012). Taking into account the complications with claims involving multi-unit buildings, retaining walls and land issues, private insurers paid out NZ\$17.8 billion in settling claims resulting from the Christchurch earthquakes in 2010 and 2011 as at the end of March 2016. The payments were apportioned into two categories, NZ\$9.6 and NZ\$8.2 billion for settlement of commercial and residential claims, respectively. This represented a significant

contribution towards the estimated NZ\$40 billion economic loss incurred in the Canterbury region. The figure includes damages to buildings and contents, as well as disruption to business activities but does not include underinsured or uninsured losses (Brookie, 2014; Kachali et al., 2015). The fact that natural disasters have both immediate and long-term economic effects has not been captured in any of these estimates. This study assumes that the economic impact of the two quakes could be far higher when all the affected aspects are financially quantified. An early estimate by Aon Benfield put the Christchurch earthquakes amongst the most significant natural disaster events in the insurance world, with insurance losses initially estimated at NZ\$13.5 billion (Brown et al., 2016; Doyle and Noy, 2015). Later in 2013, these estimates were adjusted to NZ\$16.5 billion and now the figure stands beyond NZ\$40 billion, according to the New Zealand Reserve Bank estimates (Parker and Steenkamp, 2012; Potter et al., 2015, Timar et al., 2014). Table 8-2 gives the top ten insurance loss estimates from natural disasters worldwide in 2011. The losses from the Christchurch quakes, even at the most conservative figures, stood at position two globally in the year ending 2011 (Swiss Re, 2012).

Table 8-2: Christchurch Earthquakes Compared to Global Events in 2011

Top ten insurance loss events in 2011	Estimated losses in \$ (USD ‘billions’)
Earthquake Japan	35.00
Earthquake New Zealand, 22 February 2011	13.50 (later revised to 40)
Flooding Thailand	10.78
Severe Weather USA Southeast, Plains, Mid-West	7.30
Severe Weather USA Plains, Mid-West, Southeast	6.75
Severe Weather Hurricane Irene	5.00
Flooding Australia	2.42
Severe Weather USA Southeast, Plains, Mid-West	2.00
Earthquake New Zealand, 22 December 2011	1.80
Severe Weather USA Plains, Mid-West, Southeast	1.70

(Source: Aon/Benfield, 2013)

The upward trend in overall economic losses in recent decades highlights the global economy's increasing exposure to natural catastrophes. The sigma report shows that the reinsurance industry in 2011 suffered one of the highest, if not the highest level of insured losses ever (Swiss Re, 2012). That year also saw the tsunami in Japan, an active windstorm season in North America, and Thailand and floods in Queensland Australia. Studies by (Dahlen & Peter 2012; Parker & Steenkamp 2012; Merkin, 2012) found that these disasters led to unprecedented losses for the global insurance market, where they cascade from the policyholders via primary insurers to reinsurance companies. As a result, there was a tightening of the reinsurance market, leading to a very significant increase in reinsurance costs after the Christchurch earthquakes in New Zealand. The reinsurance costs were global and translated into a significant increase in premiums for households in nations prone to natural disasters. Given that New Zealand insurers extensively participate in the offshore reinsurance market, the global reinsurance rates extensively impacted on how the local insurers priced the residential insurance policy.

8.2. Natural Disaster Insurance

8.2.1. Need for Government Participation in Natural Disaster Insurance

Table 8-2 illustrates how devastating natural disasters can be to the normal operations of an economy. The magnitude of the economic loss from catastrophes can thus never be left to the private insurance mechanism to fully protect the economy and/or to deal with the social chaos that might emerge in the aftermath of a major disaster. Thus; insurance for natural disasters is not a matter to be left to the private insurance players alone. This study demonstrates that it is absolutely necessary for the government to participate in the provision of natural disaster insurance. A good question to follow is, why and what role does the government play in the provision of natural disaster cover for the residential property insurance business. There are two key possible spatial

rationales for government involvement in the provision of natural disaster provision. The first is that, there would be spatially concentrated negative externalities and by extension, this creates cost spill-overs to major economic activities if many people in an earthquake-hit area were uninsured or underinsured. The second is that, without government involvement, many homeowners would find coverage unaffordable or unavailable which leads to mass under- or uninsured due to higher premiums required for catastrophe risk. In most cases, governments provide emergency assistance to these homeowners after large natural disasters. However, if many homeowners remain without insurance cover, this creates risks and uncertainty for homeowners, insurers, and governments every time disaster strikes. In the case of New Zealand, providing insurance to enable damaged homes to be repaired continues to be a major rationale for retaining government insurance participation via EQC. Globally, private insurance markets for catastrophe insurance tend to be marked by low rates of insurance uptake and fluctuations in the supply of insurance cover. This results in significant levels of under-insurance or uninsured properties among property owners. Previous studies (Mills, Roth & Lecomte, 2006; Kunreuther, 2017; Comerio, 2014; Pierrepiekarz et al., 2014; Cooper et al., 2015), have found only around 18 percent of California homeowners have earthquake insurance, despite California being very seismically active, and in Japan, around 28 percent of homeowners have earthquake insurance. To appreciate this low insurance uptake, it is worth reflecting on the position Canterbury homeowners and the government would be in if only 30 percent or less of earthquake affected homeowners had no natural disaster insurance coverage.

Political economic considerations make it more likely that government support would be called for if many people are uninsured than if few people are uninsured. When there are large numbers of under-insured or uninsured property owners, the experience

elsewhere in the world is that governments feel compelled to provide financial assistance to affected households. When a disaster occurs in that environment, homeowners face large catastrophic losses and most individuals depend on the uncertainties of emergency government assistance. The biggest problem posed by the emergency assistance for property owners is that, it can encourage the assisted and other owners to not buy insurance against natural disasters, generating larger future risks for homeowners and governments. In order to avoid the insurance market inefficiency and adverse selection behaviour from property owners, a form of government-sponsored insurance coverage is necessary. A region with a higher likelihood of occurrence of a disaster and without government participation is unattractive for private insurers to offer coverage due to extreme catastrophe loss exposure.

These reasons form the justification why most developed nations have some form of intervention in disaster insurance provision. Although the participation in insurance schemes in the form of government-sponsored insurance programs differ in principle, generally all government schemes are designed to address most of the issues surrounding spatially concentrated risks, availability, and affordability catastrophe insurance to most homeowners.

8.2.2. New Zealand Natural Disaster Insurance through the Earthquake Commission

In a study of 42 high-risk countries in 2011, New Zealand ranked second highest for non-life insurance penetration relative to GDP (with premiums equivalent to 5.2 percent of GDP) and highest in the world in the residential insurance penetration (CEBR, 2012). Although the residential insurance penetration is very high in New Zealand, over 90 percent, earthquake insurance penetration, in general, is about 80 percent, as compared

to that in North America at 20 percent; virtually everyone has an insurance policy protecting their home (Pierепiekarz et al., 2014). In other parts of the world, underinsurance continues to be a problem. For example, only 17 percent of the economic losses of Japan following their 2011 tsunami were covered by insurance (Cooper et al., 2015). The high penetration of insurance in the residential market can largely be attributed to two factors; (1) the fact that New Zealand is ranked third in the world for expected losses that could occur from a natural disaster as a percentage of GDP in any given year (Brown et al., 2013), and (2) the program offered by the EQC.

The EQC is a Crown entity that has its origins in an insurance pool set up in 1941 to address war damages. It was later expanded to cover earthquake damages and in 1993 became the EQC. The EQC provides natural disaster cover for buyers of residential insurance provided by private insurers. This is a unique natural disaster insurance scheme which is provided as a rider, this is an add-on to the primary policy, which offers benefits over and above the policy subject to certain conditions, on fire and general peril cover offered by the private general insurance market in New Zealand. Therefore, all residential property owners who buy fire insurance automatically acquire EQC insurance. Under the residential building and contents insurance cover provided, all general insurers in New Zealand collect a levy on behalf of the EQC. As important as it is to homeowners, those who do not buy private insurance cover for their residential properties for whatever reason do not receive this EQC cover. In return for paying their EQC premiums, homeowners are no longer reliant on uncertain emergency government assistance following a natural disaster. Instead, they have the certainty of a legislated right to catastrophe insurance with pre-established terms, backed by the government funding guarantee. Homeowners in higher risk areas also benefit from EQC's flat-rate pricing structure, which keeps private insurance premiums affordable

nationwide. That, in turn, helps keep national homeowner take-up rates of insurance against natural hazards very high. That is of direct benefit to homeowners and private insurers. The high rates of private insurance take-up also greatly reduce the risk that the government will be called on after a natural disaster to provide assistance to uninsured homeowners.

Although the government is required to provide the resources to pay EQC claims, homeowners pay EQC premium. In contrast, emergency assistance packages expose the government to large unfunded fiscal risks when catastrophes occur. Besides provision of subsidised disaster cover, EQC plays useful roles in supporting broader government and community interests. For example, the recent move of private insurers from providing full replacement value type policy to a nominated replacement value type policy may result in high levels of underinsurance if homeowners do not consider the full range of costs associated with repairing property following a natural disaster when deciding on the sum insured value. While the EQC scheme cannot compensate for inadequately set private insurance cover, it has played a key role in helping avoid underinsurance by providing homeowners with the necessary information to make better decisions about natural disaster insurance cover and natural disaster risk management more broadly. EQC has also played a critical role in transferring natural disaster financial risk to reinsurance arrangement internationally, funding research into the natural disaster and mitigating damage.

8.2.3. Natural Disaster Insurance Programs Worldwide with Government Involvement

Previous studies (Aseervatham et al., 2015; Atreya et al., 2015; Grace and Klein, 2003; Grossi et al., 2005; Klein and Kleindorfer, 1999) point to the fact that government

participation in insurance markets is not unique to New Zealand. The National Flood Insurance Program (NFIP) managed by the Federal Emergency Management Agency (FEMA), California Earthquake Authority (CEA) and Japanese Earthquake Reinsurance (JER) have similar natural disaster programs, while Turkey has one of the newest such programs now in place. Although there are disaster programs in most developed nations, this study lists a few examples to compare them with New Zealand's EQC programme. The unique features of EQC in New Zealand's government involvement reveal the greater semi-autonomous role that governments could play in the private insurance market.

In the USA, standard homeowners insurance does not cover flooding and associated natural hazard perils. The federal government established the NFIP in 1968 (Dacy and Kunreuther, 1969; Michel-Kerjan and Kousky, 2010) to help provide means for property owners to protect themselves financially from the floods associated with hurricanes, tropical storms, heavy rains and other conditions that heavily impact some states in the US. Managed by the FEMA which maps flood risks and sets flood insurance premiums, the programme is designed as a voluntary partnership between the federal government and local communities. The NFIP provides insurance up to a maximum limit for residential property damage, now set at US\$250,000 for building coverage and US\$100,000 on contents coverage. The underlying principle of the program is to subsidise the cost of flood insurance on existing homes, in order to maintain property values, while charging actuarially fair rates on new construction. Similarly, the California Earthquake Authority established by the California legislature in 1995 following the 1994 Northridge earthquake, is designed to preserve the state-mandated offer of earthquake coverage. The CEA required the participation of 70 percent of California homeowner insurers before it could begin operation. Insurers

choosing not to participate are required to offer a similar brand of earthquake coverage to residential policyholders. The CEA offers a scaled-down policy covering homes and certain apartment buildings, but not other structures such as swimming pools, garages and driveways. Unlike New Zealand's EQC, no public funds are pledged or available to cover CEA-insured losses. If an earthquake causes damage greater than the CEA's claims-paying capacity then policyholders would be paid on a prorated basis. The prorated claims would be calculated on the basis of the total amount of expected claims compared to the remaining available funds.

In Japan, the 1966 Earthquake Insurance Law (enacted after the Niigata earthquake of 1964) established the Japanese Earthquake Reinsurance (JER), to whom private non-life insurers were obliged to offer earthquake insurance and cede 100 percent of the earthquake premium and liabilities (Tsubokawa, 2004). The JER thus acts as the sole earthquake reinsurer for the private insurance market. The total claims-paying capacity of the program is currently ¥5,500 billion (US\$45 billion), which is estimated to correspond to the scenario of the 1923 Great Kanto earthquake with a return period of 220 years. In the event the insured earthquake losses exceed this amount, claims would be prorated accordingly. The maximum liability of the government of Japan, JER, and private insurers is 87%, 10%, and 3%, respectively.

In the aftermath of the two major earthquakes in 1999, the Government of Turkey decided to enforce earthquake insurance on a nationwide basis with the sole purpose of privatising the potential risk by offering insurance via the Turkish Catastrophic Insurance Pool (TCIP). This program bundles the major part of disaster risk and exports it to the international reinsurance and capital markets (Bommer et al., 2002). This measure was aimed at reducing government's fiscal exposure in the event of a major

catastrophic earthquake, as well as to encourage risk mitigation and safer construction practices. To achieve these goals all registered residential properties in Turkey (the total number currently is about 19 million) are required to be in the compulsory earthquake insurance coverage.

Initially funded by the World Bank, the TCIP program became effective as of March 2001 and is currently one of the most renowned insurance brands in the Turkish insurance market. High brand recognition and increasing earthquake insurance awareness among homeowners gives leverage to take-up rate in earthquake insurance (TCIP policy count was about two million as of September 2004, increasing to 7 million by end of 2014). The TCIP policy offers coverage on a first-loss basis, meaning that it does not impose underinsurance penalties when the value of a residential property is significantly higher than the limit of coverage obtained from the TCIP. Unlike the CEA, which imposes a deductible of 10 percent, the TCIP applies a minimum 2 percent deductible to the sum insured to avoid small claims, reduce moral hazard and reduce the pools' administrative and reinsurance cost.

This study examined just a few examples of government-sponsored programs to emphasize the centrally important role played by such programs in the natural disaster insurance. An audit of governments' involvement in insurance provision worldwide set New Zealand as the only country with unique compulsory natural disaster fund to only those who buy private home insurance cover and which is 100 percent government guaranteed. The role played by the EQC in the aftermath of Christchurch quakes cannot be understated; without the EQC, it would be almost impossible for the private insurance to single-handedly rebuild Christchurch City.

8.3. Reinsurance of the Dual Insurance Model Framework in New Zealand

This section examines the roles played by reinsurance scheme to support the dual structural-framework of natural disaster insurance in New Zealand. In the aftermath of the 2010-11 Christchurch earthquakes, questions emerged on the efficiency of the dual-insurance model in New Zealand when extreme catastrophe losses occur. This study finds that the key to success of the New Zealand dual insurance system, despite the possibly high incidence of catastrophe losses, is the elaborate reinsurance arrangements in place.

Akin to government involvement in natural disaster insurance, the existence of a global reinsurance system is of absolute necessity to the success of private insurer supply of natural disaster insurance coverage. In light of the benefit policyholders derive from government's involvement in the insurance market, it is important to note that, reinsurance is of direct benefit to primary insurers, and only of indirect benefit to the policyholder. In most cases, a reinsurance arrangement is made to make insurance available, but not always to address the problem of affordability. To this end, reinsurance does not really solve the un-affordability of risk-based premiums, and the social effects of under- (or not) insured catastrophes. In general, the insurance market appreciates four benefits of the reinsurance system to the market as follows; (i) increasing underwriting capacity, (ii) stabilising profits, (iii) reduce the unearned premium reserves, and (iv) provide protection against a catastrophic loss. The fourth benefit, provide protection against a catastrophic loss, is the center of this discussion.

A reinsurance transaction simply represents an equal transfer of risk and premium from the insurer to the reinsurer. Therefore, the fundamental question is: why do primary insurers and/or government insurance schemes buy reinsurance for catastrophe risk?

One of the main reasons primary insurers seek reinsurance arrangements is that primary insurers cannot diversify away catastrophe risk exposure, they resort to a risk-transfer arrangement with global reinsurers to rid themselves of undesirable excessive concentrations of the catastrophe risk. Thus, we can say that; many small and regional primary insurers usually do not have a well-diversified portfolio of risks. This is exacerbated by the concentration of catastrophic risk. Reinsurance arrangements allow these insurance companies to diversify underlying disaster loss exposures beyond the internal risk pool. Furthermore, insurance companies are not in many cases owned by diversified investors capable of diversifying the residual non-systemic risk inherent in an insurance company's portfolio through positions in their personal investment portfolio. As a result, reinsurance provides an alternative mechanism for further reducing the non-systemic risk to shareholders of the insurance firm.

In summary then, the reasons why reinsurance is of value to disaster insurance is centered on the ability of the reinsurance company to bear the risk of catastrophic loss at a lower cost than that of the primary insurance company. As such, by efficiently transferring risk to the reinsurer, a reinsurance contract reduces the cost of writing primary insurance, ultimately expanding primary insurance capacity. Since losses from natural disasters are highly correlated geographically and because insurance companies tend to have regional concentrations of risk from these catastrophe losses, primary insurance companies will always seek reinsurance to manage their exposure to natural disaster losses.

The effectiveness of reinsurance mechanisms in disaster risk management system directly impacts the supply of primary insurance for natural disaster risks, and indirectly feeds into the premium rates. Because of the highly correlated nature of natural disaster

risks, however, private reinsurance companies are not always able to fully diversify all disaster risks in the system. As a result, global reinsurance markets continue to experience stress from overexposure to disaster risk. In New Zealand dual insurance system, the overexposure and accumulation of risk have been partially addressed through contract modification from full replacement value or open-ended type policy to nominated replacement value type policy. This modification means that the residual risk is now borne by the policyholder rather than the reinsurance system. Local insurers may have searched for a substitute mechanism to cap exposure or moved away from reinsurance to something else. Further study to investigate this proposition is required. In addition, future studies can investigate whether the policy modification leads to higher probability of under-insurance. The possibility of under-insurance is undesirable socially, and it provides an even greater rationale for reinsurance and government continued collaboration to enhance primary insurers' capacity and affordability of coverage.

Lead by the syndicates at Lloyd's of London, the crucial role played by the reinsurance market post-Christchurch catastrophe cannot be overstated. The complex structure of the reinsurance arrangement is shown in Figure 8-2, which depicts the stages in the catastrophe insurance market through which New Zealand natural disaster business is insured. This is grouped into three levels; primary insurers, primary reinsurers, and retro-reinsurers, based on their position in the chain of insurance and reinsurance buyers and sellers.

On Level, I are the primary insurance companies that issue homeowners policies. The direct writers in turn purchase reinsurance contracts normally referred to as "catastrophe cover" from primary reinsurers on Level II. On Level II are companies

such as large professional reinsurers, many syndicates at Lloyd's of London as well as large and small broker market reinsurers worldwide. Some reinsurers specialize in this business. Typically, those companies would be leads; lead reinsurer is the reinsurer responsible for negotiating the terms and rates of insurance treaty that other reinsurers participate in, who would quote terms on contracts which other companies would then follow.

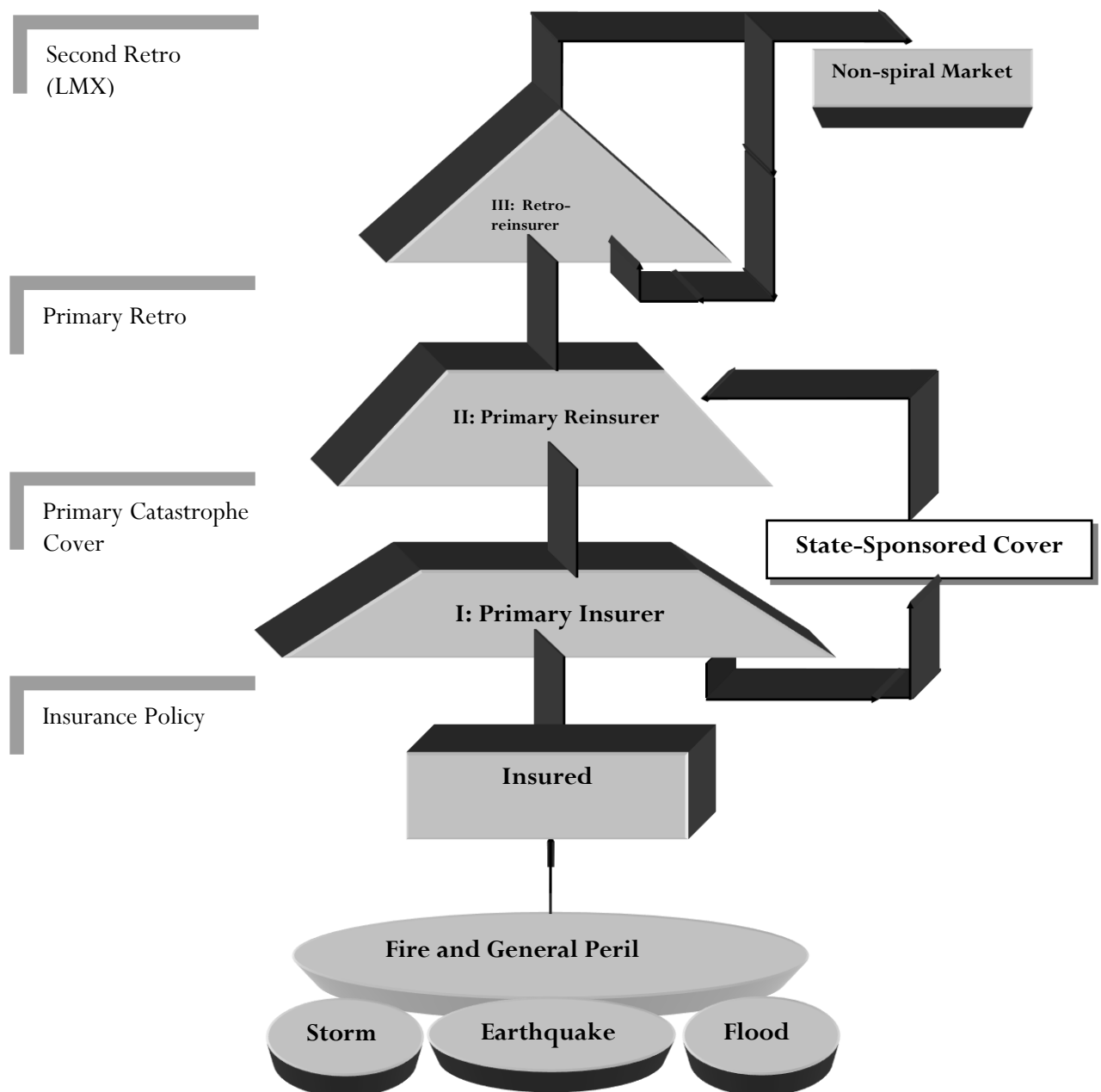


Figure 8-2: Structure of Natural Disaster Insurance and Reinsurance Transfer

Occasionally and more-so in highly catastrophe prone markets, reinsurers directly influence the premium rate and other policy conditions at level I. For example, the Christchurch earthquakes led to a switch from total replacement home insurance to the sum insured. These changes were directed by the reinsurance corporation in order for reinsurers to better understand their maximum liability for residential properties in New Zealand.

On Level III are companies who reinsure the primary reinsurers. They provide catastrophe cover referred to as “primary retrocessional contracts” for the primary reinsurers. Although many of the primary reinsurers will write a handful of these primary retro-contracts, the number of companies that specialise in and write a significant volume of this business is a small subset of the universe of reinsurers. Some syndicates at Lloyd's are specialists in this type of business. These companies at Level III themselves buy secondary retrocessional catastrophe cover referred to as London Market Excess ‘LMX’ of Loss business. There is not a distinct fourth level of companies writing these, but they are written by a subset of Level III companies themselves.

This investigation finds that an estimated 37 percent of Lloyd's total business in reinsurance has most relevance to New Zealand. Gross written premiums amounting to NZ\$340 million is generated from New Zealand private insurance customers each year. This places the market at position 47 amongst the 200 countries Lloyd's business works (Franco, 2014). The current level of reinsurance cover for EQC's reinsurance programme is \$4.6 billion and the EQC's deductible (excess) on this programme is \$1.75 billion. A further look at the financial reports of the two big brands in the New Zealand insurance industry (IAG and Suncorp), points to the fact that in the aftermath

of the quakes underwriters took-out more reinsurance arrangements than before. They had taken a view that, it is perhaps riskier hence bought as much cover as they could get. The private insurance companies under the Insurance Prudential Supervision Act are required to buy a certain quantum of reinsurance. The study confirms that the biggest insurance groups have gone further to strengthen their future financial position. For example, IAG increased its reinsurance protection for New Zealand to reinsurance payouts of NZ\$7 billion for a single big quake within the 2015 financial year. It was also protected with NZ\$6.75 billion for a second large seismic event in the same year. This is a 75 percent increase in reinsurance compared to 2011 reinsurance figures which stood at NZ\$4 billion (IAG, 2015).

8.4. Insurance Industry Reaction Post-Christchurch Earthquakes

This section examines the post-quakes reaction on the supply-side using empirical data. The main objective is to show how the 2010-11 earthquakes impacted the insurance market using various insurance business statistics. The data used in this analysis is from two sources: Insurance Council of New Zealand (ICNZ) and one confidential private insurer that provided comparable data for this analysis. The ICNZ data is the business statistic on the data portal for the periods 2008 to 2015 which is published annually, therefore it gives a broad presentation. The Council currently has 28 members who collectively write more than 95 percent of fire and general insurance in New Zealand. The study uses this business statistics to investigate the responses and implications of the earthquakes to the supply-side of the entire insurance market.

In order to give a coherent description of the supply-side insurance market response, this section also investigates two more data sub-set. The domestic building, domestic content, and earthquake: domestic cover forms the second part of the analysis. The

second data sub-set is composed of both industry and one private insurer for the period 2009 to 2014. This two data sub-set analysis aims to produce comparable plots to illustrate the changes after the earthquakes from both industry and insurer standpoint. In the end, then, this section gives a meaningful illustration and the implication of the earthquakes to the operations of insurance markets. The major obstacle faced in the attempts to source sufficient data is the unwillingness of many organisations to provide their private business statistics. An opportunity to rigorously analyse the supply-side of the insurance market responses after earthquakes have been missed.

Table 8-3 gives an outline of the New Zealand insurance market for the period 2008-2015. The most important entry for investigation is the gross written premium, the net claims incurred and the loss ratios for each year. The gross written premium is the total premium, direct and assumed, written by an insurer before the deductions for reinsurance and ceding commissions. It may include additional and/or return premiums. Gross written premium is calculated as the actual premium less all premium refunds and rebates.

Table 8-3: All Business (NZ\$ Millions) 12-months to September 2008 - 2015

Year-End	2008	2009	2010	2011	2012	2013	2014	2015
Gross Written Premium (\$)	3,260	3,417	3,604	3,980	4,449	4,770	5,258	5,261
Net Written Premium (\$)	2,808	2,911	3,119	3,179	3,462	3,653	4,018	3,880
Net Earned Premium (\$)	2,748	2,857	3,073	2,962	3,247	3,507	3,912	3,896
Claims Incurred (\$)	1,881	1,845	2,097	3,312	2,206	2,175	2,350	2,546
Loss Ratio (%)	68.46	64.59	68.22	111.81	67.94	62.03	60.07	65.35
Business Costs (Staff...) (\$)	898	941	997	1,023	1,006	1,201	1,315	1,367
Combined Ratio (%)	101.13	97.53	100.66	146.36	98.93	96.27	93.69	100.45

(Source: Insurance Council of New Zealand, 2016)

Note: Where the Combined Ratio exceeds 100 percent insurance Council members have made a loss in the 12 months reporting period.

The combined ratio is calculated in the last column of Table 8-3. The combined ratio is used in analysing the underwriting performance of insurance industry, especially for non-life insurance where the risk exposure is short-term, generally one year contracts. The displayed combined ratio is an aggregate covering different types of business lines and hence different types of risks. The reason behind the high ratios is that insurance companies had written negative premiums due to high business cost including changes in outstanding claims provision, operating expenses, staff expenses and commissions. Numerous natural disaster events also pushed the average combined ratio of the industry to higher than 100 percent in the years 2008, 2010, 2011 and 2015.

A visualisation plot of the whole industry data illustrating the insurance market changes in both premiums and claims from 2008 to 2015. Figure 8-3 shows a sharp increase in incurred claims in the years 2010, 2011 and 2012. The increase of incurred claims is due to the large earthquakes events within this years which led to unusually high claims expenditures in most of the product line. The fact that the huge claims related to earthquakes occurred over such a short time frame implies that the negative implications were cumulative and compounding to the whole industry.

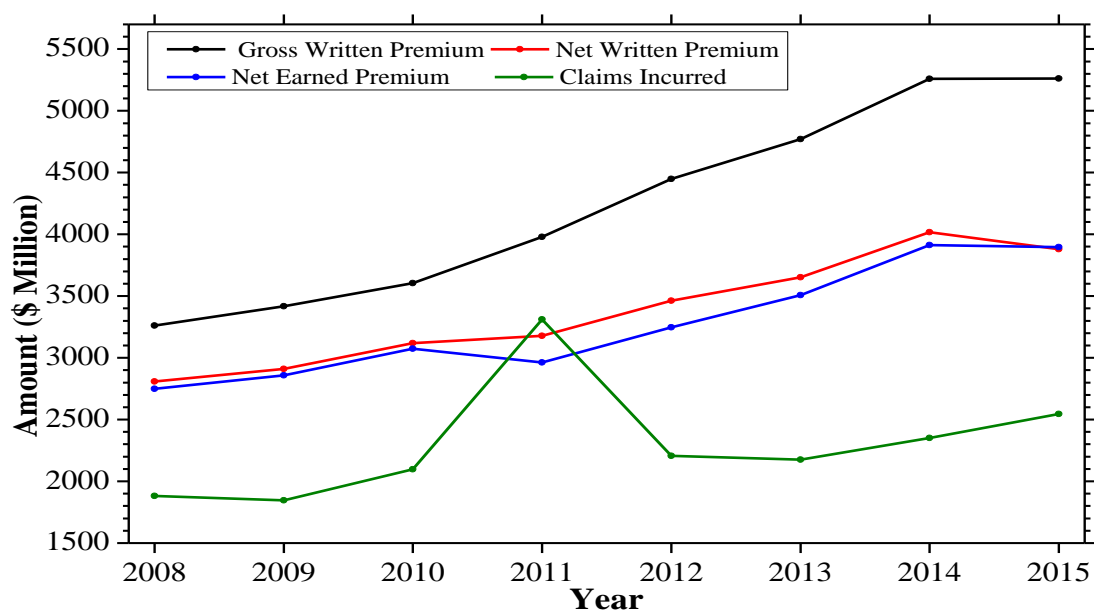


Figure 8-3: NZ Insurance Industry All Business Data for the Period 2008 - 2015

Both Table 8-3 and Figure 8-3 demonstrate steady premium growth with an average annual growth above 8 percent since 2008 with the highest positive growth in net earned premium registered in 2014.

Table 8-4 and Figure 8-4 outline the gross written premium for each product line of the whole industry in both numerical and percentage basis. The first impression inferred from Table 8-4 on the total values column is that the GWP has been experiencing steady growth from about 3.3 billion in 2008 to 5.3 billion in 2015. This apparent growth may be attributed in some part to an overall increase in the value of insured assets, insurance market competitiveness and global capital market change influence on reinsurance markets. The significant portion of the increases in premium rates, EQC levies and better reporting on the part of ICNZ members' data among other variables have also impacted on the earned premium. However, there are other hosts of varying factors which can be attributed to premium growth; a study on drivers of premium growth may be required to avoid subjective conclusions.

Table 8-4: GWP of All Business Class (NZ\$ Millions) for period 2008 - 2015

Year-End	2008	2009	2010	2011	2012	2013	2014	2015
Commercial (\$)	441	464	469	502	590	598	684	687
Residential (\$)	766	840	933	1,052	1,170	1,342	1,477	1,522
Motor (\$)	1,159	1,210	1,226	1,340	1,355	1,410	1,509	1,564
Marine (\$)	114	126	120	120	144	137	141	137
Liability (\$)	267	280	298	314	338	369	457	468
Earthquake (\$)	207	213	220	350	549	609	643	561
Other (\$)	306	283	297	296	303	305	347	321
Total (\$)	3,260	3,417	3,604	3,980	4,449	4,770	5,258	5,261

(Source: Insurance Council of New Zealand, 2016)

The industry all business data for the eight years clearly indicates that the amount of money spent on insurance cover had increased. For example, residential and earthquake insurance business class has been on an increasing trend with earthquake insurance registering double-digit growth from an annual business proportion of 6.3 percent in 2008 to 12.2 percent in 2014 and then a slight decrease to 10.7 percent in 2015 (see Figure 8-4). In dollar terms, the gross written premiums for earthquake insurance has grown three-fold from NZ\$207 million to NZ\$561 million. After the earthquakes, residential buildings and contents insurance also recorded a similar increasing trend from an annual business proportion of 23.5 percent in 2008 to a business proportion of 28.9 percent in 2015. Figure 8-4 clearly shows that earthquake insurance and residential buildings and contents insurance as the only two product lines that recorded a continuously increasing gross written premium between the periods 2010 - 2015. Despite the fact that other products lines recorded some growth in premiums; each class's growth was decreasing as a proportion of the whole insurance business. This can be interpreted as a supply-demand response after the earthquakes, however, the actual factor responsible for these changes remains ambiguous.

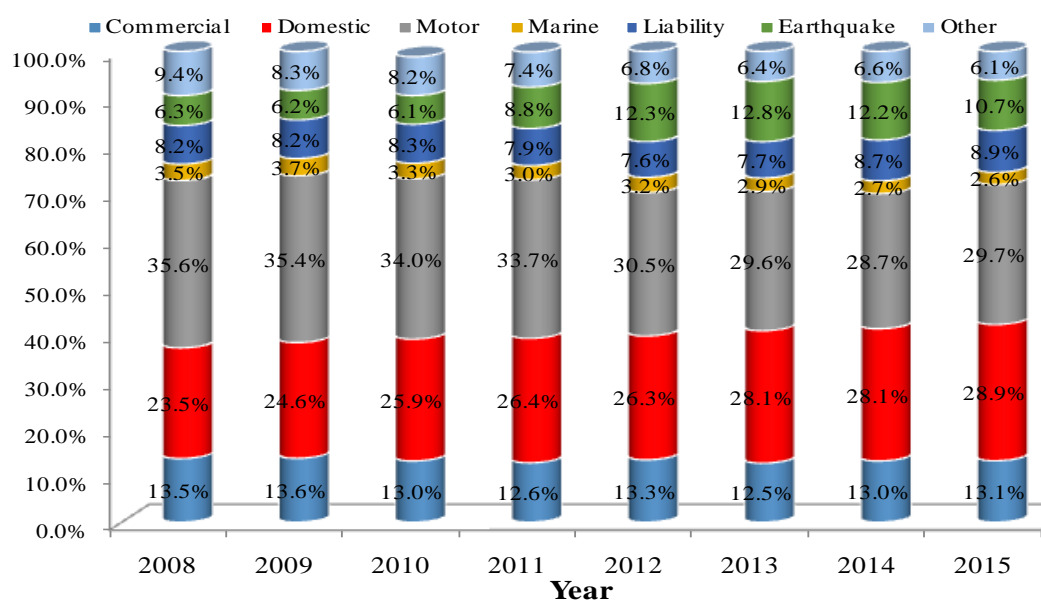


Figure 8-4: GWP of All Business Class for period 2008 - 2015

For the individual product lines with very high growth in GWP, this study postulates that the increase in premiums can be interpreted in three ways. First, it can be seen that the demand for these two classes of products has been sharply increasing since 2010; second, the increase in gross written premiums can be attributed to increases in the premium rates, both insurer and reinsurer rates, and third, increase in EQC premiums levies in order to build-up the national disaster fund: which is currently depleted.

The main objective of this section is to investigate the supply-side responses after the earthquakes using insurance business statistics. The changes on residential insurance in the last five years may be, for the major part, attributed to the earthquake experiences. There have been fundamental changes in contract design and wording in the residential property insurance market. While the impact of the changes may not be inferred from the scant data set used in this analysis; the possible future implication of the policy modification can't be underestimated. The industry data for this line of business indicates higher loss ratios, proportionate relationship of incurred losses to earned premiums expressed as a percentage, in the year's 2010, 2011 and 2012 computed to be 70%, 178% and 84% respectively, although the ratios for the 5 years are positive, the 2011 loss ratio demonstrates that the industry was extremely affected by the claims from the earthquakes. This ratio shows that the industry made a cumulative claim of about 78 percent in excess of the maximum threshold of 100 percent.

Insurance underwriters and regulators use the loss ratio as one of the tools to gauge industry's capacity to offer coverage and the ability to remain solvent when a major catastrophic event occurs. When the New Zealand residential insurance market loss ratios are compared to those in the USA property and casualty insurance industry results for the same period, the loss ratio is slightly above 70 percent (Hagendorff et al., 2015).

This confirms that the insurance industry as a whole in New Zealand was not extremely exposed in most year apart from the huge losses incurred in 2011. The sustained growth in gross written premiums, along with continued soft market conditions-characterised by some premium rate increases and low catastrophe losses after the 2011 quake has since then strengthened the residential insurance product line to withstand against any possible ruin. However, the business cost in the whole insurance section is on the increase based on the combined ratios percentages.

Table 8-5: Residential buildings and contents (NZ\$ Millions) for period 2009 - 2014

Year-End	2009	2010	2011	2012	2013	2014
Gross Written Premium (\$)	897	996	1,052	1,197	1,369	743
Net Written Premium ⁶ (\$)	825	910	901	991	1,107	617
Net Earned Premium ⁷ (\$)	806	883	803	915	1,025	576
Claims Incurred (\$)	536	619	1,431	769	732	441
Loss Ratio (%)	66%	70%	178%	84%	71%	77%

(Source: Insurance Council of New Zealand, 2015)

In the end, what these values show is that New Zealand has been a relatively good market for insurance, and has encouraged reinsurers to stay in New Zealand following the Christchurch earthquakes. This is supported by the fact that even after the major earthquakes most of the local insurance and the EQC have been able to fully meet there claim obligations on time.

⁶Net written premium is gross written premium less outward treaty and facultative reinsurance premium.

⁷Amount of total premiums collected by an insurance company over a period that have been earned based on the ratio of the time passed on the policies to their effective period. Net earned premium is net written premium plus unearned net premium at beginning of quarter less unearned net premium at end of quarter. Gross earned premium is gross written premium plus unearned gross premium at beginning of quarter less unearned gross premium at end of quarter.

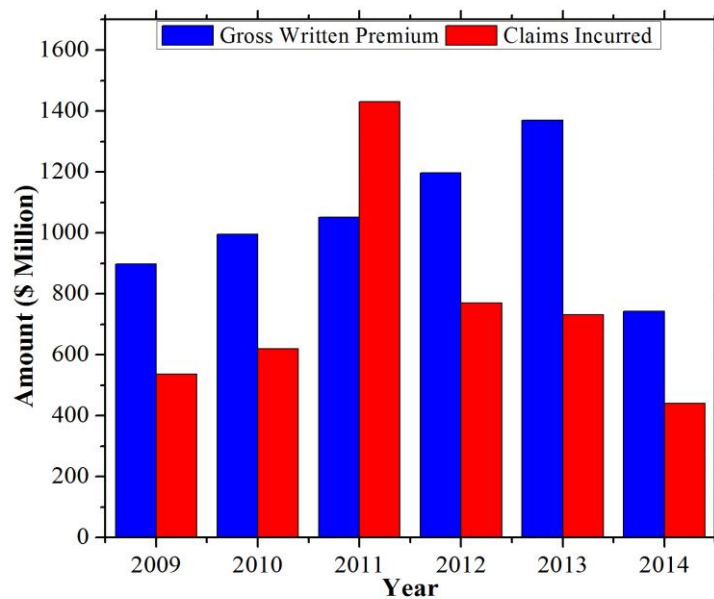


Figure 8-5: GWP and Claims Incurred for the Industry
(Residential buildings and contents)

Figure 8-5 depicts the overall situation in the industry, showing the total net claims incurred in the 6 years versus the gross written premium in the same period for residential insurance cover. At glance, Figure 8-5 depicts New Zealand residential insurance market as a stable product line. It is totally remarkable that there is only one spike on incurred claims around the earthquakes of 2011. This can be explained by the fact that the majority of the earthquakes claims were either dealt with by EQC as under-cap, and it does confirm the important role played by the government-sponsored insurance scheme in addressing catastrophe losses, or the industry received substantial reinsurance recoveries after the earthquakes. The data for 2014 represents 6-months only, thus it should not be interpreted as a decrease in both premium growth and incurred claims. It is also observed that the residential building insurance markets is historically volatile since sales or construction of properties largely depend on the appetite of banks to sell mortgage which indirectly effects on insurance premiums.

It is also important to note the implication of the earthquakes from insurer's standpoint. One of the main responses after the earthquakes is that insurers are now approaching

the market more cautiously and have learned the important lesson to treat each risk independently. To illustrate the supply-side responses from insurer's point of view, this study presents data from one private insurance company that provided a confidential business statistic that could be compared with those from the industry. Thus, the dataset from the insurer representing premiums and claims runs from 2009 to 2014.

Table 8-6: Residential buildings and contents (NZ\$ Millions) for period 2009 – 2014

	Jan-Dec 2009	Jan-Dec 2010	Jan-Dec 2011	Jan-Dec 2012	Jan-Dec 2013	Jan-Jun 2014
Gross Written Premium (\$)	56,900	63,000	77,500	84,700	89,600	50,300
Net Written Units	184,100	193,300	193,200	184,600	194,700	102,900
Claims Incurred Total (\$)	36,960	123,370	269,440	48,640	83,080	51,700
Number of Claims	24,230	27,270	29,930	22,500	22,620	12,300
Reinsurance Recoveries	(200)	(81,800)	(218,700)	(9,100)	(41,000)	(25,800)
Net Claims Incurred	36,760	41,570	50,740	39,540	42,080	25,900
Loss Ratio (%)	65%	66%	65%	47%	47%	51%

(Source: Confidential Private Insurance Company in New Zealand)

The first impressive observation from the Table 8-6 values is that, all the loss ratios are positive and in fact very low when compared to those of the entire industry. The loss ratios for the private insurer average to 57 percent per annum for the 6 years. In essence, the 57 percent loss ratio indicates that on average, the insurers needed 57 percent of the annual premium earned simply to pay losses and loss adjustment expenses, leaving 43 percent of premiums available to cover all other business expenses. Again it can be inferred from this data that, the reinsurance recoveries plays an important role by offsetting a big proportion of the amount of claims incurred by the private insurers. This implies that, although the private insurer was affected at a gross level, sufficient reinsurance arrangement kept the insurer's business at a very stable position even after large loss experience.

Results from one insurer may not be representative of all other insurance companies who might have (or not) diversified portfolio of residential insurance policies

distributed evenly across the New Zealand insurance market. Since this investigation uses business statistics for the period 2009-2014, the statistics are not sufficient for the study to form trends in the insurance business cycle. Thus, the results provide only a useful illustration of the impact of the earthquakes claims within this period from the insurer's perspective.

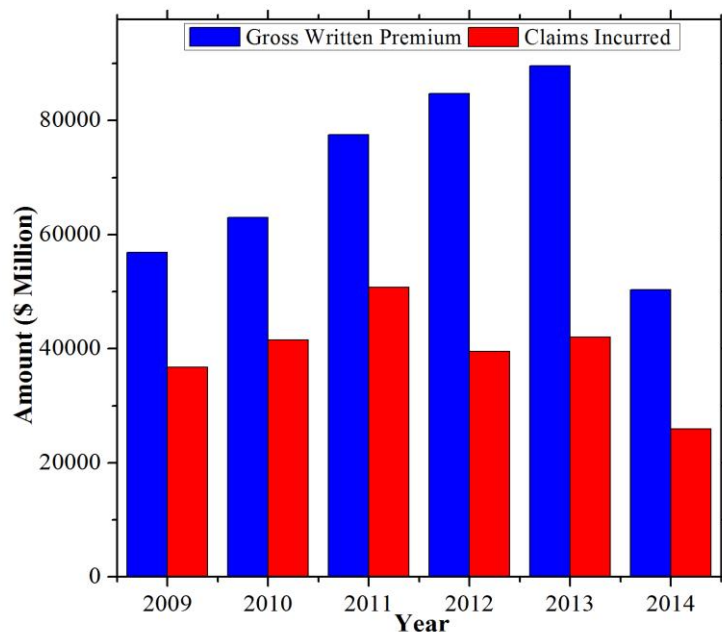


Figure 8-6: GWP and Claims Incurred for the Insurer
(Residential buildings and contents)

It is rather straightforward to identify the business implications of the earthquakes from the loss ratio percentages and the premiums growth as presented in Figure 8-6. As mentioned earlier, the loss ratio may not necessarily imply that insurance inadvertently made losses, however, the magnitude of the ratio should give an impression of the claims experience of the insurance company. Therefore higher or lower ratios do not in totality mean the underwriters made losses or profits in a particular product line, it is indicative of the challenges faced by the underwriters in settlement of claims especially those associated with extreme catastrophe events. However, the ratio figures are more meaningful when looked at over a decade rather than year on year to understand various changes and derive some trend.

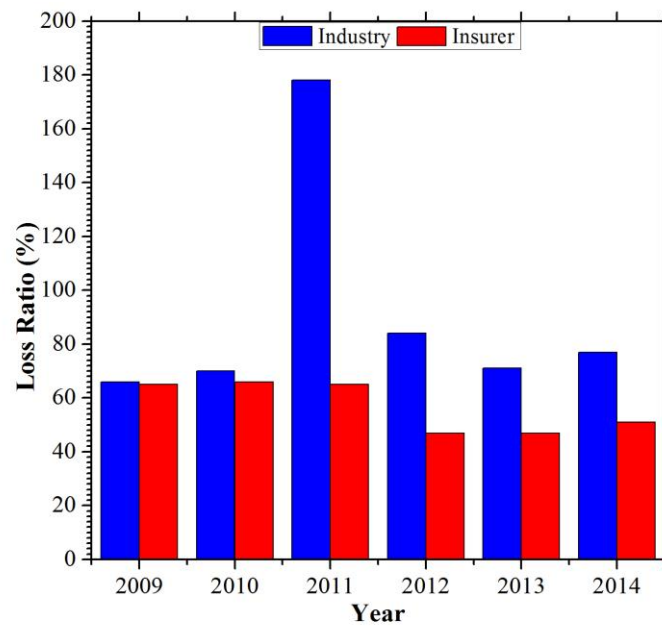


Figure 8-7: Loss Ratio for the Industry (Blue) Insurer (Red)
(Residential buildings and contents)

A plot of the loss ratio of the private insurer alongside that of the whole insurance industry for periods Jan 2009 to June 2014 is presented in Figure 8-7. This plot clearly shows the industry loss ratios for 2011 to be very high when compared to the average loss ratio for the years pre- and post-earthquakes. In such a scenario of a very high ratio of earned premium versus incurred claims, the insurance industry has a reason to worry about its ability to meet all the insured claims and the business operating costs once they fall due. In most cases, however, the industry will be fully protected either by catastrophe reserves or claims recoveries from reinsurance arrangements and other alternative risk transfer systems out in place. The private insurer registered significantly lower percentages of loss ratio for the 6 years, 2009-2014 when compared to the whole industry. Perhaps this can be attributed to a lower claims ratio, a lower claim payable as a percentage of premium income. In most cases insurers with access to superior data analyses large volumes of data set to identify high-level risk trends, such as the most common reasons for claims in a particular product line. Insurers then take steps to

mitigate those causes and improve their underwriting loss ratios; this is certainly the case for this private insurer understudy.

8.5. Conclusions

This chapter has argued that government intervention in the provision of natural disaster insurance is of absolute necessity to avert situation of noninsurance and underinsurance. It has been shown that, in a situation of mass noninsurance and underinsurance, spatially concentration of both catastrophe risk and negative externalities creates cost spill-overs and social chaos. This study demonstrated that, political economy considerations make it more likely for government support to be called for if many people are uninsured than if few people are uninsured. However, the analysis finds that emergency assistance for property owners after catastrophe events can encourage most property owners to not buy insurance against natural disaster and also develop adverse selection behaviour, generating larger future risks for homeowners and governments.

This study observes that homeowners in higher risk areas benefit from EQC's flat-rate pricing structure of the dual insurance model, which keeps private insurance premiums affordable nationwide. That, in turn, helps keep national homeowner take-up rates of insurance against natural disaster very high. The high rates of private insurance take-up also greatly reduce the risk that the government will be called on after a natural disaster to provide assistance to uninsured homeowners.

The key to success of the dual insurance system despite the high prevalence of catastrophe losses is that, the New Zealand insurers and the EQC have an elaborate reinsurance arrangement in place. As such, by efficiently transferring risk to the reinsurer, the cost of writing primary insurance is considerably reduced ultimately expanding primary insurance capacity and supply of insurance coverage. Since losses

from natural disasters are highly correlated geographically and because insurance companies tend to have regional concentrations of risk from these catastrophe losses, primary insurance companies will always seek reinsurance to manage their exposure to natural disaster losses. In New Zealand's dual insurance system, overexposure and accumulation of risk at reinsurance market have been partially addressed through contract modification from full replacement value type policy to nominated replacement value type policy. This modification means that the residual risk is now borne by the policyholder rather than the reinsurance system. Local insurers may have searched for a substitute mechanism to cap exposure, move away from reinsurance to something else, study to investigate this proposition is required. Similarly, future studies can investigate to what extent does the policy modification leads to higher probability of under-insurance.

This analysis also concludes that large claim experience related to earthquakes occurred over a short-time frame creating a cumulative and compounding losses in domestic building, domestic contents and earthquake domestic product line for the whole industry. This led to depletion of national disaster fund from EQC perspective and a net loss ratio of 178 percent for 2011. There was also a drastic increase in both the EQC levies and the private insurance premiums. Furthermore, the ICNZ and private insurer data show that the insurance premiums have been on steady growth with the highest growth registered after the earthquakes. However, it is ambiguous to form a reasonable conclusion specific reasons for growth in premium and if this is in some part as a response to the changes after the earthquakes. The premium growth can be attributed to a host of varying factors; a study on drivers of premium growth may be required to avoid subjective conclusions.

CHAPTER NINE

9. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

9.0. Introduction

This chapter gives the main findings and general conclusions based on the results of this study. The recommendations, limitations and policy implications of this research are considered and suggestions for further research into the reactions of residential property insurance market in the aftermath of the natural disaster are given. This conclusion chapter also summarises the contributions of the thesis and its possible impact, and discuss the important directions of future work.

The rest of the chapter is organised as follows: Section 9.1 lists the summary and conclusions of this research. Section 9.2 presents the contributions and significance of the study. Finally, section 9.3 presents the recommendations and discusses the policy implications of the study.

9.1. Summary and Conclusions

The general goals of this research are centered towards establishing insurance market response after earthquakes. This study has only investigated the property and content insurance from both demand and supply standpoint for the period pre- and post- Christchurch earthquakes. The Christchurch earthquakes are used as a case study to investigate how catastrophic natural disaster affects insurance coverage. The thesis presents post-catastrophe responses on both supply-side and demand-side and captures the perception towards risk in the period immediately after the catastrophe and how this drives insurance decisions. The study has reviewed existing work on natural disaster

insurance and conducted a survey and interviews on both the demand-side and the supply-side of the residential property insurance market. The study's findings are based on results of descriptive and statistical analysis, and simulation using theoretic models.

The key findings of this study are:

- i). Natural disasters create challenges for insurers because there is substantial ambiguity associated with the probability of such events occurring and spatially concentrated negative externalities to major economic activities when disasters occur. This, in turn, implies that the premiums for such events are much higher than the expected loss because the insurer has to provide a large amount of capital and reserves required to insure catastrophic events.
- ii). The demand for catastrophe insurance may be too low since it is not optimal for the policyholder to buy insurance coverage at such a high premium. Thus, high premium suppresses insurance demand, but the magnitude of how high premiums and high probability of risk actually affect insurance demand is still largely unknown.
- iii). In other catastrophe insurance markets, the supply of disaster coverage is curtailed unless the government provides some form of subsidy to private insurers. However, the reason why insurance demand decreases with time from the last disaster, even when the private insurers' supply of coverage is highly subsidised by the government, is still unsettled.
- iv). Political economic considerations make it more likely that government support would be called for if many people are uninsured than if few people are uninsured. When there are large numbers of under-insured or uninsured

property owners, the experience elsewhere in the world is that governments feel compelled to provide financial assistance to affected households.

- v). Homeowners in higher risk areas also benefit from EQC's flat-rate pricing structure, which keeps private insurance premiums affordable nationwide. That, in turn, helps keep national homeowner take-up rates of insurance against natural hazards very high. This is of direct benefit to homeowners and private insurers. The high rates of private insurance take-up also greatly reduce the risk that the government would be called on after a natural disaster to provide assistance to uninsured homeowners.
- vi). The results of this analysis show that, the change from full replacement value type policy to nominated replacement value type policy is the key determinant of the direction of change in the level of insurance coverage. The outcome of the analysis clearly indicates that most policyholders increased the level of insurance coverage so as to comply with the new policy modification.
- vii). The survey has added further evidence to the existing literature that insurance policyholders update their risk perception immediately after major catastrophe losses. Those who have had a recent experience with disaster loss report increased risk perception that a similar event could happen in future with females reporting higher risk perception than males.
- viii). Most studies have reported decreased insurance supply post-disaster loss; this study presents new opportunities from an underwriting perspective. The findings show that a short period of moratorium immediately after the earthquake helps the insurance market to understand the new risk exposures and put in place stringent measures to provide insurance coverage for new risks.

- ix). There is a causality relationship between gender and the changes in household insurance cover. However, the exact direction of change is still ambiguous. The relationship would depend on insureds' degree of risk aversion and how it changes with changes in the level of income, the change in value of insured assets and the change in insurance premiums.
- x). An increase in an individual's income alone has no major effect on insurance demand. The direction of the effect depends on whether an increase in income increases both the premium rates and the insured asset, and on whether the insurance demander has increasing or decreasing absolute risk aversion. Thus, if the insurance demanders perceive a higher possibility of natural disaster then they adjust their coverage appropriately.
- xi). Large claim experience related to earthquakes occurrence over a short-time frame created cumulative and compounding losses in domestic building, domestic contents and earthquake domestic product line for the whole industry. This led to depletion of national disaster fund from EQC perspective and an industry net loss ratio of 178 percent for 2011. There was also drastic increase in both the EQC levies and the private insurance premiums. The post-earthquake average loss ratio is equal to 91 percent for residential buildings and contents insurance coverage in New Zealand for the period 2009 to 2014. This can be compared to USA property & casualty insurance industry results for the same period in states with similar risks, where the loss ratio is slightly above 75 percent (Hagendorff et al., 2015). This shows the product line has been underperforming in New Zealand insurance market when compared to the USA insurance market.

- xii). The EQC creates a positive market distortion by providing a huge excess for natural disaster cover, however, these distortions are mostly positive distortion to both policyholders and private insurers. The existence of the EQC scheme taking the first loss for dwellings based on a flat levy irrespective of size or location of dwelling mutes the risk signal and potentially creates adverse selection behaviour from insureds perspective and on the other side it enables private insurance which has a higher degree of risk rating to be cheaper because it doesn't have to meet the first loss and this therefore helps keep insurance in total more affordable.

9.2. Contributions and Significance of the Study

This study has made an array of contributions from its findings. This research provides unique empirical and theoretical contributions through first conducting a demand-side survey of individuals who had been affected by catastrophic events. The survey responses are then analysed with an aim to understanding how catastrophes affect insured's demand. Then supply-side interviews and discussions with key stakeholders in insurance supply were carried out. The empirical data from both the supply-side and demand-side is collectively analysed and interpreted with the theoretical models' outputs to generate comparable findings.

Secondly, contributions are made through the intertemporal model and the actuarial model employed to empirically and theoretically test how demand and supply respond to natural disaster events.

The main contributions of this approach for the present study are:

- i.) The theoretical model simulation results present a novel approach in which pre- and post-loss insurance markets can be analysed. The key innovation and contributions of this model are:
 - a) The model provides a natural theoretical way to establish how the demand for insurance is affected by the size of the loss suffered in the previous period, that is, the post-loss insurance demand.
 - b) The model provides a unique way to study the effects of increases in risk aversion, increases in the premium, and increases in the perceived probability of loss on the demand for insurance especially when this occurs in different periods.
 - c) It is notable that with this model insurance could be sought sequentially in two periods of time, and in the second period it is known whether or not a loss event happened in period one. And then the model incorporates a parameter on probability updating in an effort to explain why demand for coverage increases after a loss event.
 - d) The period one demand for insurance increases relative to the standard single period model, when the second period is taken into consideration. Period two insurance demand is higher post-loss, higher than both the period one demand, and the period two demand without a period one loss.
 - e) Lastly, when the intertemporal model results are compared to the findings from previous studies on the insurance demand, it can be inferred that insurers tighten the underwriting criteria when the insurance demand increases post-loss. Positive change in the insurance demand increases the cost of insurance cover in the short-run. Two major policy implication outcomes of increase in insurance demand post-loss based on Christchurch

earthquakes is that; (i) deductibles changing from a percentage of the claim to a percentage of the insured value, and (ii) stringent risk-based underwriting measures in attempt to address adverse selection behaviour and risk classification.

ii.) An actuarial perspective to pricing residential property coverage against natural disasters with an earthquake catastrophe endorsement, presents a unique risk-based approach. The key innovation and contribution of this actuarial model are:

- a) It presents a new simple approach for rate-marking. This is an insightful contribution to the literature on catastrophe insurance especially with respect to premium loading. This model will play an important role to set internal benchmark rates in pricing natural disaster insurance coverage. However, it is crucial to study some models of market behaviour to find out the expected tendencies from market conditions; and how the consumer reacts to the premium rates proposed.
- b) This modelling framework provides a structure to examine the complex natural disaster risk pricing. This is a unique model that could also help in addressing the complexities and challenges posed by the integration of compulsory EQC cover to the primary private insurance cover without risk-based underwriting the natural disaster risk. Thus the model presents an efficient risk-based pricing approach that can be used for natural disaster rate-making in any insurance market with similar risk characteristics.
- c) When the proposed model incorporates the new RMS high-definition New Zealand Earthquake Model, insurers can then use the model to uniquely identify losses at a granular level so as to calculate the competitive premium.

This is a major contribution given that the local insurer has revealed earthquake modelling marginally inform underwriting and pricing at a geographical level in relation to the likelihood and severity of the events. And as such, there have been no major moves to price technically for an earthquake as there is still limited accurate information from predictive models that can usefully provide incidence or severity information.

- iii.) The statistical analysis contributes to the existing literature on insurance demand determinants and other demand associated variables by:
 - a) Examining whether the variables in question have a significant association with the household demographic characteristics, and how these collectively affect change in level of the insurance demand post-loss.
 - b) Conducting a demand-side survey to tease out, purely, the insurance market response from the demand-side perspective and investigate how various insurance demand determinant variables influence change in the level of insurance coverage post-catastrophe using simple descriptive analysis and correlation analysis. The output of this analysis is a crucial contribution to understand how insurance demanders have adjusted their level of insurance as a result of the contract modifications and the effects of insurance demand determinant variables post-disaster. In essence, this gives an innovative way to understand the effect of catastrophes on both the demand and supply sides of the insurance market.

9.3. Recommendations and Policy Implications

The present study was driven by the desire to understand the domestic insurance market response, both on the demand-side and the supply-side, in the aftermath of a major

disaster. A number of results have been achieved that can be incorporated into the market's best practice while some parts of this study could be improved to generate better results.

Within the post-Christchurch disaster insurance outlook, with increased risk-based pricing and stringent underwriting terms in New Zealand, there is a higher risk of underinsurance among property owners. This is more likely so with the new policy requirements in place where the property owners are now required to nominate the sum insured for their property. When there are large numbers of under-insured or uninsured property owners, the experience elsewhere in the world is that governments feel compelled to provide financial assistance to affected households. When a disaster occurs in such an environment, homeowners face large catastrophic losses and most individuals can only depend on the uncertainties of emergency government assistance. The biggest problem posed by the emergency assistance for property owners is that, it can encourage the assisted and other owners to not buy insurance against natural disaster, generating larger future risks for homeowners and governments. In order to avoid the insurance market inefficiency and adverse selection behaviour from property owners, a form of government-sponsored insurance coverage is necessary.

Further to government interventions:

- i.) There is a need to develop education awareness program for property owners in order to improve their accuracy in estimating a sufficient sum insured, and the benefit of regular updates of insurance cover limits.
- ii.) Risk-based underwriting is the way forward. Insurance premium rates that reflect building seismic risk provides risk signals and future savings to individual owners and encourage them to engage in cost-effective mitigation

strategies to reduce their vulnerability. There are several benefits of adopting a good earthquake insurance policy in both property risk management and earthquake disaster management, but its role in managing seismic residual risk in New Zealand's insurance market has yet to reach its full potential.

The EQC scheme has not delivered to the degree envisaged by all the stakeholders, this conclusion is drawn from the comments raised by the survey respondents and the numerous under-cap/over-cap claims filed in courts. It is grossly underfunded in that the premiums payable by policyholders for this dual system have no actuarial basis. EQC pricing arrangements and the structure of the flat rate premium creates two main concerns; first, the EQC does not require premiums to reflect the costs and risks as EQC has an unlimited government funding guarantee. Second, EQC premiums are almost never changed. The premium rate first established in 1945 remained unchanged, per dollar of cover, for over 65 years. In 2012, it was then tripled in response to the losses generated by the Christchurch earthquakes. The EQC premium on home and contents insurance increased on 1 November 2017 for the second time post-earthquakes. The proposal put forward is that, at the previous premium rate of 15 cents per \$100 of cover it would have taken more than 30 years to rebuild the Natural Disaster Fund (NDF) to \$1.75 billion, the amount of excess EQC needs to pay on its current reinsurance programme. Increasing the premium rate to 20 cents would help EQC meet its long-term costs and rebuild the NDF to this level within 10 years. The scheme is also unfair, in that it benefits only those who have taken out fire and general peril insurance with the local private insurance companies. Having observed this, the recommendations of this study are:

- i.) A more inclusive quasi-social government guarantee insurance mechanism could be considered for the property owners electing to carry out alternative risk mitigation measures such as self-insurance backed by advance seismic retrofitting and flood mitigation measures in line with the local council codes. Perhaps future studies could look into how to introduce compulsory minimum actuarial based levies as premiums for the government guaranteed insurance mechanism or some sort of risk-differentiated premiums.
- ii.) Some of the supply-side distortions observed should be addressed. The feature of the current dual insurance model is a risk-sharing arrangement between EQC and the private insurer. At present, EQC takes on natural disaster risk as a result of a private insurer selling a fire policy. Therefore, there is the potential for the private insurer to impose risks on EQC that they are not exposed to, for example by selling fire-only policies, in contrary, most residential insurance policies sold in New Zealand are all-risks policies that cover natural disaster damage. These complexities and challenges posed by the integration of compulsory EQC cover under the fire and general insurance coverage could be looked into for future efficiency.

In the present study, interviews and discussions with local insurers have found that earthquake modelling marginally informs underwriting and pricing at a geographical level in relation to the likelihood and severity of the events. A popular common approach in New Zealand has been to ensure that the insurer is not over-exposed in terms of geographical market share and in this light; the major risk mitigation for earthquakes has only been through reinsurance. In addition, many insurers now decline to provide standalone earthquake cover in certain parts of Christchurch and some

buildings are now simply uninsurable for natural catastrophes. Having observed this, the study recommends that:

- i.) With the cost of insurance increasing, attention needs to focus on efficient reinsurance mechanisms. Insurers and other catastrophe management stakeholders must be innovative to develop other catastrophe risk management avenues, ranging from the private securitization of insurance risks to public-private partnerships to increase insurance capacity in constrained markets. Insurers can also explore the availability of alternative risk financing instrument supplement traditional reinsurance and achieve cost-efficient means of obtaining coverage and capacity for different levels of catastrophic loss by examining the options and choices. Alternative Risk Transfer (ART) market solutions, like cat-bonds, will enable insurers to select the most appropriate risk finance and acquire contingent capital at economic cost, shifting the insurance risk away from traditional reinsurers to the wider capital markets.
- ii.) The modelling framework provides a structure with which to examine the complex natural disaster risk pricing and, as such, it should offer a number of opportunities for insurers to update their pricing models, and to look for improvements and future innovations. An emerging question is how to use risk-based models to measure the risk tolerance of the underwriting insurer against natural disaster. When the proposed model incorporates the new RMS high-definition New Zealand Earthquake Model for example, then insurers can use the model to identify losses at a granular level, for better risk management decisions.

- iii.) This model may also be improved in order to be useful for assessing natural disaster loss capital requirements and reserves strategy so as to meet solvency margin requirements or other reserve requirements.

The increases in catastrophes around the world have had a remarkable effect on the New Zealand insurance industry and the ability to obtain insurance and reinsurance coverage. In practical terms, reinsurance costs have skyrocketed for insurers. Major underwriting restrictions are being applied to policy coverage also. This implies a lot of pressure for increased premiums. From an underwriting perspective insurers are now looking for more rating factors, like the age of buildings, land structure, nature of construction, the spread of risk, and extent of strengthening work. The current state of catastrophe modelling does not allow comprehensive pricing of the perils covered by both EQC and private insurers. There are gaps in modelling for land risks, as well as for building damage from the non-earthquake perils covered. This is due to gaps in data and scientific understanding that are unlikely to be filled in the short to medium term. However, insurers are requesting seismic reports in high seismic regions. The seismic reports together with geophysical and technical data collected throughout the Christchurch earthquakes settlement process are extremely valuable in ongoing research of hazard risk mitigation and management. Going forward, higher risk regions and properties are expected to face further increases in premiums in the coming years, as insurers become better at pricing individual risks. Continuous premium increases would be unaffordable for some homeowners and are likely to result in lower rates of insurance cover in higher risk areas.

In this context, the study recommends that:

- i.) Insurance stakeholders should develop a nation-wide scheme or a registered facility that presents insurers and other key stakeholders with a list of known risks situated across the country.
- iii.) Insurance stakeholders should develop a national awareness program for property owners to improve their understanding of alternative natural disaster mitigation strategies such as seismic retrofitting their properties and securing house contents. This measure should be able to reduce the pressure on insurance costs and those who have installed sufficient risk mitigation strategies should be treated more favourably from an underwriting viewpoint.
- iv.) Due to the increased occurrence of catastrophes and the changing nature of disasters, risk-based pricing could mean that those who cannot afford mitigation measures also might not be able to afford insurance coverage. Therefore, there is a need for both private insurers and public disaster managers to develop a strategy of how to reduce losses from future natural disasters as well as to appreciate the limitations of individuals, organisations and communities in dealing with low-probability, high-magnitude events.

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Appendix

Appendix 1: The Text of the Electronic Survey

Preview Survey

Survey to examine how insurance demanders reacted to their insurance coverage in the aftermath of 2010-11 Christchurch earthquakes
You have unlocked your survey. When you have finished editing, please lock your survey again.

PART A: GENERAL HOUSEHOLD INFORMATION

Thank you for taking the time to answer this anonymous short online survey regarding residential property and contents insurance coverage. The survey is directed only to insured home owners and real-estate property owners and should take no more than 10 minutes to complete.

Select a graphic to use for this question

1) Which age group do you belong to?

- | | |
|---|--|
| <input checked="" type="radio"/> a) 18 - 30 years | <input type="radio"/> d) 51 - 60 years |
| <input type="radio"/> b) 31 - 40 years | <input type="radio"/> e) 61 - 70 years |
| <input type="radio"/> c) 41 - 50 years | <input type="radio"/> f) Over 71 years |

2) What is your gender ?

- ☐ a) Male
- ☒ b) Female

3) Highest level of education;

- ☒ a) High school graduate
- ☐ b) Technical/University graduate
- ☐ c) Postgraduate degree
- ☐ d) Other

4) Annual income;

- | | |
|--|--|
| <input type="radio"/> a) Below \$14,000 | <input type="radio"/> c) \$48,001 - \$70,000 |
| <input type="radio"/> b) \$14,001 - \$48,000 | <input type="radio"/> d) Above \$70,000 |

5) What is your property's postcode or suburb

6) Was your property built after June 2012

- ☐ a) Yes
- ☐ b) No

7) If your property was built prior to June 2012, have you previously filed for earthquake or any other natural hazard claim through EQC or your insurer?

- ☐ a) Yes
- ☐ b) No

8) What is the approximate value of your property?

- ☐ a) Below \$300,000
- ☐ b) \$300,000 - \$400,000
- ☐ c) \$400,000 - \$500,000
- ☐ d) \$500,000 - \$600,000
- ☐ e) \$600,000 - \$700,000
- ☐ f) Above \$700,000

PART B: INSURANCE COVERAGE INFORMATION

9) Did you consider the possible occurrence of a **natural disaster** when you bought or moved into your current property?

- ☐ a) Yes
- ☐ b) No

10) Would you be willing to spend more money on your property that would make it more disaster resistant in line with new council seismic and floods standards?

- ☐ a) Yes
- ☐ b) No
- ☐ c) Not decided

11) What is the **maximum** premium you are willing to pay per annum to fully protect your residential property and contents from natural disasters **through insurance coverage** (please check only one)

- ☐ a) Below - \$600
- ☐ b) \$600 - \$900
- ☐ c) \$900 - \$1,200
- ☐ d) Above \$1,200

12) What is the **maximum** amount of money that you are willing to pay per annum to fully protect your residential property and contents from the risk of damage from natural disasters **through alternative risk management and risk reductions measures in line with the new or updated council standards** (please check only one)

- ☐ a) Below - \$20,000
- ☐ b) \$20,000 - \$40,000
- ☐ c) \$40,000 - \$60,000
- ☐ d) Above - \$60,000

13) How has the total premium you pay for residential property insurance changed from pre-earthquake period to post-earthquake period:

- ☒ a) Increased

- ☐ b) Decreased
- ☐ c) No change

14) Do you perceive insurance coverage per dollar of property insured is greater now than before the earthquakes

- ☐ a) Yes
- ☐ b) No
- ☐ c) Do not know

15) In the aftermath of the 2010 and 2011 Canterbury earthquakes how have you voluntarily changed the level of your past insurance coverage?

- ☐ a) Increased
- ☐ b) Decreased
- ☐ c) No change

16) If **increase**, in response to *Question 15* above; why? (check all that apply)

- ☐ a) To cover a more valuable asset
- ☐ b) The risk is now higher
- ☐ c) Insurance payout allowed me to dedicate more to insurance
- ☐ d) In response to changes in the premium
- ☐ e) Other

17) If **decrease**, in response to *Question 15* above; why? (check all that apply)

- ☐ a) To cover a less valuable asset
- ☐ b) The risk is now lower
- ☐ c) Insurance payout was insufficient to allow me to dedicate more to

insurance

- ☐ d) In response to changes in the premium
- ☐ e) Other

18) Comparing the new post-earthquake "sum insured" insurance coverage to the pre-earthquake "full replacement value" insurance coverage, how do you rate your satisfaction?

- ☒ a) More satisfied
- ☐ b) Less satisfied

☐ c) Indifferent

19) Based on your perception (including actual experience, observations and also what you have heard from others; e.g. insurance companies, banks, independent financial advisers or government agencies), in relation to your current residential property and contents insurance policy in the aftermath of 2010 and 2011 Canterbury earthquakes, how would you rate the **overall changes** in the following items?

	Increased significantly	Increase d	Increase d slightly	Neither increase d nor decrease d	Decrease d slightly	Decrease d	Decreased significantly
a) Probability of loss from another earthquake	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
b) Availability of insurance coverage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
c) Property value	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
d) Money spent on insurance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

20) Based on your perception (including actual experience, observations and also what you have heard from others), how would you rate your **overall satisfaction** with the New Zealand residential property and contents insurance market on the following items;

	Very Dissatisfied	Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Satisfied	Very Satisfied
a) Premium rate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
b) EQC and other government levies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	Very Dissatisfi ed	Dissatisfi ed	Somewha t Dissatisfi ed	Neutr al	Somewh at Satisfied	Satisfi ed	Very Satisfi ed
c)Policy Deductible/Exc ess	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
d) Claims handling process	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

21) Based on your perception (including actual experience, observations and also what you have heard from others), how would you rate the **overall market perception** that, prior to 2010 and 2011 Canterbury earthquakes most properties where considered to be:

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
a) Under-insured	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
b) Insured for true value	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
c) Over-insured	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

22) In the aftermath of the 2010 and 2011 Canterbury earthquakes the New Zealand residential and content insurance policy has changed from an open ended insurance cover to specific sum insured coverage. Based on your current property value, how would you rate the **overall market perception** that, residential properties and contents are now considered to be:

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
a) Under-insured	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
b) Insured for true value	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
c) Over-insured	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

23) Have you had a case where an insurance provider declined to offer insurance coverage to protect your property against any potential risk?

- ☐ a) Yes
- ☐ b) No

24) If yes to *Question 23* above, what was the reason given for the decline to provide insurance coverage?

- ☒ a) Property falls in exclusion/red zone
- ☐ b) Pre-existing earthquake damage
- ☐ c) Property did not meet minimum construction standards
- ☐ d) Others