國立交通大學

交通運輸研究所

博 士 論 文

No.55

新車車主重複購買汽車保險行為之研究

Modeling Repeated Choice Behaviors of Automobile Insurance Policies for New Car Owners

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中 華 民 國 九 十 七 年 一 月

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博 士 論 文

A Dissertation
Submitted to Institute of Traffic and Transportation
College of Management
National Chiao Tung University
in Partial Fulfillment of the Requirements
for the Degree of
Doctor of Philosophy
in
Management

January 2008

Taipei, Taiwan, Republic of China

中 華 民 國 九 十 七 年 一 月

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摘　　要

汽車所有人購買汽車保險常是為了轉移因發生交通事故而造成體傷或財損的風險。在大部分國家，車體損失保險是最昂貴的保單，也是產險公司主要收入來源。無論如何，新車車主傾向於在前幾年購買車體損失險，但為減少保費負擔，經常在往後幾年減少保障範圍或不再購買車體險，而導致產險公司的保費收入明顯減少。本研究之動機是希望建立模式架構以深入了解消費者選擇汽車保險之行為。

本研究的模式架構分為兩大部分：第一部分為車體損失險保單的選擇；第二部分為非車體保單（例如第三人責任險及其他附加險）的選擇。本研究的重點放在第一部分，探討投保人每年持續選擇車體險種的問題。研究方法採用離散選擇模式，替選方案包含車體險種及持續投保相同險種的年數。離散選擇模式考慮多項羅吉特模式(multinomial logit model)、巢式羅吉特模式(nested logit model)、及成對組合模式(paired combinatorial logit model)。

本研究收集台灣某家產險公司被保險人數年的資料，驗證所建立的模式架構。研究結果顯示，重複購買汽車車體損失險保單之行為受年齡、汽車為國產/進口及汽車汽缸量大小所影響。巢式羅吉特模式不僅在概念上或透過統計檢定，皆比多項羅吉特模式適用於分析消費者重複選擇行為。本研究亦發現，雖然成對組合羅吉特模式比多項羅吉特模式與巢式羅吉特模式更具有彈性，但此模式在方案數很多的情況時，校估相當困難，且不易得出理想的結果。本模式架構之發展有助於了解投保人重複選擇汽車保險之行為，且校估結果可提供保險公司修訂現有的汽車保單或研擬新的行銷策略，以吸引消費者重複購買車體損失險保單。

關鍵詞：汽車保險保單、離散選擇模式、重複選擇行為、成對組合羅吉特

Modeling Repeated Choice Behaviors of Automobile Insurance Policies for New Car Owners

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ABSTRACT

Car owners purchase appropriate automobile insurance policies (AIP) to provide coverage for property damages and personal injuries incurred by traffic accidents. Physical damage coverage, the most expensive policy, is the major source of revenues for non-life insurance companies in most countries today. However, new car owners are likely to purchase physical damage coverage in the first few years and then downgrade their insurance by either purchasing reduced physical damage coverage or not even buying any physical damage coverage in the subsequent years. As such, premium revenues for non-life insurance companies will be substantially reduced. The study is motivated by the importance of developing a modeling framework to gain insights into the insured's choice for AIP.

The research develops a model system that consists of two components: the first component is the decision to select different types of physical damage coverage; the second component is the choice of non-physical damage coverage involving third party liability as a basic protection with additional coverage. This study focuses on the first component and, particularly, explores repeated choices of different types of physical damage coverage. A discrete choice modeling framework including the choice of physical damage coverage type and the number of consecutive years that the insured has purchased the same type of coverage is further developed. Various discrete choice models including multinomial logit, nested logit, and paired combinatorial logit are attempted.

The proposed modeling framework is empirically tested using a panel data provided by a non-life insurance company in Taiwan. The results indicate that the repeated choices of physical damage coverage AIP are influenced by age of the driver, vehicle make, and engine capacity. The nested logit model statistically rejected the multinomial logit model, which demonstrates the statistical and structural superiority of the nested logit model in analyzing the insured's repeated choices. Although the paired combinatorial logit model is more flexible than the multinomial logit or nested logit model, it is found that estimation of such model becomes very difficult when the number of alternatives gets large. The model framework developed in the study has improved our understanding of the repeated choices of AIP, and the estimation results have provided valuable implications for the insurer to modify existing automobile insurance policies or to develop marketing strategies so as to enhance the insured intension to repurchase the physical damage coverage AIP.

Keywords: Automobile insurance policies, Discrete choice model, Repeated choice behaviors, Paired combinatorial logit model

誌　　謝

本論文得以順利完成，最要感謝的是恩師藍教授武王的悉心指導，舉凡從研究方向的指引，研究架構的建立，研究方法的啟迪，到投稿文章字字句句的再三斟酌，均使我獲益良多。尤其跨領域的博士班課程與之前大不相同，課業上的壓力與學習上的困頓皆因有藍教授武王的開導與協助，讓學生有了越挫越勇的信心與毅力，並且不厭其煩的糾正過去研究上的錯誤觀念與用法，讓學生有重生的深刻感受。陪伴學生一路走來，對學生的好與無盡的付出，即使公務繁忙卻仍為學生工作至深夜不辭辛勞，感動與感激之情無以言喻，令學生銘感五內、永生難忘，其為師之道為學生表率。其認真嚴謹的學者風範、為學精神與處世態度，實為學生日後治學求知與待人接物的典範。

在研究方法上因有溫教授傑華的指導讓學生得以更深入了解該方法的奧義，亦因老師謹慎再謹慎的態度，雖然時間上需時較長，卻也因此碰觸自己長久以來急性子又粗枝大葉的毛病，勇於面對自己的缺點藉以磨練自己的個性，是為另一個收獲與試煉。兩位恩師的諄諄教誨，學生永感銘心，在此謹向兩位恩師致上最高之敬意與謝忱。

在論文計畫書審查期間，承蒙馮教授正民、許教授鉅秉不吝指正，提供諸多寶貴意見及建議。此外，學位口試時，周教授義華、張教授新立、陳教授敦基及宋教授明哲等的懇切指正與中肯評論，使本論文更臻充實與完備，在此由衷地對其表達誠摯的謝意。求學期間，承蒙丁教授承、黃教授承傳、徐教授淵靜、汪教授進財、黃教授台生、陳教授穆臻及邱教授裕鈞等諸多學識淵博的老師授業解惑，豐富我的學識與知識，在此亦對師長們表達深切之謝忱。同時感謝進入博士班前張教授新立的啟蒙與教導方萌生跨領域的勇氣而與交大結緣。曾教授國雄擴展研究方法新視野，杰炤學長及豐裕學長於入學準備及求學期間特別照顧與關懷，易詩學弟的諸多協助，在在感激於心。

此外，有所辦洪小姐、柳小姐、何小姐及圖書館陳小姐的各項協助，學長鄭董、成蔚、新薰、士展、村基、至宏、政棋、在莒、學姐劍雲、瓊文、同學曾董、銘德、Percy、輝煌，學弟益三、世昌、彥蘅、志誠、永祥、群明、文斌等學業上的相互砥礪及生活上的相互關懷，都將成為我永難忘懷的回憶。

最後，僅將本論文獻給我摯愛的先生在程式軟體上的協助及熬夜時默默陪伴，小蘿蔔頭們常常忍受吃不到媽咪親手煮菜的遺憾及默默幫助我的師父們，感謝大家不計的付出; 並獻給我敬愛的雙親，感謝他們不辭辛勞的養育之恩，以及關心我的公婆及諸親友。畢業並非結束，而是另一個嶄新的開始，我將會秉持出發心，盡力完成使命，以不負各方所望。

民國九十七年一月謹記於臺中

Modeling Repeated Choice Behaviors of Automobile Insurance Policies for New Car Owners

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CHAPTER 1 INTRODUCTION

1.1 Background and Motivation

Traffic accident is a critical issue from the perspective of society as a whole. The potential risks of using an automobile involve damage to one's own property, damage to the property of others, personal injury, and injury to others. Many governments have promulgated laws mandating compulsory automobile insurance to provide basic compensation for property damage and personal injury occurred by traffic accidents (Murray et al., 1994). However, the basic compensation system of compulsory insurance cannot transfer all risks involved in using vehicles.

Car owners often purchase appropriate automobile insurance policies (AIP) to cover potential risks in traffic situations so as to reduce the personal worry or stress incurred from traffic accidents (Sherden, 1984). Except for compulsory insurance, auto owners in many countries are required, in compliance with the law, to obtain voluntary AIP to protect themselves from lawsuits when accidents involve vehicle damage and personal injuries (Murray *et al*., 1994).

AIP in many countries is characterized by complicated bundled designs that provide distinct degrees of insurance coverage to accommodate various risks in traffic accidents. The exact composition of AIP is up to the insured. Today, the total written premiums of automobile insurance constitute the bulk of the non-life insurance market and are the main source of revenues for non-life insurance companies. In most developed countries, the automobile insurance market is thus highly competitive, with an increasing number of service providers.

Physical damage coverage, the most expensive policy, is the major source of incomes for non-life insurance companies. In most countries, the rate for physical damage coverage is higher than other (non-physical damage coverage) policies. New car owners are likely to purchase physical damage coverage in the first year. However, they may decrease their automobile insurance expenditures by purchasing reduced coverage or not buying any physical damage coverage in the subsequent years. As such, premium revenues for non-life insurance companies will be substantially decreased.

Accordingly, it is crucial for automobile insurance companies to understand the insured's repeated choice behavior, particularly in the first few years after purchasing a new car. Understanding of the insured's preferences on selection of bundled AIP is vital for non-life insurance firms seeking to maintain their competitive advantages. The insurer can use the insights to modify insurance policies and provide enough incentives for the insured to enhance repurchase intention so as to retain stable revenues. Consumers, on the other hand, can benefit from the understanding as well since sufficient insurance knowledge assures adequate compensation for property damage loss. Unfortunately, the information between the insured and the insurer is asymmetric and the insured's repurchase behaviors are not well understood so far (Cohen, 2005).

Despite a significant number of studies have been devoted to automobile insurance rates, moral hazard, fraud behavior, adverse selection and risk perception of claims, yet exploration of factors affecting the insured's selection of bundled AIP has been very limited. The choice of bundled AIP is very similar to the problem of selecting individual items from a menu (Ben-Akiva and Gershenfeld, 1998). The insurer offers bundles of insurance policies that cover different risks associated with traffic and related accidents. Recent study by Wen, *et al.* (2005) has proposed the use of discrete choice models (Ben-Akiva and Lerman, 1985) to identify important variables associated with the selection of bundled AIP and to explore substitution patterns among highly similar AIP bundles using one year dataset from an automobile insurance company in Taiwan. To the best of our knowledge, no research has examined the insured's repeated choice of AIP bundles except Wen *et al*. (2007). Therefore, the research is motivated by the need of developing an analytical approach to obtain insights of the demand choice for AIP. It is hoped that the research could offer valuable implications for the insurer to develop effective marketing strategies to ensure their stable revenues.

1.2 Research Objectives

The objectives of the research are:

1. To understand better the insured's behavior, the research develops a methodological framework that enables us to analyze insured's choice of AIP. In particular, the development of operational models allows exploring repeated choices associated with AIP.
2. The proposed modeling framework is empirically illustrated using a panel data provided by a non-life insurance company in Taiwan. The applicability and usefulness of the model structures is explicitly demonstrated and properly tested.
3. The insurer can use the results to modify existing insurance policies or develop marketing strategies that enable the insured to increase repurchase intention.

1.3 Research Scope

Pacing Taiwan's economic development, the number of automobiles and motorcycles has increased rapidly. In a highly populated area as Taiwan, the vehicle density is the source of many problems, particularly traffic accidents. During the last few decades, the percentage of autos used for non-commercial purposes has been approximately 97 percent of all autos. As a result, the written premiums of non-commercial vehicles are the main source of revenues for non-life insurance companies. Thus, the study only examines the insured of non-commercial automobiles and will exclude motorcycles or other types of privately owned vehicles.

The data used in the research are drawn from a non-life insurance company that has the largest market share among the 16 non-life insurance companies in Taiwan. The data set consists of the new car owners who repeatedly purchased bundled AIP from the company since 2000. In other words, we selected the data in which the insured purchased new cars in 2000 and also purchased physical damage coverage for that year and the subsequent years. Those purchasing new cars before and after 2000 were excluded.

Due to data availability, the explanatory variables in this study are limited only to age, gender, marital status, vehicle make and engine capacity. Other important personal attributes (e.g., income, education, occupation and religion) are confidential by law and its access is absolutely forbidden.

1.4 Research Approach

The choice of bundled AIP is similar to selecting features from a menu available for customization. Consumers may decide simultaneously which coverage should be included in their insurance package. An AIP alternative (i.e. possible outcomes of the decision process) thus consists of a combination of different coverage. However, the total number of AIP alternatives in our choice problem may be relatively large, especially when the number of available insurance coverage increases. For model development, inclusion of all alternatives in an individual model would increase the difficulty of model calibration and interpretation of parameter estimates. To simplify the complex choice problem, a model system involving separate models would become more feasible. The development of a simplified model can serve as a preliminary step towards a more general and behaviorally realistic model.

The proposed model system for the choice of bundled AIP in this study consists of two components. The first component is the decision to select physical damage coverage. The insured can select from among three types of physical damage coverage and/or without any coverage. The second component in the model system is the choice of non-physical damage coverage involving third party liability as a basic protection with addition of passenger liability or other endorsement, such as the coverage for bodily injury due to intoxicated driver and/or injury to any persons in the vehicle, including the driver. This research focuses on the first component of the model system, and the decision for choosing non-physical damage coverage involving third party liability is included in the bundle of physical damage coverage.

Car owners who have disposed of their vehicles more than five years old may do so in part because of the yearly inspection requirement by the motor vehicles department or the rapidly increasing repair cost for such old vehicles. Thus, the data set for model development and estimations consists of the insured repeatedly purchasing bundled AIP from the selected company over three, four and five years.

To gain insights into the insured's repeated choice behaviors in the first few years after purchasing a new car, this research develops a discrete choice modeling framework for analysis of repeated choices associated with physical damage coverage types, and the number of consecutive years the insured has purchased the same type of physical damage coverage. Our proposed model extends the work by Wen, *et al.* (2005) which examined a selection of bundled AIP using a one year cross-sectional database from a non-life insurance company. To capture the dynamic aspects of AIP choice behavior, this research uses panel data offered by a non-life insurance company that include the sequence of AIP choices made by the insured.

The discrete choice model is derived from random utility theory. An insured faces a choice among a set of mutually exclusive and exhaustive alternatives in terms of combinations of physical damage coverage types and the number of consecutive years the insured has purchased the same coverage. Under the principle of utility maximization, the insured chooses the alternative with the highest utility. The utility function of an alternative consists of the deterministic and random error components. Depending on assumptions which impose on distributions of error terms, various discrete choice models can be derived.

The multinomial logit model is the most commonly used discrete choice model due to its simple mathematical structure and ease of estimation and interpretation of coefficient estimates. The multinomial logit model is derived from the assumptions that the error terms are independent and identically Gumbel distributed. Due to the restrictive assumptions, the multinomial logit model exhibits the property of Independence from Irrelevant Alternatives (IIA), which is unrealistic in many choice problems.

The most widely used model to relax the undesirable IIA property is the nested logit (McFadden, 1978; Williams, 1977), which accounts for interdependence between pairs of alternatives by grouping alternatives in the nest. In the nested logit model, each alternative only appears in one nest, and each nest consists of one or multiple alternatives. In our case, a two-level nested model with physical damage coverage choice (Types A, B, and C) at the upper level and number of consecutive years purchasing the same type of physical damage coverage at the lower level is developed. An alternative nested structure which includes the number of consecutive years at the upper level and coverage type choice at the lower level is also tested.

Although the nested logit model accounts for interdependence between pairs of alternatives in the same grouping, the restriction on the identical correlations of the alternative pairs in the same nest may be unrealistic in some cases. The paired combinatorial logit Model enables better representation of substitution patterns among the bundled AIP alternatives. The paired combinatorial logit model has a more flexible error correlation structure than the multinomial logit and nested logit models and allows differential correlation between pairs of alternatives. The formulation of the proposed choice models such as the multinomial logit, nested logit and paired combinatorial logit is explicitly described.

The data used for empirical analysis were drawn from a non-life insurance company that has the largest market share among the 16 non-life insurance companies in Taiwan. The data set consists of the new car owners who repeatedly purchased bundled AIP from 2000. We selected the data in which the insured purchased new cars in 2000 and also repeatedly purchased physical damage coverage from the same company.

The estimation results of the multinomial logit, nested logit and paired combinatorial logit models were performed using the NLOGIT and GAUSS software. The parameter estimates in the models were tested, and the model performance was evaluated using goodness-of-fit indices and likelihood ratio tests. The applicability of the proposed choice models is explicitly demonstrated.

1.5 Research Procedure

The research procedure is elaborated in the following and depicted in Figure 1.1.

(1) Problem identification

The first step is to identify the purposes and scope of this study, and to address problems which need to be explored.

(2) Literature review

The second step is to review the AIP related research, including current practices of automobile insurance, automobile insurance decision and discrete choice modeling and panel data analysis. The methods, including multinomial logit model, nested logit model and paired combinatorial logit model with a cross section data and panel data, used in this study are also reviewed. This step helps to realize the current state of development of choice behavior and to facilitate the theoretical modeling.

(3) Automobile Insurance Policies (AIP) choice behavior and model development

We presented the modeling framework developed for conducting the empirical analysis of bundled AIP choice behavior of new car owners. The methods included multinomial logit model, nested logit nodel and paired combinatorial logit model. This research presents a discrete choice modeling framework for analysis of repeated choices associated with physical damage coverage types, and the number of consecutive years the insured has purchased the same type of physical damage coverage.

(4) Empirical data and estimation result

The selected samples were drawn from a non-life insurance company. To capture the dynamic aspects of AIP choice behavior, this research uses panel data that include the sequence of AIP choices made by the insured. To investigate the factor of choice behavior of the proposed multinomial logit model and nested logit models, the panel data with a non-life insurance company the proposed nested logit with repeated buying the same policies consecutive three, four and five years. Paired combinatorial logit model analyses are conducted to examine the panel data with consecutive years not only purchasing the same policies for four consecutives years, but also consists with the change of buying different type of bundles policies for consecutive years. In this procedure, the exemplified examples and field cases are simulated by the programs coded by the GAUSS.

(5) Conclusions and implications

The major findings in the processes of model formulation and model validation will be summarized. The strengths and weaknesses of the proposed models will be thoroughly discussed. At last, some suggestions for future studies will be identified.

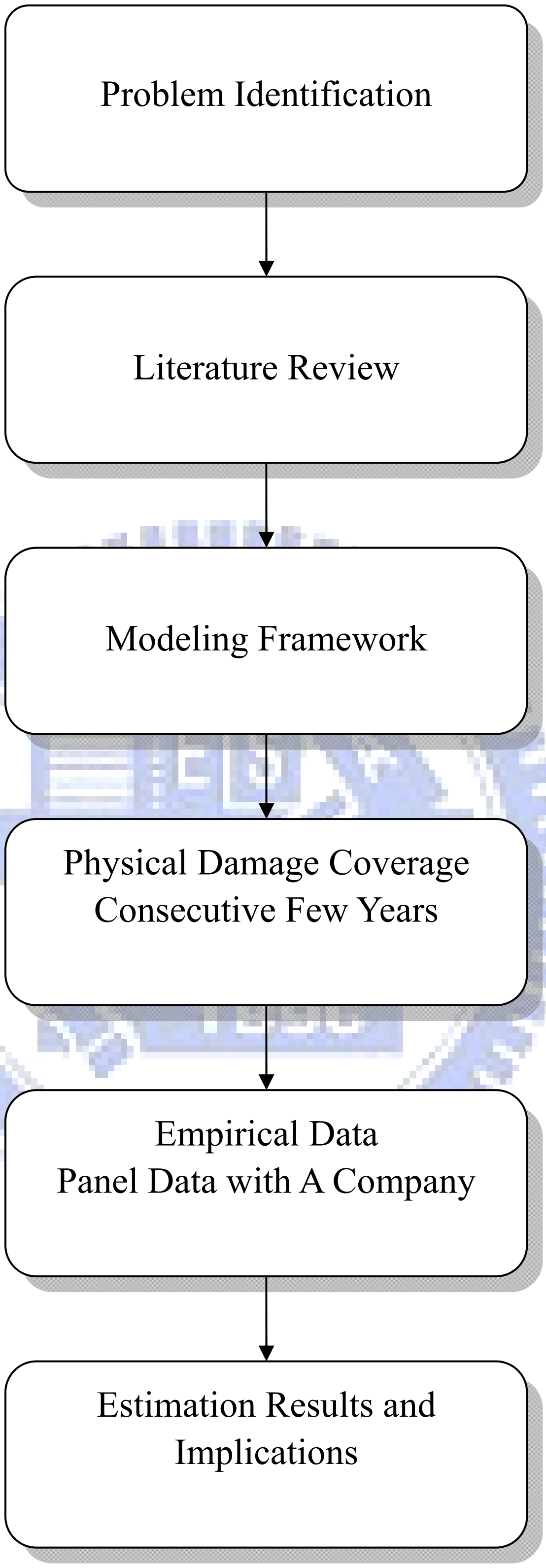


Figure 1.1 Research Flowchart

1.6 Chapters Organization

The rest of the dissertation is organized as follows. Chapter two presents a comprehensive review of automobile insurance practice and related literature. Chapter three proposes a methodological framework of AIP choice and develops the formulation of discrete choice models that characterize selection of different physical damage coverage and number of consecutive years purchasing the same coverage type. Chapter four describes the dataset to be used and presents frequency and cross table analysis of chosen alternatives and explanatory variables. Chapters five and six consist of the estimation results of various choice models. Chapter seven summarizes the research findings and concludes with issues for further studies.

CHAPTER 2 LITERATURE REVIEW

The chapter reviews previous literature relevant to this study, including current practices of automobile insurance, automobile insurance decision and discrete choice modelling and panel data analysis. Section 2.1 describes automobile insurance practices in some developed countries and in Taiwan. The special characteristics with asymmetric information in automobile insurance are described in Section 2.2. The remainder of the sections comprises the existing literature on AIP selection, discrete choice modelling approaches used in automobile insurance and repeat purchase behaviour with panel data.

2.1 Automobile Insurance Practice

Automobile insurance represents nearly 50 percent of property/liability insurance premium volume in many countries (Ma and Schmit, 2000). AIP products in many countries are characterized by complicated designs, most of which are in bundled packages. Different bundled packages provide different degrees of protection (coverage). New policies and new extended coverage are often provided by insurers.

Two different systems of automobile insurance are in common practice around the world: compulsory and voluntary insurance. Most countries impose compulsory insurance, generally defined as the minimum amount of automobile liability insurance that meets the law. In addition to compulsory insurance, automobile drivers may purchase higher amounts of optional liability insurance to satisfy their particular needs and transfer possible risks associated with traffic and other related accidents. As a result, most drivers purchase voluntary insurance coverage for physical damage to own vehicles, property damage, bodily injury, and other special liabilities. Voluntary insurance offers a multitude of optional coverages, characterized by complicated designs, most of which are in bundled packages with different degrees of coverage.

There are several different types of insurance coverages for vehicle physical damage. One type covers any accidental loss to the insured on an all-risks basis, while another, termed perils coverage, covers particular causes of loss under the selected items, and no coverage is offered for perils not listed. As in Table 2.1, physical damage coverage designed on an all-risks basis in some countries includes the risks associated with collision, fire, lightning, struck by lightning, explosion, missiles or fall objects, malicious mischief or vandalism, theft and any unidentified reasons other than the exclusions (designated P1+P2+P3+P4+P5+P6+P7+P8). In addition, the insured in such countries can purchase an optional insurance policy that only covers collision (P1). In the US (Pataki and Serio, 2004), physical damage coverage includes the risks associated with (P2+P3+P4+P5+P6+P7+P8), but not P1. In the UK, insurers provide two additional policies to protect against damage that might occur during situations involving both fire and theft (P2+P8) as well as windscreen damage (P9) in which the insurer will pay to replace or repair broken glass in the windscreen or windows of the car, along with scratches on the bodywork caused by the broken glass, as long as there has not been any other loss or damage.

Table 2.1 Voluntary Automobile Insurance System in Selected Countries

Insurance Coverage	Japan	US (New York State)	UK	Taiwan
Physical Damage Coverage	• P1+P2+P3+P4+P5+P6+P7+P8	• P2+P3+P4+P5+P6+P7+P8	• P1+P2+P3+P4+P5+P6+P7+P8	• P1+P2+P3+P4+P5+P6+P7 [PA]
				• P1+P2+P3+P4+P5 [PB]
	• P1	• P1		• P1 [PC]
			• P2+P8	• P8 [T]
			• P9	
Non-Physical Damage Coverage	• L1	• L1	• L1	• L1+L2 [TP]
	• L2	• L2+L3	• L2+L3	• L1+L2+L3 [TP+I]
		• L1+L4	• L1+L4+L7	
		• L2+L4	• L2+L4+L7	
	• L6	• L5+L6+L7		• L1+L2+L4+L5+L6+L7 [TP+PL]
		• L6+L7		• L1+L2+L3+L4+L5+L6+L7 [TP+I+PL]
	• L8	• L8	• L8	
	• L9	• L9		
	• L10	• L10		
			• L10	
				• L10
Perils	P1: Collision		L1: Property damage	
	P2: Fire		L2: Bodily injury	
	P3: Lightning, struck by lightning		L3: Intoxicated driver	
	P4: Explosion		L4: Spousal liability	
	P5: Missiles or fall objects		L5: Family's personal injury	
	P6: Vandalism		L6: Passenger's (personal accident) or liability	
	P7: Any unidentified reasons other than the exclusions		L7: Drivers' personal injury	
	P8: Theft		L8: Uninsured motorists	
	P9: Windscreen damage		L9: Additional PIP (No-Fault) benefits	
			L10: Other special coverage	

Sources: Non-life Insurance Rating Organization (2004)
Pataki, G.E. and Serio, G.V. (2004)
Department of Insurance, Ministry of Finance (2004)
Screen Trade Insurance Company (2005)

In Taiwan, three types of physical damage coverage not involving theft loss are offered in the automobile insurance market. Physical damage Type A coverage (PA) covers all risks of collision and non-collision losses except for theft. Physical damage Type B coverage (PB) which excludes losses where it is hard to verify the cause or source covers almost the same range of risks as PA except for vandalism and any unidentified reasons other than the exclusions in the policy. Physical damage Type C (PC) only covers damage in a collision and here will be termed P1. Drivers in Taiwan can select from three types of physical damage coverage (PA, PB, and PC) with an optional coverage, theft loss (T).

Voluntary insurance other than physical damage coverage consists of third party liability, accident liability, and other special liabilities. Third party liability covers a third party in or out of the vehicle. Third party liability in selected countries covers property damage (L1) or bodily injury (L2) and the limits of the coverage are agreed upon separately for L1 and L2. The coverage for bodily injury due to intoxicated driver (L3) is included in L2. The spousal liability (L4) covers the liability due to death of or injury to the spouse and should be purchased jointly with L1 or L2 in the US. However, the L4 and L7 coverages (called personal accident benefits in UK) should be acquired together with L1 or L2. The bundled policies L5+L6+L7 and L6+L7 are named "accidental death and dismemberment" and "medical payment" coverages, respectively, in the US.

Special coverage in general includes two policies: one is to protect against the injuries that the driver, the driver's family, or passengers might suffer in a hit-and-run accident or in an accident with an uninsured vehicle, called uninsured motorists coverage (L8). Additional personal injury protection-PIP (no-fault) benefit (L9) is designed to add more no-fault protection. Each country also has unique forms of insurance (L10). For instance, in Japan there is "long-term automobile policies with a maturity refund," a recently developed product (Non-life Insurance Rating Organization, 2004).

In Taiwan, the third party liability (TP = L1+L2) is a basic coverage. The L3 (renamed to I) coverage, if purchased, should be bought jointly with L1+L2. The PL (=L4+L5+L6+L7) covers injury to any persons in the vehicle, including the driver. Generally speaking, non-physical damage coverage in other countries has a more complex design that includes complete coverages to cover property damage and personal injuries than similar coverage in Taiwan. This is due to the fact that non-life insurance companies in Taiwan are not permitted to sell insurance coverage associated with personal risks.

2.2 Asymmetric Information in Automobile Insurance

The information of AIP market is asymmetric, which means the insurers may understand the "terms and conditions" much better than the insured; but the insured definitely understand the "real risk of their own driving behaviors" much better than the insurers. Compared with the insurers, the insured may not have sufficient knowledge about the AIP products and they are likely to misunderstand the exact protection offered by the policies. Although the AIP products themselves are completely visible, certain aspects such as policy clauses, calculation of premiums, and degrees of coverage do require professional knowledge to understand. This asymmetric information frequently leads to an "adverse selection" phenomenon (from insurers' perspectives), which further complicates the insurance provision (Hosios, and Peters, 1989; Jee, 1989; Landsberger and Meilijson, 1994; Lewis and Sappington, 1995; Ligon and Thistle, 1996; Inderst and Wambach, 2001; Ania *et al*., 2002; Theilen, 2003).

By definition, more risk-averse persons demand for more insurance coverage. Adverse selection is the tendency of persons with higher-than-average chance of loss to seek insurance at standard rates, which, if not controlled by underwriting, would result in higher-than-expected loss levels. The high-risk drivers would choose for auto insurance at lower (standard) rates; a driver with higher loss probability or higher degree of risk aversion would choose for lower deductible; these are two good examples of adverse selection of AIP (Smith and Head, 1978; Schlesinger, 1981; Dahlby and Riley, 1983; Dellaert, *et al*., 1990; Dionne and Doherty, 1994; Venezia, 1984; Artis *et al*., 2002;). Another example of adverse selection was found where either a tort system or a no-fault system of compensation being provided, the high-risk drivers would prefer to choose the no-fault system, which was associated with higher levels of uninsured motorists (Carr, 1989; Ma and Schmit, 2000; Devlin, 2002; Schmit and Yeh, 2003).

The insurance industry is a limited information subscription market, which is a type of market characterized by five properties and brings about the problem of adverse selection. First, by law all drivers in most developed countries must purchase auto insurance to drive, consumers purchase the products continuously over time. Second, these markets are generally characterized by tenure dependence in demand (Joskow, 1973). Many consumers are unaware that there are price differences among insurance companies since they in a different risk class, lives in a different community, and drives a different kinds of car. Third, long term relationships provide an opportunity for consumers and firms to learn about one another. For example, automobile insurance consumers learn the quality of their firm's claims service (Bond and Stone, 2004). With regard to the cost of switching suppliers, that is a reason why consumers may not opt for lower priced policies (Schlesinger and Schulenburg, 1991). Fourth, characteristic of these markets is limited consumer information about the existence, price and attributes of alternate firms. Firms use observed claims to update expectations of consumer claims risk (Boyer, *et al*., 1989). Finally, firms in these markets are able to price discriminate on the basis of consumer characteristics and histories. The source of observed tenure dependence in demand, the value placed on claims service and the speed with which this service is learned, and the impact of expected future price changes (Barros, 1996).

Properties 1 to 3 show both insurer and insured need to learn about another by long term repeat buying. The insured first perceive satisfaction when claims are processed, while the insured learn the risk type of insured from their claims records. Properties 4 to 5 show the insurer must deal with the problems of adverse selection .Although adverse selection can never be completely eliminated, they can be controlled by careful underwriting. Underwriting refers to the process of selecting and classifying applicants for insurance. Applications who meet the underwriting standards are insured at standard rates. If the underwriting standards are not met, the insurance is denied or an extra premium must be paid.

2.3 Automobile Insurance Decision

The potential risks of using an automobile involve damage to one's own and others' vehicles and property in collision, vandalism, theft and related loss, and injuries to driver, passengers and third parties. Car owners often purchase appropriate AIP to cover such potential risks so as to reduce the personal worry or stress incurred from traffic accidents. In compliance with the law, auto owners in many countries are required to purchase compulsory AIP to protect themselves from lawsuits when accidents involve damage and injuries (Murray *et al.*, 1994). People are willing to purchase insurance, thereby paying a risk premium, in order to eliminate the possibility of a large loss in the future. Schlesinger (1981) and Hayakawa (2000) found that insurance demand and risk aversion were positively correlated. The insured essentially expect their insurance to cover what is supposed to do (Schlesinger and Schulenburg, 1993; sherden, 1984). Namely, car owners normally desire a policy that can provide protection through the reimbursement to their claims and that is accompanied with good service at a reasonable price.

The insured often does not have sufficient knowledge about the AIP product such as policy clauses, calculation of premiums, and degrees of coverage. They do not seem to care about the details of the insurance policies; instead, they very likely rely on others (e.g., the dealers (Anderson and Weitz, 1998)) to make the selection decisions for them, or at least to provide recommendations on such issues as limits, deductibles and other coverage. Car dealers play an important role in automobile insurance market in Taiwan.

2.4 Discrete Choice Modeling of AIP Choice

Previous studies of AIP have examined choosing between no-fault and tort systems (Zador and Lund, 1986; Carr, 1989; Berrig *et al.*, 1994; Harrington, 1994; Schmit and Yeh, 2003) or selection of the deductible in a single policy (Smith and Head, 1978; Schlesinger, 1981; Venezia, 1984; Chiappori and Salanie, 2000). Despite numerous prior studies on insurance rates (Sant, 1980; Jee, 1989; Bonato and Peter, 2002; Dionne and Ghali, 2005), moral hazard, fraud (Viaene *et al.*, 2002; Major and Riedinger, 2002; Picard, 1996; Brockett *et al.*, 2002), adverse selection (Murray *et al.*, 1994; Cummins and Weiss, 1991; Dionne and Doherty, 1994; Janssen and Karamychev, 2005), and risk perception of claims (Dellaert *et al.*, 1990, Lee and Urrutia, 1996; Lee *et al.*, 2001; Tennyson and Pau, 2002; Caudill *et al.*, 2005), the underlying factors affecting insured selection of bundled AIP have not been addressed explicitly.

The choice of bundled AIP is similar to selecting individual features or items from a menu, such as purchase of cable TV service or buying computers (Ben-Akiva and Gershenfeld, 1998). The discrete choice modeling approach has been extensively used to examine the choice of one from a set of mutually exclusive alternatives. However, applications of discrete choice model in the field of automobile insurance have been relatively scarce in the literature.

Artis *et al*. (1999) employed discrete choice models to study fraud behavior and assessed the effect of the personal characteristics of the insured on claims and fraud behavior. Artis *et al*. (2002) further used the multinomial logit and nested logit models to estimate the influence of the insured and claim characteristics on the probability of committing fraud. Recent work by Wen *et al*., (2005) proposed the use of the multinomial logit and nested logit models to identify variables related to the selection of bundled AIP and to explore substitution patterns among highly similar AIP bundles. We need to analyze insured choice of AIP by using an alternative model that enables better representation of similar characteristics of bundled AIP. The paired combinatorial logit model has a more flexible error correlation structure than the multinomial logit and nested logit models, and allows the estimation of differential substitution patterns between each pair of alternatives while retaining the computational advantages of close-form generalized extreme value models. Wen *et al*., (2006) using Paired Combinatorial Logit model for analyzing the determinants that influence demand for bundled automobile insurance policies and simplify the complex choice problem, a model system involving two separate models is developed by draw one year of insured records from a non-life insurance company. And find that non-physical damage coverage involving third party liability be regard as a basic protection with addition of passenger liability and/or intoxicated driver. This research indicated that the multinomial logit or nested logit models may not be appropriate for analyzing the insured's choice behavior.

2.5 Panel Data Analysis

Panel data analysis has been applied in brand choice with different products (Allenby and Rossi, 1991; Buckley, 1988; Seetharaman and Chintagunta, 1998), electoral systems or vote on the move (Shively, 1982; Sarlvik and Crewe, 1983; Rochon, 1981; Richardson, 1975,1977, 1986, 1988) and insurance (Cooper and Hayes, 1987; Israel, 2001; Nekby, 2004; Rubinstein and Yaari, 1983;Wang, 2004), where research focuses on adverse selection and moral hazard.

Marketing research often focuses on understanding consumer choice behavior for products and brands over time using panel data (Roy *et al.*, 1996). In marketing research studies, Howard and Sheth (1969) proposed that households may routinize their brand purchases by using the same brand repeatedly over time. This means that the currently chosen brand has a higher probability of being chosen in the future than other brands. In such a situation, we can observe the repeat purchase behavior to understand the brand choice behavior of consumers. The estimation of brand choice using a repeated buying pattern may be performed using the Bernoulli model, which assumes that the previously bought brand does not affect the subsequent purchase choice. However, this model cannot estimate the carry-over effect. The Markov model, on the other hand, helps estimation of the carry-over effect but specifies that the current purchase choice is based on only one period of previous purchase behavior. In the past a logit model has been widely applied to brand choice (Jones and Landwehr, 1988; Currim, 1982; Kamakura and Srivatava, 1984; Allenby, 1989). Guadagni and Little (1983) indicated that the logit model is suitable for estimation of the real buying behaviors of consumers.

A small number of studies of AIP choice have considered panel data over a few years, but have not observed new car owners' insurance choice behaviors over several years. Austin (1996), Sant (1980) and Artis *et al*. (1999; 2002) used the multinomial logit model to estimate the effect of the insured and the claim, but the observed period was only a two-period game between a risk neutral insurance seller and a risk. Previous literature on automobile insurance using panel data discussed the loss characteristics due to rate discrimination (e.g. Wang, 2004). Obviously, the insured's repurchase behaviors are not well understood, and it deserves to be investigated. Wen *et al*., (2007) first presents a discrete choice modeling framework for analysis of repeated choices associated with expensive AIP-the bundled physical damage coverage and the number of consecutive years the insured has purchased the same type of AIP with above four years panel data. This study find insured purchase automobile insurance from car dealers, they are likely to buy expensive coverage, imply car dealer control most of source of automobile insurance market by new car. But this study only using nested logit model and only choose the data in which the insured purchased new cars in 2000 and also purchased physical damage coverage for that year and the subsequent over three years.

2.6 Summary

This section summarizes the main findings of the review and, where applicable, identifies the gaps that exist in the literature.

Insurance products are different from other products in that they are intangible, existing only as a promise from the insurer. The insurance industry is a limited information subscription market, both insurer and insured need to learn about another by long term repeat buying. Repeat buying can help insurer seeks to maintain the income flow from the insured during the first few years. It can eliminate the adverse selection and moral hazard in the insurance market and enable sellers to obtain market power and higher profits even it supported long sought to develop products that adjust their benefits and premiums to match the needs of buyers as the buyers progress through life. We need collected panel data to analyze data to achieve the goal.

Previous study of AIP have examined choosing between no-fault and tort systems or selection of the deductible in a single policy and only considered the data with single year. Panel data analysis of previous study is used in adverse selection and moral hazard. A small number of studies of AIP choice have not considered new car owners' insurance choice behaviors over several years and not observed consecutive few years simultaneously for new car owners by using discrete choice model.

Bundled AIP alternatives have a high degree of similarity. It is therefore essential to develop appropriate models that can explain the purchasing behaviors of similar bundled products in many countries and in Taiwan. AIPs in many countries are characterized by complicated designs, most of which are in bundled packages. Wen *et al*.,(2007) presents a discrete choice modeling framework for analysis of repeated choices but have not use paired combinatorial logit model to confirm repeated choice behavior and the behavior of different group with repeated purchase three, four or five years individuals have not addressed.

CHAPTER 3 MODELING FRAMEWORK

This chapter presents the modeling framework developed for conducting the empirical analysis of bundled AIP choice behavior of new car owners. The theoretical framework is addressed in Section 3.1. Multinomial logit model specification is introduced in Section 3.2. Nested logit model specification is described in section 3.3. Paired combinatorial logit model is presented in Section 3.4. Explanatory variables and hypothesis testings are summarized in Sections 3.5 and 3.6, respectively.

3.1 Methodology Framework

Two systems of automobile insurance are in wide use around the world: compulsory insurance and voluntary insurance. Compulsory insurance imposed in most countries is defined as the minimum amount of automobile liability insurance that meets the law. In addition to compulsory insurance, automobile drivers may purchase higher amounts of optional liability insurance to transfer possible risks related to traffic and other accidents. As a result, most drivers purchase voluntary insurance coverage for physical damage to own vehicles, property damage, bodily injury, and other special liabilities**.** Voluntary insurance offers a multitude of optional coverage, characterized by complicated design, most of which are in bundled packages with different degrees of coverage.

The choice of bundled AIP is similar to selecting features from a menu available for customization. Consumers may decide simultaneously which coverage should be included in their insurance package. Table 3.1 shows the proposed model, first Wen *et al.*, (2005) proposed the use of the multinomial logit and nested logit models to identify variables related to the selection of bundled AIP and to explore substitution patterns among highly similar AIP bundles. An AIP alternative (i.e. possible outcomes of the decision process) thus consists of a combination of different coverage. However, the total number of AIP alternatives in our choice problem may be relatively large, especially as the number of available insurance coverage becomes large. For model development, inclusion of all the alternatives in an individual model would raise the difficulty of model calibration and interpretation of parameter estimates. To simplify the complex choice problem, a model system involving separate models could be developed. This representation of the choice situation may be viewed as unrealistic from a behavioral perspective. However, the development of a simplified model can serve as a preliminary step towards a more general and behaviorally realistic model. Second, Wen *et al*., (2006) using paired combinatorial logit model for analyzing the determinants that influence demand for bundled automobile insurance policies and simplify the complex choice problem, a model system involving two separate models is developed by draw one year of insured records from a non-life insurance company.

The proposed model system for the choice of bundled AIP in Taiwan consists of two components. The first component is the decision to select physical damage coverage. The insured can select from among different types of physical damage coverage and/or without any coverage. In Taiwan, three types of physical damage coverage without involving theft loss are offered in the automobile insurance market. Physical damage coverage Type A covers all the risks of collision and non-collision losses, except for theft. Physical damage coverage Type B excludes the losses that are hard to verify the cause or source, but it covers almost the same range of risks as Type A, except for vandalism and any unidentified reasons other than the exclusions in the policy. Physical damage coverage Type C only covers damage in a collision. Drivers can select from these three types of physical damage coverage with an optional coverage -- theft loss. Voluntary insurance other than physical damage coverage consists of third party liability, accident liability, and other special liabilities.

Most new car owners purchase physical damage coverage in the first year. Because the premium of physical damage coverage (especially Type A) is very expensive, car owners may choose to decrease their automobile insurance expenditures by purchasing the reduced coverage or not buying any physical damage coverage in the succeeding years. Physical damage coverage also involves the selection of deductible. The basic deductible of Type A, B or C was NT$3,000 for the first claim. The insured can choose different levels of deductible. However, incorporating the choice of deductible will increase the complex the model.

The second component in the model system is the choice of non-physical damage coverage involving third party liability as a basic protection with addition of passenger liability or other endorsement, such as the coverage for bodily injury due to intoxicated driver and/or injury to any persons in the vehicle, including the driver. Third party liability policy can be extended to include personal accident or other third party liability coverage.

Physical damage coverage, the most expensive policy, constitutes the major source of revenues for the insurance companies. In most countries the level of premiums for physical damage coverage is higher than other policies. If a new car owner purchases a physical damage coverage policy in the first year and then switches to cheaper coverage policies or do not buy any physical damage coverage policies in the following years, premium revenues for non-life insurance companies certainly will be significantly decreased. Thus, knowledge of the factors affecting the insured to switch their choice of the three types of physical damage coverage is critical for insurance companies.

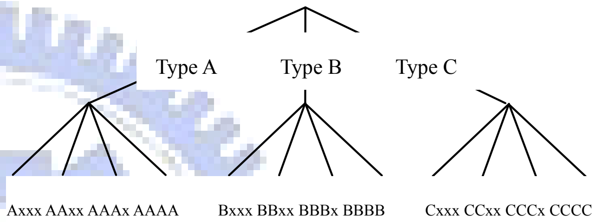
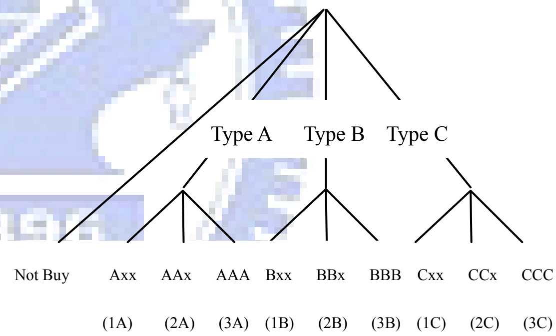
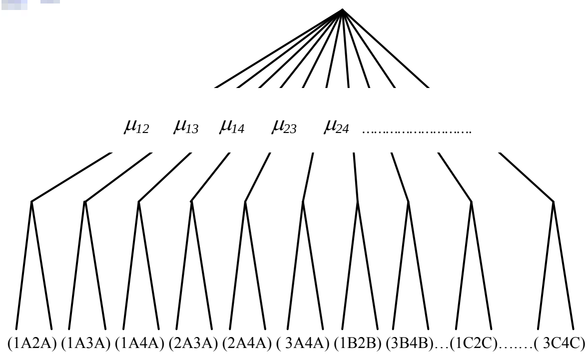
To ensure stable revenues, insurance companies often attempt to enhance customer loyalty and encourage them to repurchase the same physical damage policy or cheaper physical damage policy year after year. This research focuses on the first component of the model system, and the decision for choosing non-physical damage coverage involving third party liability is included in the bundle of physical damage coverage.

Car owners often dispose of vehicles over five years old in part due to the bothersome yearly inspection required by the motor vehicle department, and in part due to the rapidly increasing repair cost for such old vehicles. Third, Wen *et al*., (2007) first presents a discrete choice modeling framework for analysis of repeated choices associated with expensive AIP-the bundled physical damage coverage and the number of consecutive years the insured has purchased the same type of AIP with above four years panel data. In practice, car dealer has provide at least two years maintain contract to new car buyers, and give many additional service or discount to incentive new car owners to repeated purchase AIP at least two or three years. In addition, repurchase data of two consecutive years is still too short to identify behavioral trends. Thus, the data used for model development and estimations only comprise the insured repeatedly purchasing bundled AIP over three, four and five years.

During the last few decades, the percentage of autos used for non-commercial purposes has been approximately 97 percent of all autos. As a result, the written premiums of non-commercial vehicles are the main source of revenues for non-life insurance companies. To simplify the complex choice problem, the study only examines the insured of non-commercial automobiles and also excludes motorcycles and other types of privately owned vehicles.

To gain insights into the insured's repeated choice behaviors in the first few years after purchasing a new car, this research presents a discrete choice modeling framework for investigation of repeated choices associated with physical damage coverage types, and the number of consecutive years the insured has purchased the same type of physical damage coverage. Table 3.1 show the proposed model extends the work by Wen, *et al*. (2005) which examined a selection of bundled AIP using a cross-section data in one year from a non-life insurance company using multinomial logit model and nested logit model. Wen, *et al*. (2006) goes a step further to examine a selection of bundled AIP using a cross-section data in one year using paired combinatorial logit to find the similarity of each pair of alternatives. To capture the dynamic aspects of AIP choice behavior, Wen, *et al*. (2007) uses panel data that include the sequence of AIP choices made by the insured using nested logit to analyze the choice behavior of new car owners repeated purchase the same type of bundle physical damage type consecutive over four years. According to this research, we adopted the way to divided model into two parts, first part: upper level with physical damage type, lower level with consecutive few years; Second part: upper level with consecutive few years, lower level with physical damage type. The estimation result of nested logit and paired combinatorial logit is to observe the choice behavior of similarity alternatives by consecutive three, four and five year groups.

Table 3.1 Proposed Model

<table>
<tr><th>Data Collection</th><th>Model Development</th><th>Findings</th></tr>
<tr><td>One year database</td><td>MNL
(Wen, et al, 2005)</td><td>Factor of choice behavior</td></tr>
<tr><td>One year database</td><td>NL
(Wen, et al, 2005)</td><td>Various AIP bundles have a high degree of similarity</td></tr>
<tr><td>One year database</td><td>PCL
(Wen, et al, 2006)</td><td>PCL prefer to NL
Choice Model of physical damage coverage is suitable for analysis of AIP choice</td></tr>
<tr><td>Panel data
(over 4 consecutive years)</td><td>MNL
(Wen, et al, 2007)</td><td>Factor of repeat buying the same choice of AIP</td></tr>
<tr><td>Panel data
(4 consecutive years)</td><td>NL
(Wen, et al, 2007)</td><td>Preferred Nested logit model is:
</td></tr>
<tr><td rowspan="2">Panel data
(three-year Samples, four-year Samples, five-year Samples)</td><td>NL</td><td>
Three-year Samples</td></tr>
<tr><td>PCL</td><td></td></tr>
</table>

3.2 Multinomial Logit Model

The discrete choice model is derived from random utility theory (Ben-Akiva and Lerman, 1985). An insured faces a choice among a set of mutually exclusive alternatives in terms of combinations of physical damage coverage types and the number of consecutive years the insured has purchased the same coverage. Within the framework of utility maximizing principle, the insured is assumed to choose the alternative with the highest utility.

The choice alternatives for physical damage coverage for three, four, or five years are given in Table 3.2.

Table 3.2 Possible Alternatives for Physical Damage Coverage Bundles

Coverage type	Number of consecutive years	Three- year samples	Four-year samples	Five-year samples
Not buy physical damage coverage				
Type A	1A	Axx	Axxx	Axxxx
	2A	AAx	AAxx	AAxxx
	3A	AAA	AAAx	AAAxx
	4A	-	AAAA	AAAAx
	5A	-	-	AAAAA
Type B	1B	Bxx	Bxxx	Bxxxx
	2B	BBx	BBxx	BBxxx
	3B	BBB	BBBx	BBBxx
	4B	-	BBBB	BBBBx
	5B	-	-	BBBBB
Type C	1C	Cxx	Cxxx	Cxxxx
	2C	CCx	CCxx	CCxxx
	3C	CCC	CCCx	CCCxx
	4C	-	CCCC	CCCCx
	5C	-	-	CCCCC

The utility function of an alternative in terms of physical damage coverage type (*t*) and number consecutive years (*y*) for the decision maker *n* can be expressed as:

$$U_{ytn} = V_{ytn} + \varepsilon_{ytn} \quad (3.1)$$

where V_{ytn} and ε_{ytn} represents the deterministic (observable) and random (error) components of utilities for alternative (*y*, *t*). The deterministic components of utilities can be specified to be function of observable attributes (e.g., insured and vehicle characteristics).

Linear-in-parameters utility functions are often used due to computational ease and straightforward interpretation of coefficient estimates. The systematic components of the utilities for alternatives (*y*, *t*) can be expressed as

$$V_{ytn} = \alpha_{yt} + \sum_{k} \beta_k X_{ytkn} \tag{3.2}$$

where α_{yt} is a constant term specific to the alternative (*y*, *t*); X_{ytkn} is the explanatory variable *k* for alternative (*y*, *t*); β_k is an unknown parameter reflecting the relative importance of the variable *k*.

Different assumptions on the distributions of error terms result in different discrete choice models. The multinomial logit model is the most commonly used discrete choice model due to its simple mathematical structure and ease of estimation of parameter estimates. Given the assumptions that the error terms are independent and identically Gumbel distributed, the probability formulation for the multinomial logit model can be derived as:

$$P_{ytn} = \frac{\exp(V_{ytn})}{\sum_{y't'} \exp(V_{y't'n})} \tag{3.3}$$

3.3 Nested Logit Model

Due to the restrictive assumptions that the error terms are independent and identically distributed, the multinomial logit model exhibits the property of Independence from Irrelevant Alternatives, which is unrealistic in many choice problems. Specifically, the multinomial logit model will lead to erroneous prediction if the assumption of error distributions is violated.

The most widely used relaxation of this undesirable property is the nested logit model (McFadden, 1978; Williams, 1977), which accounts for interdependence between pairs of alternatives in the same nest. Figure 3.1 presents a two-level nested structure with physical damage coverage choice (Types A, B, and C) at the upper level and number of consecutive years (i.e., 1 to 3 years) purchasing the same type of physical damage coverage at the lower level. The structure is applied to the new car owners who purchased insurance at the same company for only three consecutive years. Three elemental alternatives under branch Type A denote the number of consecutive three years purchasing type A coverage. Axx (1A) alternative indicates the case in which new car owners purchase physical damage coverage in the first year and switch to other coverage policies (for example, type B or C) in the following years. In contrast, AAA (3As) alternative represents the case that new car owners purchased type A coverage for three consecutive years.

Figures 3.2 and 3.3 depict the similar hierarchical structure with physical damage coverage choice at the upper level and number of consecutive years at the lower level. The difference is that the two nested structures correspond to the case where the insured purchased insurance for four and five consecutive years, respectively. Consider a two-level nested logit with physical damage coverage choice at the upper level and number of consecutive years at the lower level. The probability that alternative (y, t) is chosen by insured n is expressed as

$$P_n(y,t) = P_n(y \mid t) P_n(t) \tag{3.4}$$

where the conditional and marginal probabilities in equation 3.4 are:

$$P_n(y \mid t) = \frac{\exp\left(\frac{V_{ytn}}{\mu_t}\right)}{\sum_{y' \in N_t} \exp\left(\frac{V_{y'tn}}{\mu_t}\right)} \tag{3.5}$$

$$P_n(t) = \frac{\exp\left(\mu_t \Gamma_{tn}\right)}{\sum_{t'} \exp\left(\mu_{t'} \Gamma_{t'n}\right)} \tag{3.6}$$

$$\Gamma_{tn} = \ln\left(\sum_{y' \in N_t} \exp\left(\frac{V_{y'tn}}{\mu_t}\right)\right) \tag{3.7}$$

where $P_n(y \mid t)$ is the conditional probability of insured n selecting a number of consecutive years y among choice set N_t conditional on choosing coverage type t; $P_n(t)$ is the marginal probability of insured n choosing coverage type t; Γ_{tn} is the logsum variable for insured n choosing coverage type t; μ_t is the logsum (or inclusive value) parameter for coverage type nest t.

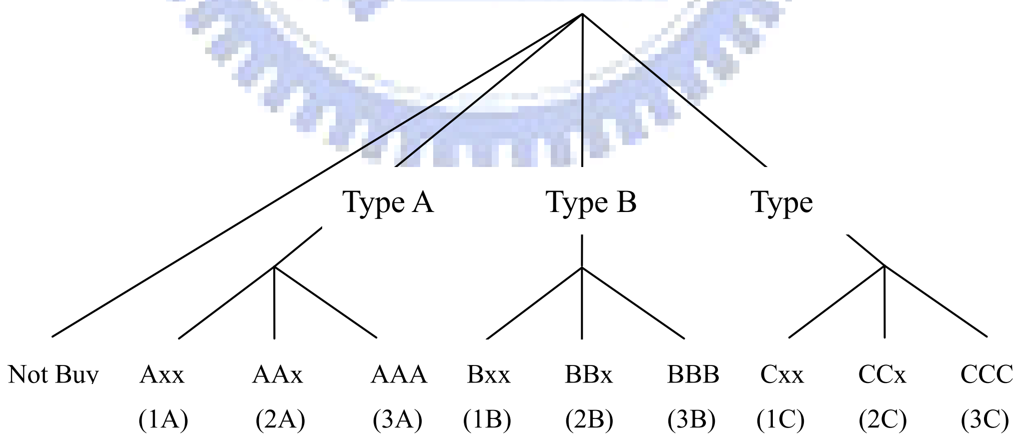


Figure 3.1 Nested Structure (I) – Three- year samples

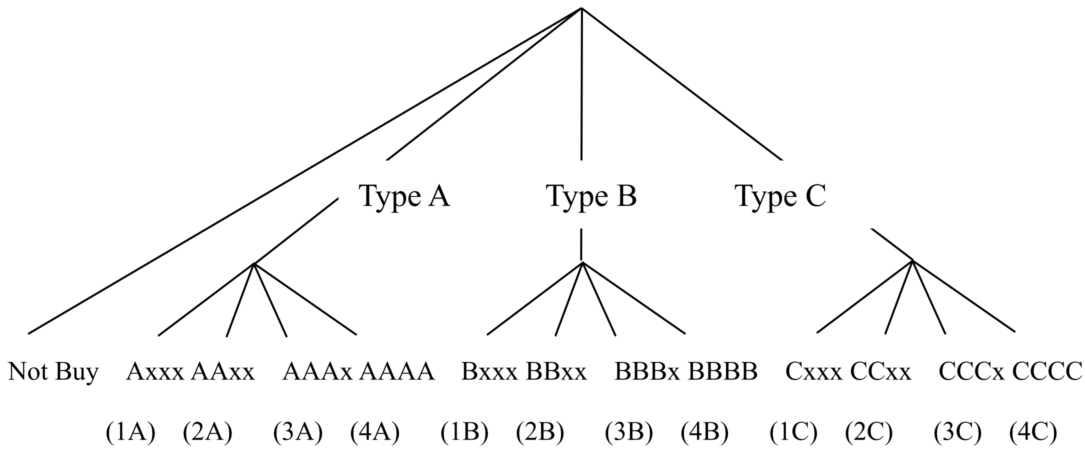


Figure 3.2 Nested Structure (I) – Four-year samples

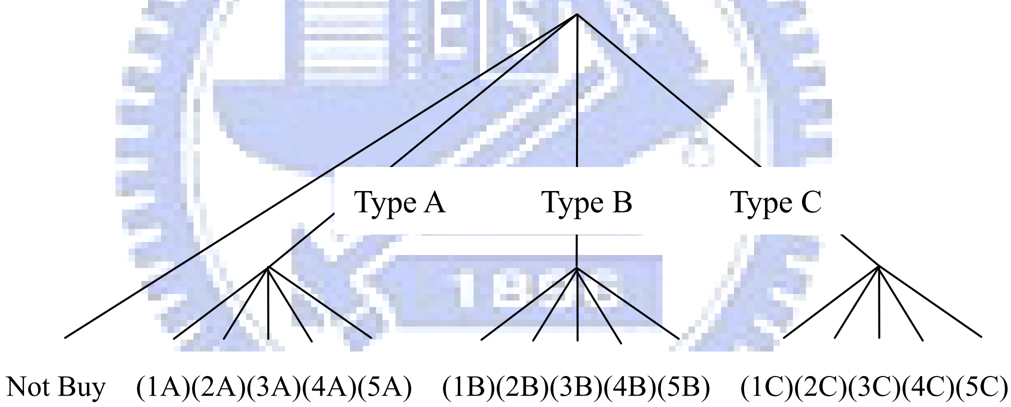


Figure 3.3 Nested Structure (I) – Five-year samples

The nested logit model is consistent with utility maximization if the conditions, $0 < \mu_t \leq 1$, are satisfied for all *t*. A logsum parameter associated with a nest lies within the range from zero to one, indicating that any pair of utilities in the nest are correlated. If μ_t is equal to one for all *t*, the nested logit model collapses to the multinomial logit model.

An alternative choice structure depicted in Figure 3.4 includes the number of consecutive years at the upper level and type choice at the lower level. In this structure, the second branch Yxx, for instance, represents the situation in which new car owners purchase physical damage coverage in the first year (Y corresponds to Type A, B or C) and switch to other coverage policies (symbolized by x) in the following years. Alternative Cxx represents the case that new car owners purchased type C coverage in the first year and switch to other coverage policies in the next two years. Under this branch, three elemental alternatives consist of different coverage types (i.e., type A, B and C). Figures 3.5 and 3.6 illustrate the similar nested structure for the insured purchasing four and five consecutive years, respectively.

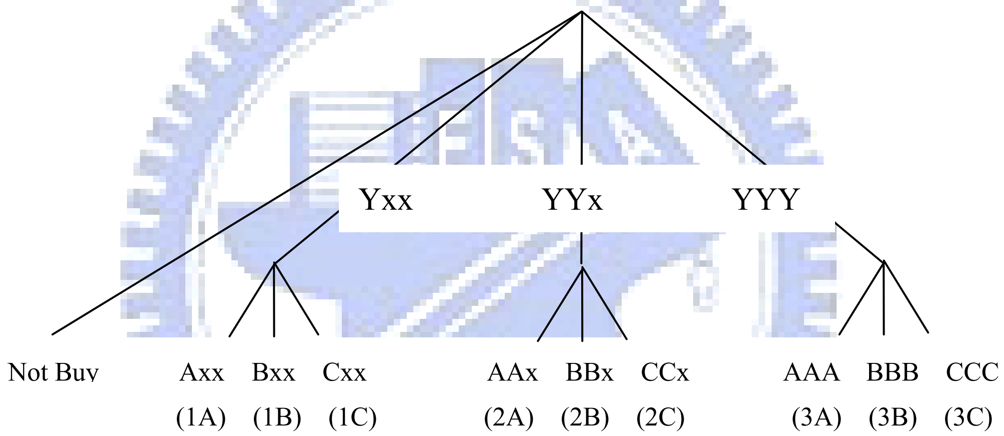


Figure 3.4 Nested Structure (II) – Three-year samples

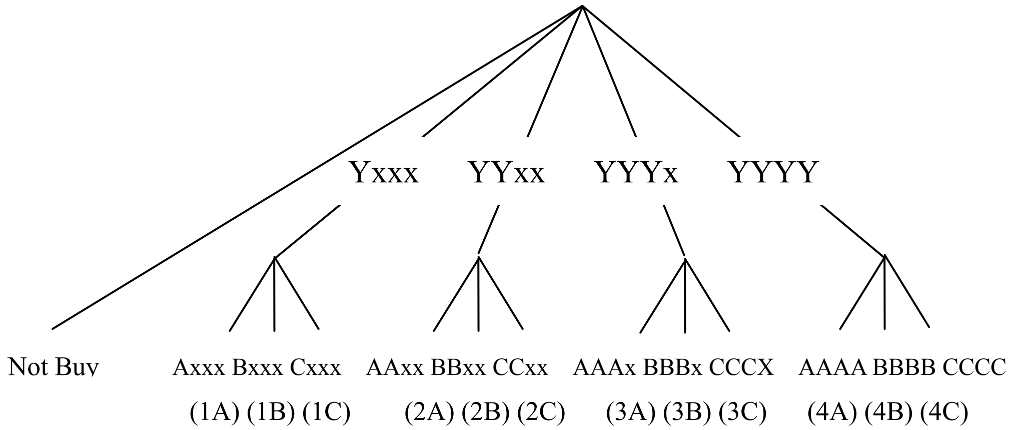


Figure 3.5 Nested Structure (II) – Four-year samples

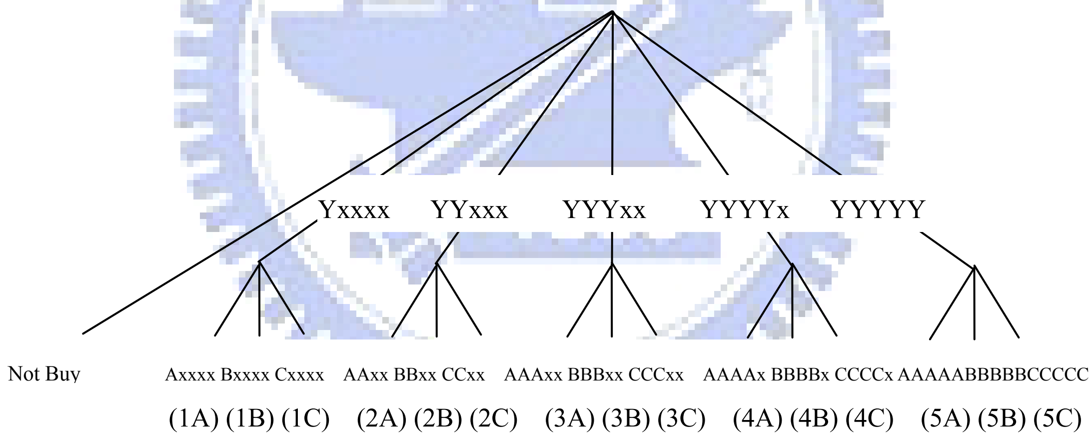


Figure 3.6 Nested Structure (II) –Five-year samples

3.4 Paired Combinatorial Logit Model

Although the nested logit model accounts for interdependence between pairs of alternatives in the same grouping, the restriction on the similarity of the alternative pairs in the same nest may be unrealistic in some cases. The paired combinatorial logit model enables better representation of substitution patterns among the bundled AIP alternatives. The paired combinatorial logit model has a more flexible error correlation structure than the multinomial logit and nested logit models in that it allows for differential correlation between pairs of alternatives (Koppelman and Wen, 2000). The choice probability of alternative *i*, a combination (*y*, *t*), is given by (for simplification, index *n* is omitted):

$$P_i = \sum_{j \neq i} \left(\frac{\exp(V_i / \mu_{ij})}{\exp(V_i / \mu_{ij}) + \exp(V_j / \mu_{ij})} \right) \times \frac{\left(\exp(V_i / \mu_{ij}) + \exp(V_j / \mu_{ij})\right)^{\mu_{ij}}}{\sum_{k=1}^{N-1} \sum_{m=k+1}^{N} \left(\exp(V_k / \mu_{km}) + \exp(V_m / \mu_{km})\right)^{\mu_{km}}} \quad (3.8)$$

where μ_{ij} is the logsum parameter associated with paired alternatives *i* and *j*; while *N* is the number of alternatives. If μ_{ij} close to 0, alternatives *i* and *j* are strongly associated. If μ_{ij} is close to 1, alternatives *i* and *j* are not related. The paired combinatorial logit model is consistent with random utility maximization if the condition, $0<\mu_{ij}\leq 1$, is satisfied for all (*i* , *j*) pairs.

In the paired combinatorial logit model, each alternative appears once for its pairing with each alternative. The nested structure for the model can be illustrated in Figure 3.7.

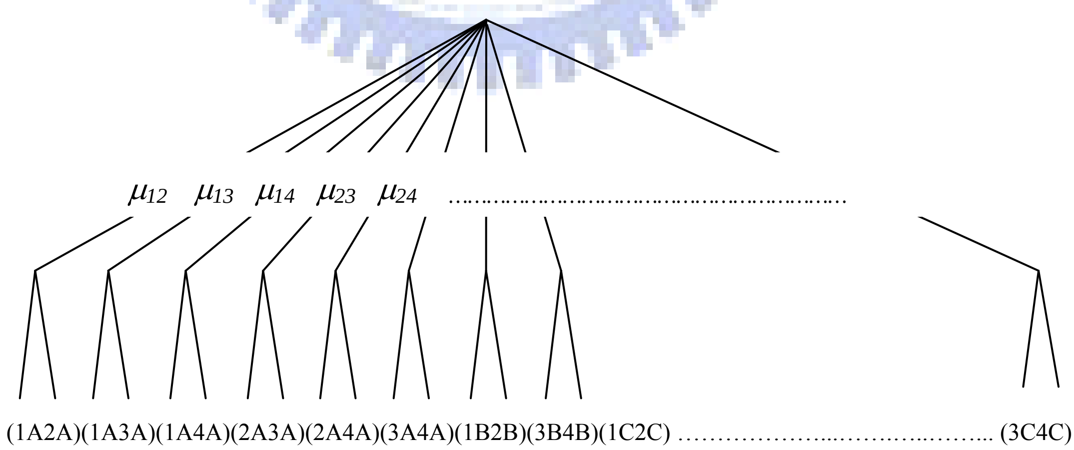


Figure 3.7 Nested Structure of the Paired Combinatorial Logit Model

3.5 Explanatory Variables in Choice Models

The observed attributes in the utility function consist of the characteristics of the insured and the vehicle. Insured characteristics include age and marital status. Haleck and Eisenhauer (2001) provided empirical evidence of the relative risk aversion associated with financial decision making across age. Lemaire (1985) has shown a significant relationship between age and losses. Older adults perceive high risks related to severe personal injuries in case of traffic accidents. Thus, older drivers may be expected to purchase expensive bundled AIP with Type A or Type B for more consecutive years. High-risk insured are likely to demand more insurance coverage than the low-risk ones. This provides evidence of adverse selection phenomenon -- the wider the insurance coverage, the less motivation for the insured attempt to reduce the number of claims (or prevent the accidents).

Vehicle characteristics include engine capacity, and whether the insured vehicle is domestic or imported. Vehicles that are new, have large engines, or are imported usually have higher market values. Any accidental loss to such vehicles may lead to high repair costs. Owners of such vehicles thus have an incentive to choose the same expensive AIP, especially bundles with Type A, during the first few years. On the contrary, owners of lower-value vehicles may prefer to buy Type C during the first few years.

Due to data availability, the explanatory variables in this study are limited to age, gender, marital status, age of vehicle, and engine capacity. Other personal attributes (such as name, address, telephone number, income, education, occupation, or religion,) are confidential by law and access is forbidden. Gender cannot be used as an explanatory variable because of the habit of married males using the names of their spouses or daughters when purchasing vehicle insurance in order to enjoy a lower insurance premium. The age of the vehicle is not a relevant variable because we collected data on new car owners whose vehicles were all of the same age. Individual claims records were different in each year of the consecutive periods, requiring dynamic model analysis; hence claims records are excluded in our study. Similarly, the variable of purchase channel was also different each year.

Notably, the cost of premium is considered as an important variable that may affect the choice of AIP. The premium of AIP is varied by coverage type and insured characteristics, especially the main premium was according to the value of vehicle – engine capacity, vehicle made and age of vehicle. We substitute premium by the three variables: engine capacity, vehicle made and age of vehicle. However, the data only include the premium for the chosen alternative by the insured and do not have the information on the premium of the non-chosen alternatives in the choice set. Thus, the cost of premium is excluded from our analysis.

3. 6 Hypothesis Testing and Goodness-of-fit Measures

The asymptotic t statistic is used to test whether a particular parameter in the choice model differs from some known constant, often zero. It is used in the same way as the t test in linear regression, except that in the case of nonlinear models this test is valid only asymptotically—that is, it is valid only for large samples.

The likelihood ratio test is used in the same way that the F test is used in regression models for joint tests of several parameters. Under the null hypotheses that all the parameter coefficients are zero and all the parameters other than the alternative specific constants are zero, the likelihood ratio test is used. The likelihood ratio test for a more specific hypothesis should define unrestricted and restricted models with the following test statistic:

$$X^2 = -2\left(LL(\hat{\beta}_R) - LL(\hat{\beta}_U)\right) \quad (3.9)$$

where $LL(\hat{\beta}_U)$ denotes the log likelihood at convergence of the unrestricted model; $LL(\hat{\beta}_R)$ denotes the log likelihood at convergence of the restricted model; $\hat{\beta}_U$ and $\hat{\beta}_R$ are vectors of parameters in the unrestricted and restricted. The test statistic is chi-squared distributed with degrees of freedom equal to the difference in the number of parameters between the two models.

Goodness-of-fit measures include ρ^2 and $\bar{\rho}^2$. Both measures lie between zero and one. ρ^2 is the fraction of an initial log likelihood value explained by the model. The likelihood ratio index is similar to R^2 in regression analysis. It can be defined as

$$\rho^2 = 1 - \frac{LL(\hat{\beta})}{LL(0)} \quad (3.10)$$

where LL (0) is the value of the log likelihood function when all the parameters are zero. An alternative index that the value of the log likelihood function at it maximum compares with the value of the log likelihood function when only alternative specific constants LL (*c*) is defined as

$$\rho^2 = 1 - \frac{LL(\hat{\beta})}{LL(c)} \quad (3.11)$$

$\bar{\rho}^2$ is similar to ρ^2 but corrected for the number of parameters (*K*) estimated. The adjusted likelihood ratio index is similar to $\bar{R}^2$ used in regression. It is defined as

$$\bar{\rho}^2 = 1 - \frac{LL(\hat{\beta}) - K}{LL(0)} \quad (3.11)$$

Non-nested hypotheses where we wish to compare two models, and one is not a nested hypothesis of the other. We cannot employ the likelihood ratio test to test one of these two models as a restriction of the other. The adjusted likelihood ratio index $\bar{\rho}^2$ can be used for testing non-nested hypotheses of discrete choice models.

To choose between two models (called 1 and 2), Ben-Akiva and Swait (1984) used a test developed by Horowitz (1983) to show that, under the null hypothesis that model 1 is the true specification, the following holds asymptotically:

$$P(\bar{\rho}_2^2 - \bar{\rho}_1^2 > z) \leq \Phi\left\{-\left[-2\ z\ LL(0) + (K_2 - K_1)\right]^{0.5}\right\} \quad (3.12)$$

$$z = \bar{\rho}_2^2 - \bar{\rho}_1^2 \quad (3.13)$$

$\bar{\rho}_h^2$ = the adjusted likelihood ratio index for model, h = 1, 2

K_h = the number of parameters in model h

Φ = the standard normal cumulative distribution function.

The probability that the adjusted likelihood ratio index of model 2 is greater by some $z > 0$ than that of model 1, given that the latter (model 1) is the true model, is asymptotically bounded above by the right-hand side of the equation.

If we select the model with the greater $\bar{\rho}^2$, then this bounds the probability of erroneously choosing the incorrect model over the true specification. This result implies that for 250 or more observations with two or more alternatives and models having the same number of parameters, if the $\bar{\rho}^2$ of the two models differ by 0.01 or more, the model with the lower $\bar{\rho}^2$ is almost certainly incorrect.

For example:

	Number of parameters	$\bar{\rho}^2$
Model 1	15	0.3102
Model 2	16	0.3089

The difference in adjusted likelihood ratios is approximately 0.0013; the probability that such a difference would be exceeded for a sample of 1,136 observations and 3 alternatives is less than 0.02, so we can be fairly sure that the model 1 is the one to merit further considerations.

CHAPTER 4 Empirical Data

This chapter narrates the empirical data of this study. The selected samples were drawn from a non-life insurance company in Taiwan. Frequency analyses of insured driver and vehicle characteristics are presented. Exploratory analysis of the chosen alternatives and explanatory variables are reported.

4.1 Sample Selection

The data used for empirical analysis were extracted from a non-life insurance company (hereinafter called Company A) that has the largest market share among all non-life insurance companies in Taiwan. Over the recent seven years, Company A has accounted for approximate 20 percent of the market share, in terms of the gross non-life insurance volume (see Table 4.1).

Table 4.1 Market Share of the Selected
Non-life Insurance Company A

Year	Market share
2000	19.04
2001	19.76
2002	19.80
2003	20.34
2004	20.26
2005	20.48
2006	20.40
Average	20.20

Table 4.2 illustrates that the selected insurance company comprises more than 20 percent share of the total written premium of physical damage Type A coverage among all non-life insurance companies during the recent seven years. The total written premium of physical

damage Type B coverage accounted for nearly 20 percent share in each year (see Table 4.3). However, the market share of the total written premium of physical damage Type C coverage decreased from 30 percent in 2000 to 19 percent in 2006 (see Table 4.4).

Table 4.2 Percentage of Total Written Premium of
Type A Coverage by Company A

Year	Company A (1)	All companies (2)	Percentage (3) = (1)/(2)
2000	955,064,256	4,434,105,661	22%
2001	818,549,720	3,542,554,546	23%
2002	600,769,573	2,709,271,090	22%
2003	490,452,345	2,378,145,736	21%
2004	479,604,262	2,192,340,665	22%
2005	495,358,872	1,976,704,055	25%
2006	453,687,802	1,816,440,498	25%

Table 4.3 Percentage of Total Written premium of
Type B coverage by Company A

Year	Company A (1)	All companies (2)	Percentage (3)= (1)/(2)
2000	937,041,481	5,975,445,556	16%
2001	1,049,388,902	6,269,506,636	17%
2002	1,155,316,337	7,188,301,891	16%
2003	1,351,814,190	8,443,863,952	16%
2004	1,630,089,687	10,105,653,850	16%
2005	2,117,593,776	11,823,756,967	18%
2006	1,984,096,337	10,824,604,414	18%

Table 4.4 Percentage of Total Written Premium of
Type C Coverage by Company A

Year	Company A (1)	All companies (2)	Percentage (3)= (1)/(2)
2000	353,225,413	1,167,931,458	30%
2001	336,077,090	1,266,650,438	27%
2002	326,039,517	1,448,365,020	23%
2003	394,780,096	1,988,769,097	20%
2004	490,915,569	2,716,373,582	18%
2005	575,957,583	3,150,257,764	18%
2006	574,885,526	2,972,473,295	19%

The data set consists of the new car owners who have repeatedly purchased bundled AIP since 2000. Specifically, we selected the data in which the insured purchased new cars in 2000 and also purchased physical damage coverage for that year and the subsequent two, three or four years. The term of AIP usually takes one year, and the insured can decide to purchase the same policy, switch to other policies or even change their insurer next year. The insured may buy AIP from Company A in the first year and change their insurer to other company in the next year. Additionally, the insured may buy physical damage coverage from Company A and buy theft loss coverage from other company in the same year. The research only took the samples by selecting new car owners who have repeatedly purchased bundled physical damage coverage from Company A.

Table 4.5 reports the number and percentage of the selected insured who purchased bundled physical damage coverage from the same company for three to five consecutive years. The result illustrates that majority of the insured purchased bundled physical damage coverage for five consecutive years. The number of the insured purchasing physical damage coverage for three and four consecutive years is 2,570 and 2,540, respectively. However, the number of insured who purchased six consecutive years from Company A fell to only 291, while only 7 individuals purchased physical damage coverage for seven consecutive years. In general, new car owners are likely to dispose their vehicles after the fifth year because of the yearly inspection required by law or the rapidly increasing repair cost of older vehicles. Therefore, the data used for model estimations consist of only the insured purchasing physical damage coverage for three, four and five consecutive years from Company A, as indicated by a substantial fall-off in purchases after the fifth year.

Table 4.5 Number and Percentage of Sampled Insured by Consecutive Years

Consecutive years	Not purchasing any physical damage		Purchasing physical damage		Subtotal
	Number	Percent	Number	Percent	
3	823	32.02	1,747	67.98	2,570
4	824	32.44	1,716	67.56	2,540
5	2,172	30.28	5,000	69.72	7,172
6	291				
7	4				
8	1				
9	2				
Total	12,580				

4.2 Frequency Analysis of Chosen Alternatives

Table 4.6 reports the result of frequency analysis of the insured and vehicle characteristics. For the insured purchasing physical damage coverage for three consecutive years, 66.0% are female, which is a counterintuitive result mainly due to the habit of married males using the names of their spouses or daughters when purchasing vehicle insurance to obtain a lower insurance premium. 84% of the insured are aged between 30 and 59, and 26% own imported vehicles. The major channel of purchase for automobile insurance is automobile dealers (67%). Over 60% of vehicle engine capacities fall between 1,000 cc to 2,000 cc.

Table 4.6 Frequency Analysis of the Insured and Vehicle Characteristics

Characteristics		Three-year samples		Four-year samples		Five-year samples	
		Number	Percent	Number	Percent	Number	Percent
Gender	Female	1,698	66.07	1,667	65.63	4,748	66.20
	Male	872	33.93	873	34.37	2,424	33.80
Age of the driver	<20	1	0.04	3	0.12	5	0.07
	20-29	388	15.10	366	14.41	902	12.58
	30-39	1,051	40.89	1,050	41.34	3,076	42.89
	40-49	747	29.07	702	27.64	2,005	27.96
	50-59	336	13.07	365	14.37	1,022	14.25
	60-69	42	1.63	52	2.05	140	1.95
	70-79	4	0.16	2	0.08	22	0.31
	80+	1	0.04	0	0	0	0
Marital status	Married	2,157	83.93	2,170	85.43	6,202	86.48
	Single	413	16.07	370	14.57	970	13.52
Purchase channel	Automobile dealer	1,815	70.62	1,696	66.77	4,193	58.46
	Insurance salesman	755	29.38	844	33.23	2,979	41.54
Vehicle made	Domestic	1,922	74.79	1,955	76.97	5,270	73.48
	Imported	648	25.21	585	23.03	1,902	26.52
Engine capacity	< 1,000 cc	26	1.01	29	1.14	61	0.85
	1,000-1,999 cc	1,814	70.58	1,762	69.37	4,923	68.64
	2,000-2,999 cc	664	25.84	682	26.85	1,953	27.23
	3,000+ cc	66	2.57	67	2.64	235	3.28

Table 4.7 shows the sample frequencies of the alternatives. The insured who did not purchase physical damage coverage account for 30 percent. The number of insured who repeatedly purchase physical damage coverage drastically decreases in the second and third year. The insured often switch to cheaper coverage policies or do not buy any physical damage coverage after the second or third year. The insured prefer to purchase physical damage Type B than other coverage types. Table 4.8 shows three-year samples whom all alternatives was combined in ten alternatives (not buy physical damage coverage, AXX, AAX, AAA, BXX, BBX, BBB, CXX, CCX, CCC). Because many bundled alternatives have too few, we combined it in the ten mostly popular alternatives. The same way apply in four-year samples with thirteen alternatives and five- year samples with sixteen alternatives.

Table 4.7 Sample Frequencies of the Alternatives

Alternative		Three-year samples		Four-year samples		Five-year samples	
		Number	Percent	Number	Percent	Number	Percent
Not buy physical damage coverage		823	32.02	824	32.44	2,172	30.28
Type A	1 year	159	6.19	155	6.10	475	6.62
	2 years	34	1.32	30	1.18	102	1.42
	3 years	49	1.91	19	0.75	39	0.54
	4 years	-	-	29	1.14	25	0.35
	5 years	-	-	-	-	84	1.17
Type B	1 year	644	25.06	627	24.69	1,603	22.35
	2 years	250	9.73	231	9.09	488	6.80
	3 years	271	10.54	97	3.82	262	3.65
	4 years	-	-	182	7.17	170	2.37
	5 years	-	-	-	-	559	7.79
Type C	1 year	128	4.98	140	5.12	436	6.08
	2 years	59	2.30	62	2.44	114	1.59
	3 years	153	5.95	17	0.67	75	1.05
	4 years	-	-	127	5.00	40	0.56
	5 years	-	-	-	-	528	7.36
Subtotal		1,747		1,716		5,000	
Total	8,463	2,570	100.00	2,540	100.00	7,172	100.00

Table 4.8 Chosen Alternatives - Three-year samples

Sample Frequencies	Numbers	Combine alternatives
NNN	777	Not buy
NNC	5	Not buy
NNB	4	Not buy
NNA	4	Not buy
NCN	8	Not buy
NCC	11	Not buy
NCB	1	Not buy
NBN	6	Not buy
NBB	6	Not buy
NAN	1	Not buy
CNN	118	CXX
CNC	3	CXX
CCN	50	CCX
CCC	153	CCC
CCB	1	CCX
CCA	1	CCX
CBN	7	CXX
CBC	2	CXX
CBB	4	CXX
CAN	1	CXX
BNN	514	BXX
BNC	6	BXX
BNB	2	BXX
BCN	35	BXX
BCC	77	BXX
BCB	6	BXX
BBN	197	BBX
BBC	50	BBX
BBB	271	BBB
BBA	3	BBX
BAN	2	BXX
BAA	2	BXX
ANN	94	AXX
ACN	4	AXX
ACC	14	AXX
ACB	2	AXX
ABN	17	AXX
ABC	2	AXX
ABB	26	AXX
AAN	17	AAX
AAC	6	AAX
AAB	11	AAX
AAA	49	AAA

Note: N= not buy any physical damage coverage. A= Type A. B= Type B. C= Type C.

4.3 Cross Tabulations of Alternatives by Variables

In Tables 4.9 – 4.11, the ages of the insured are generally between 30 and 49. Older adults perceive higher risks related to severe injuries in traffic accidents than younger people, and are likely to purchase expensive bundles of AIP (i.e., Types A and B) for 5 consecutive years to obtain sufficient protection.

Table 4.9 Chosen Alternatives by Age for
Three-year Samples

Alternative	<30		30-39		40-49		50-59		>59	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Not buy	178	21.63	316	38.40	221	26.85	86	10.45	22	2.67
1C	31	24.22	49	38.28	24	18.75	21	16.41	3	2.34
2C	9	15.25	27	45.76	16	27.12	5	8.48	2	3.39
3C	21	13.73	73	47.71	40	26.14	18	11.76	1	0.65
1B	74	11.49	281	43.63	193	29.97	89	13.82	7	1.09
2B	29	11.6	94	37.60	88	35.20	33	13.20	6	2.40
3B	25	9.23	115	42.44	79	29.15	49	18.08	3	1.11
1A	14	8.81	60	37.74	62	38.99	21	13.21	2	1.26
2A	2	5.88	12	35.29	13	38.24	7	20.59	0	0.00
3A	6	12.24	24	48.98	11	22.45	7	14.29	1	2.04
Total	389	15.14	1,051	40.89	747	29.07	336	13.07	47	1.83

Table 4.10 Chosen Alternatives by Age for
Four-year Samples

Alternative	<30		30-39		40-49		50-59		>59	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
not buy	157	19.05	334	40.53	208	25.24	99	12.01	26	3.16
1C	27	19.29	61	43.57	31	22.14	17	12.14	4	2.86
2C	11	17.74	27	43.55	17	27.42	7	11.29	0	0
3C	1	5.88	7	41.18	4	23.53	3	17.65	2	11.76
4C	20	15.75	60	47.24	32	25.20	14	11.02	1	0.79
1B	76	12.12	259	41.31	183	29.19	104	16.59	5	0.80
2B	27	11.69	81	35.06	77	33.33	42	18.18	4	1.73
3B	6	6.19	47	48.45	27	27.84	14	14.43	3	3.09
4B	20	10.99	80	43.96	55	30.22	27	14.84	0	0
1A	21	13.55	60	38.71	48	30.97	21	13.55	5	3.23
2A	2	6.67	13	43.33	9	30.00	6	20.00	0	0
3A	0	0	5	26.32	7	36.84	4	21.05	3	15.78
4A	1	3.45	16	55.17	4	13.79	7	24.14	1	3.45
Total	369	14.53	1050	41.34	702	27.64	365	14.37	54	2.127

Table 4.11 Chosen Alternatives by Age for Five-year Samples

Alternative	<30		30-39		40-49		50-59		>59	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Not buy	340	15.65	892	41.07	626	28.82	246	11.33	68	3.13
1C	72	16.51	194	44.50	105	24.08	58	13.30	7	1.61
2C	21	18.42	58	50.88	23	20.18	9	7.90	3	2.63
3C	15	20.00	32	42.67	17	22.67	8	10.67	3	4.00
4C	4	10.00	21	52.50	10	25.00	4	10.00	1	2.50
5C	69	13.07	257	48.67	130	24.62	63	11.93	9	1.71
1B	199	12.41	703	43.86	428	26.70	251	15.66	22	1.37
2B	48	9.84	206	42.21	138	28.28	85	17.42	11	2.25
3B	17	6.49	103	39.31	80	30.53	57	21.76	5	1.91
4B	10	5.88	82	48.24	43	25.29	31	18.24	4	2.35
5B	51	9.12	242	43.29	172	30.77	81	14.49	13	2.33
1A	47	9.90	187	39.37	145	30.53	86	18.11	10	2.11
2A	6	5.88	42	41.18	33	32.35	19	18.63	2	1.96
3A	3	7.69	19	48.72	12	30.77	5	12.82	0	0
4A	1	4.00	10	40.00	11	44.00	2	8.00	1	4.00
5A	4	4.76	28	33.33	32	38.10	17	20.24	2	3.57
Total	907	12.65	3076	42.89	2005	27.96	1022	14.25	162	2.26

In Tables 4.12 – 4.14, owners of imported cars tend to purchase expensive bundles of AIP, such as Type A, because imported vehicles are generally more expensive, and owners need to pay large amount of money in case of vehicle damage. The choice behavior of owners of domestic vehicle purchasing three consecutive years is very similar to those of purchasing four and five consecutive years.

Table 4.12 Chosen Alternatives by Vehicle Make for Three-year Samples

Alternative	Domestic		Imported	
	Number	Percent	Number	Percent
Not buy	612	74.36	211	25.64
1C	91	71.09	37	28.91
2C	49	83.05	10	16.95
3C	101	66.01	52	33.99
1B	537	83.39	107	16.61
2B	196	78.40	54	21.60
3B	178	65.68	93	34.32
1A	117	73.58	42	26.42
2A	17	50.00	17	50.00
3A	24	48.98	25	51.02
Total	1922	74.79	648	25.21

Table 4.13 Chosen Alternatives by Vehicle Make for Four-year Samples

Alternative	Domestic		Imported	
	Number	Percent	Number	Percent
Not buy	617	74.88	207	25.12
1C	109	77.86	31	22.14
2C	51	82.26	11	17.74
3C	13	76.47	4	23.53
4C	99	77.95	28	22.05
1B	529	84.37	98	15.63
2B	186	80.52	45	19.48
3B	72	74.23	25	25.77
4B	116	63.74	66	36.26
1A	121	78.06	34	21.94
2A	22	73.33	8	26.67
3A	9	47.37	10	52.63
4A	11	37.93	18	62.07
Total	1955	76.97	585	23.03

Table 4.14 Chosen Alternatives by Vehicle Make for Five-year Samples

Alternative	Domestic		Imported	
	Number	Percent	Number	Percent
Not buy	1581	72.79	591	27.21
1C	319	73.17	117	26.83
2C	90	78.95	24	21.05
3C	53	70.67	22	29.33
4C	25	62.50	15	37.50
5C	374	70.83	154	29.17
1B	1317	82.16	286	17.84
2B	395	80.94	93	19.06
3B	180	68.70	82	31.30
4B	111	65.29	59	34.71
5B	331	59.21	228	40.79
1A	357	75.16	118	24.84
2A	60	58.82	42	41.18
3A	25	64.10	14	35.90
4A	15	60.00	10	40.00
5A	37	44.05	47	55.95
Total	5270	73.48	1902	26.52

As indicated in Tables 4.15 – 4.17, owners of vehicles with large engine capacity prefer expensive policies. For example, owners of vehicles with 2000cc~2999cc engines prefer 3B, 3A and 2A. The owners of vehicles whose engine capacity exceeds 3000cc prefer 3A, followed by 2A and 1A. Owners of smaller engine capacity vehicles prefer 1B, followed by 2B, 1C and 2C. Owners of large engine capacity vehicles are likely to purchase expensive physical damage coverage for longer periods.

Table 4.15 Chosen Alternatives by Engine Capacity for Three-year Samples

Alternative	<2,000cc		2,000-2,999cc		>3,000cc	
	Number	Percent	Number	Percent	Number	Percent
Not buy	599	72.78	208	25.30	16	1.94
1C	92	71.88	33	25.80	3	2.34
2C	43	72.88	15	25.40	1	1.69
3C	111	72.55	38	24.80	4	2.61
1B	486	75.47	148	23.00	10	1.55
2B	185	74.00	60	24.00	5	2.00
3B	178	65.68	83	30.60	10	3.69
1A	107	67.30	45	28.30	7	4.40
2A	17	50.00	13	38.20	4	11.80
3A	22	44.90	21	42.90	6	12.20
Total	1,840	71.60	664	25.80	66	2.57

Table 4.16 Chosen Alternatives by Engine Capacity for Four-year Samples

Alternative	<2,000cc		2,000-2,999cc		>3,000cc	
	Number	Percent	Number	Percent	Number	Percent
not buy	583	70.75	219	26.60	22	2.67
1C	97	69.29	41	29.30	2	1.43
2C	49	79.03	13	21.00	0	0.0
3C	11	64.71	6	35.30	0	0.0
4C	85	66.93	37	29.10	5	3.94
1B	459	73.21	159	25.40	9	1.44
2B	170	73.59	58	25.10	3	1.30
3B	61	62.89	35	36.10	1	1.03
4B	120	65.93	48	26.40	14	7.69
1A	116	74.84	36	23.20	3	1.94
2A	19	63.33	10	33.30	1	3.33
3A	10	52.63	7	36.80	2	10.50
4A	11	37.93	13	44.80	5	17.20
Total	1,791	70.51	682	26.9	67	2.64

Table 4.17 Chosen Alternatives by Engine Capacity for Five-year Samples

Alternative	<2,000cc		2,000-2,999cc		>3,000cc	
	Number	Percent	Number	Percent	Number	Percent
Not buy	1484	68.32	618	28.50	70	3.22
1C	318	72.94	116	26.60	2	0.46
2C	89	78.07	23	20.20	2	1.75
3C	52	69.33	19	25.30	4	5.33
4C	25	62.50	13	32.50	2	5.00
5C	340	64.39	166	31.40	22	4.17
1B	1191	74.30	389	24.30	23	1.43
2B	384	78.69	98	20.10	6	1.23
3B	175	66.79	78	29.80	9	3.44
4B	118	69.41	46	27.10	6	3.53
5B	350	62.61	172	30.80	37	6.62
1A	329	69.26	124	26.10	22	4.63
2A	64	62.75	32	31.40	6	5.88
3A	25	64.10	10	25.60	4	10.30
4A	9	36.00	12	48.00	4	16.00
5A	31	36.90	37	44.00	16	19.00
Total	4984	69.49	1953	27.20	235	3.28

CHAPTER 5 ESTIMATION RESULTS OF MULTINOMIAL LOGIT AND NESTED LOGIT MODELS

In this chapter, two types of models are examined: multinomial logit models and nested logit models. Section 5.1 reports the estimation results of multinomial logit models. Section 5.2 presents the estimation results of nested logit models. Section 5.3 discusses the findings.

5.1 Estimation Results of Multinomial Logit Models

The multinomial logit model was initially estimated to identify the important explanatory variables associated with the choice of physical damage coverage and number of years. Not buying any physical damage coverage is selected as the referent alternative. None of the explanatory variables vary over the alternatives; thus they are treated as alternative specific variables.

Table 5.1 reports the estimation result of the multinomial logit model using three-year samples. The coefficients of alternative specific variables for the age of the driver, vehicle make, and engine capacity were significantly different from zero at the 10% level of significance. Older adults perceive higher risks related to severe injuries in case of traffic accidents than younger people, and are more likely to purchase expensive bundles of AIP such as Type A for one or two consecutive years or Type B for three consecutive years to obtain sufficient protection. Older adults are less likely to purchase Type C as well as Type A for three consecutive years.

Owners of imported vehicles prefer to purchase Type A and Type C for three consecutive years. The value of imported vehicles depends on engine size. It is not necessary for owners of imported vehicles to choose expensive AIP. An imported vehicle with a large engine capacity usually has a higher value, and thus the owner is more likely to purchase expensive AIP to obtain enough coverage. On the contrary, the value of an imported vehicle with a small engine size is low, and Type C coverage is therefore sufficient. However, a vehicle with a larger engine size is more expensive in general, and the owner needs to pay a large amount of money in case of physical damage. The estimated coefficient of 3A (=0.8427) for the engine capacity variable is the highest one, which provides the evidence that owners of vehicles with larger engine capacities are more likely to repurchase Type A coverage for three consecutive years than owners of vehicles with smaller engines.

Table 5.1 Estimation Result of Multinomial Logit Model Using Three-year Samples

Variables	Coefficient	t-value
Alternative Specific Constants		
1A	-2.3364	-6.71
2A	-4.6282	-6.27
3A	-4.5930	-8.96
1B	0.5373	2.38
2B	-1.1915	-16.50
3B	-1.6472	-6.03
1C	-1.8609	-19.59
2C	-2.6354	-19.55
3C	-1.8145	-17.10
Age of the Insured		
1A	0.0175	2.09
2A	0.0357	2.10
3B	0.0136	2.06
Vehicle Make (1 = imported, 0 = domestic)		
3A	0.8427	2.63
3C	0.4522	2.55
Engine Capacity		
3A	0.7506	2.93
1B	-0.4364	-3.54
Log-likelihood value		
At convergence	-4814.24	
At market share	-4842.43	
At zero	-5917.64	
Likelihood ratio index		
At market share	0.0058	
At zero	0.1866	

Table 5.2 reports the estimation result of multinomial logit model using four-year samples. As indicated in this table, the coefficients of explanatory variables were significantly different from zero at the 10% level. The results show that older adults prefer to purchase expensive bundles of AIP (e.g., Type A or B) in the first few years. Likewise, they tend to buy cheaper coverage for three consecutive years. Owners of imported cars are strongly associated with buying expensive bundles of AIP such as Type A and B for four consecutive years, as indicated by the estimated coefficients of 4A (=1.1651) and 4B (=0.4981), respectively. A vehicle with a larger engine is more expensive, and the owner is more likely to purchase Type A or B coverage for four consecutive years.

Table 5.2 Estimation Results of Multinomial Logit Model

Using Four-year Samples

Variables	Coefficient	t-value
Alternative Specific Constants		
1A	-1.6708	-19.08
2A	-3.3130	-17.82
3A	-7.2642	-6.73
4A	-6.0044	-9.34
1B	-0.1993	-0.67
2B	-2.1093	-7.01
3B	-2.1395	-19.93
4B	-2.2400	-6.71
1C	-1.7725	-19.39
2C	-1.3456	-2.06
3C	-5.5580	-5.26
4C	-1.8700	-19.62
Age of the Insured		
3A	0.0821	3.64
1B	0.0107	2.15
2B	0.0212	2.93
3C	0.0414	1.71
Vehicle Make (1 = imported, 0 = domestic)		
4A	1.1651	2.71
1B	-0.4617	-3.58
4B	0.4981	2.81
Engine Capacity		
4A	1.0823	3.58
1B	-0.2234	-1.68
4B	0.3114	1.74
2C	-0.7007	-1.90
Log-likelihood value		
At convergence	-4993.58	
At market share	-5045.92	
At zero	-6514.97	
Likelihood ratio index		
At market share	0.0104	
At zero	0.2335	

Table 5.3 reports the estimation result of the multinomial logit model using five-year samples. The value of the estimated coefficients for the vehicle make variable indicates that owners of imported cars are more likely to purchase Type A for five consecutive years, followed by Type B for five consecutive years. Owners of imported cars tend to purchase expensive bundles of AIP such as Type A for five consecutive years. But owners of imported vehicles less like to purchase 1B. Owners of vehicles with a larger engine favor expensive coverage. Older adults,

the insured with imported vehicles and owners of large engine vehicles prefer to purchase expensive bundles of AIP for four or five consecutive years.

Table 5.3 Estimation Results of Multinomial Logit Model Using Five-year Samples

Variables	Coefficient	t-value
Alternative Specific Constants		
1A	-2.1481	-10.40
2A	-3.0584	-30.19
3A	-4.0198	-24.88
4A	-6.3784	-8.55
5A	-6.5907	-10.79
1B	0.3889	2.59
2B	-1.4931	-29.80
3B	-3.1356	-11.48
4B	-2.6624	-27.25
5B	-1.9667	-10.02
1C	-0.5516	-1.78
2C	-1.7743	-4.26
3C	-4.3152	-8.95
4C	-3.9945	-25.03
5C	-1.9613	-9.75
Age of the Insured		
1A	0.0157	3.18
5A	0.0280	2.49
3B	0.0253	3.95
5B	0.0100	2.14
1C	-0.0121	-2.21
2C	-0.0309	-2.81
Vehicle Make (1 = imported, 0 = domestic)		
5A	0.7992	3.16
1B	-0.4235	-5.55
4B	0.3746	2.27
5B	0.6318	6.84
Engine Capacity		
4A	0.9824	2.84
5A	0.9411	4.65
1B	-0.3318	-3.97
1C	-0.3235	-2.44
3C	0.5020	2.09
5C	0.2925	2.83
Log-likelihood value		
At convergence	-15161.45	
At market share	-15299.41	
At zero	-19885.01	
Likelihood ratio index		
At market share	0.0090	
At zero	0.2375	

5.2 Estimation Results of Nested Logit Models

Using the specifications of the multinomial logit models, the estimation results of two nested logit models depicted in Figures 3.1 and 3.4 are reported in Table 5.4. The nested logit model (NL1) corresponding to Figure 5.1 includes the physical damage coverage choice at the upper level and the number of consecutive years at the lower level. If a logsum parameter is within the zero and one range, it indicates that any pair of utilities in the nest is correlated and possible substitution patterns among alternatives in the nest exist. The estimates of the logsum parameters for two nests (Type A and B) fell within the zero to one range (In Figure 5.1) and were significantly different from one. However, the estimate of the logsum parameter for Type C nest was insignificant, and thus the logsum parameter was set equal to one. By contrast, the nested logit model (NL2) corresponding to Figure 5.2 includes number of consecutive years at the upper level and physical damage coverage choice at the lower level. The estimates of all three logsum parameters were significantly different from one and lied within the reasonable range.

The NL1 model statistically rejected the multinomial logit model in Table 5.1, using the likelihood ratio test with the value of chi-square 10.48, larger than the critical value 5.99 with two degrees of freedom. The NL2 model also statistically rejected the same multinomial logit model, using the likelihood ratio test with the value of chi-square 15.32, larger than the critical value 7.81 with three degrees of freedom. The log-likelihood value of the NL2 model is slightly better than that of the NL1. Using the non-nested hypothesis test developed by Horowitz, (1983), the NL2 model cannot statistically reject the NL1. These two models had approximately the same goodness-of-fit values but different hierarchical structures and behavioral interpretations. To resolve the problems, one of the solutions is to use more flexible models such as the paired combinatorial logit model. Nevertheless, the results imply a high correlation between unobserved utilities of different coverage types and the number of consecutive years.

Table 5.4 Estimation Results of Nested Logit Models Using Three-year Samples

Variables	NL1		NL2	
	Coefficient	t-value	Coefficient	t-value
Alternative Specific Constants				
1A	-3.1340	-5.34	-13.9873	-1.66
2A	-8.2361	-2.35	-42.6254	-0.90
3A	-8.0199	-3.35	-23.5687	-1.37
1B	-9.7965	-0.57	-1.4572	-0.87
2B	-27.3972	-0.61	-5.4484	-0.84
3B	-29.1585	-0.68	-5.7269	-1.57
1C	-1.8610	-19.58	-11.9607	-1.36
2C	-2.6352	-19.55	-25.7716	-0.73
3C	-1.8228	-17.15	-9.3028	-1.34
Age of the Insured				
1A	0.0242	1.82	0.0851	2.97
2A	0.0602	1.17	0.2214	2.93
3B	0.0820	4.34	0.0234	2.23
Vehicle Make (1 = imported, 0 = domestic)				
3A	1.6983	2.64	4.4090	1.24
3C	0.4867	2.73	0.2248	0.19
Engine Capacity				
3A	1.2198	2.81	1.7498	1.81
1B	-0.3024	-1.57	-0.3728	-2.24
Logsum parameter (t value vs. 1)				
Type A	0.4263	3.12		
Type B	0.0555	10.53		
Type C	1.0000	-		
1 year (Yxx)			0.1640	7.00
2 years (YYx)			0.0701	9.39
3 years (YYY)			0.1289	8.10
Log-likelihood value				
At convergence	-4809.00		-4806.58	
At market share	-4842.43		-4842.43	
At zero	-5917.64		-5917.64	
Likelihood ratio index				
At market share	0.0069		0.0074	
At zero	0.1873		0.1877	

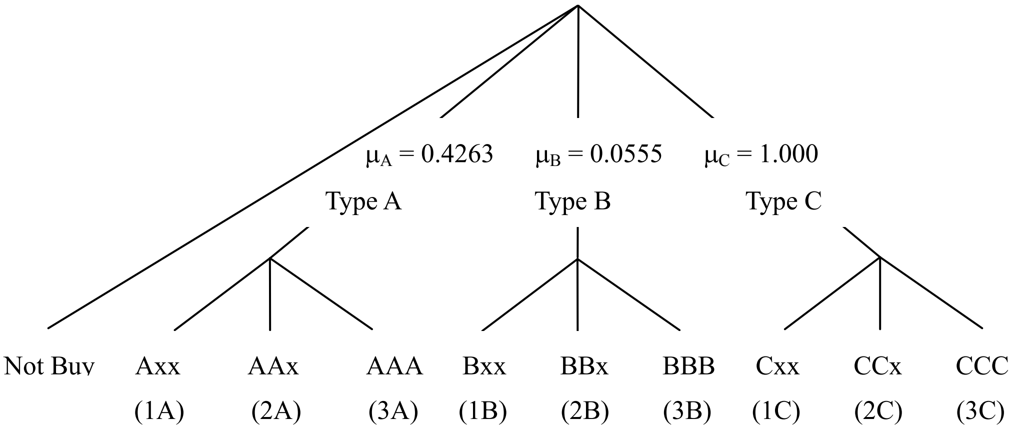


Figure 5.1 Estimation Results of Nested Structure (I) – Three-year samples

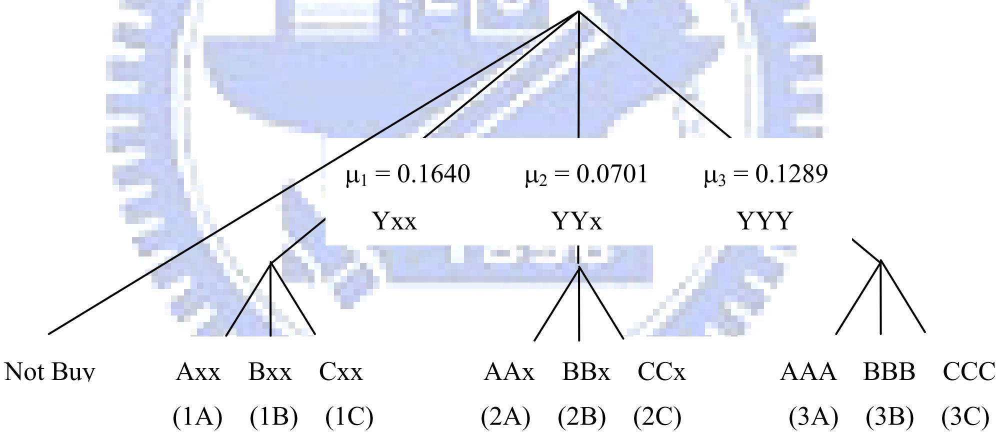


Figure 5.2 Estimation Results of Nested Structure (II) – Three-year samples

The estimation results of two nested logit models illustrated in Figures 3.2 and 3.5 are listed in Table 5.5. The nested logit model (NL3) corresponding to Figure 5.3 includes the physical damage coverage choice at the upper level and the number of consecutive years at the lower level. The estimates of the logsum parameters for two nests (Type A and B) fell within the zero to one range and were significantly different from one. As the previous estimation result, the estimate of the logsum parameter for Type C nest was insignificant, and thus the logsum parameter was set equal to one. Corresponding to Figure 5.4, the NL4 model consists of number of consecutive years at the upper level and physical damage coverage choice at the lower level. The estimates of the logsum parameters for two nests (two and three consecutive years) were significantly different from one at 5% level. However, the estimates of two logsum parameters for one- and four-years nests were insignificant and thus imposed equal to one. Both the NL3 and NL4 models statistically rejected the multinomial logit model, using the likelihood ratio tests. Again, these two models had almost identical goodness-of-fit values and cannot reject each other using the non-nested test.

Table 5.5 Estimation Results of Nested Logit Models Using Four-year Samples

Variables	NL3		NL4	
	Coefficient	t-value	Coefficient	t-value
Alternative Specific Constants				
1A	-2.0566	-7.10	-1.6708	-19.07
2A	-5.3396	-3.44	-13.4673	-1.12
3A	-13.2675	-3.23	-14.4937	-2.60
4A	-9.6297	-3.44	-5.9415	-9.02
1B	-0.8679	-1.09	-0.1844	-0.60
2B	-6.1534	-1.53	-3.7761	-2.15
3B	-7.1921	-1.38	-2.6162	-5.87
4B	-7.3775	-1.40	-2.1670	-6.90
1C	-1.7725	-19.39	-1.7725	-19.39
2C	-1.3128	-2.07	-5.9027	-0.76
3C	-5.7067	-5.83	-9.2549	-2.74
4C	-1.8700	-19.61	-1.8700	-19.61
Age of the Insured				
3A	0.1644	3.05	0.1730	2.67
1B	0.0145	1.51	0.0125	2.44
2B	0.0406	1.69	0.0271	2.87
3C	0.0425	2.03	0.0496	0.94
Vehicle Make (1 = imported, 0 = domestic)				
4A	2.1603	2.09	1.1660	2.36
1B	-1.0541	-1.69	-0.4598	-3.57
4B	1.8484	1.23	0.5001	2.82
Engine Capacity				
4A	1.5848	2.63	1.0472	3.05
1B	-0.5546	-1.75	-0.2709	-1.97
4B	0.8473	1.32	0.2712	1.61
2C	-0.7188	-2.00	-2.1112	-2.20
Logsum parameter (t value vs. 1)				
Type A	0.5002	2.68		
Type B	0.3271	2.98		
Type C	1.0000	-		
1 year (Yxxx)			1.0000	-
2 years (YYxx)			0.1893	4.50
3 years (YYYx)			0.3801	2.93
4 years (YYYY)			1.0000	-
Log-likelihood value				
At convergence	-4989.84		-4990.54	
At market share	-5045.92		-5045.92	
At zero	-6514.97		-6514.97	
Likelihood ratio index				
At market share	0.0111		0.0110	
At zero	0.2341		0.2340	

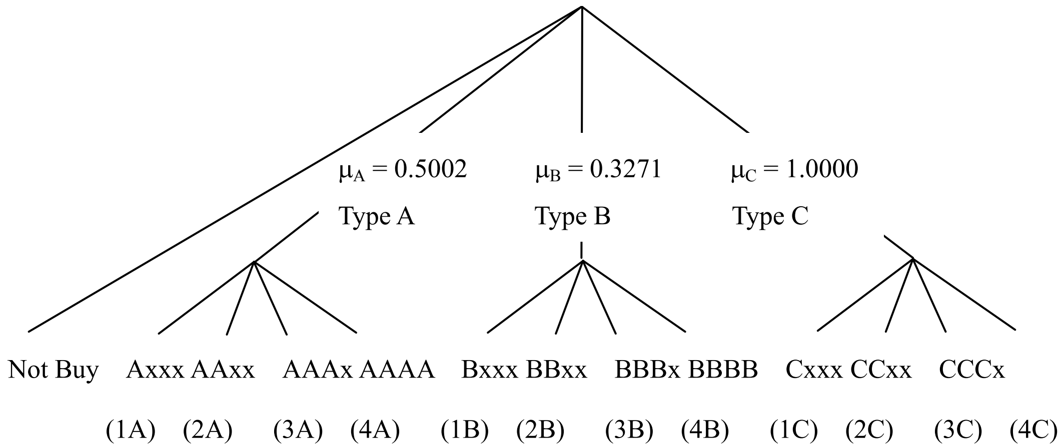


Figure 5.3 Estimation Result of Nested Structure (I) – Four-year samples

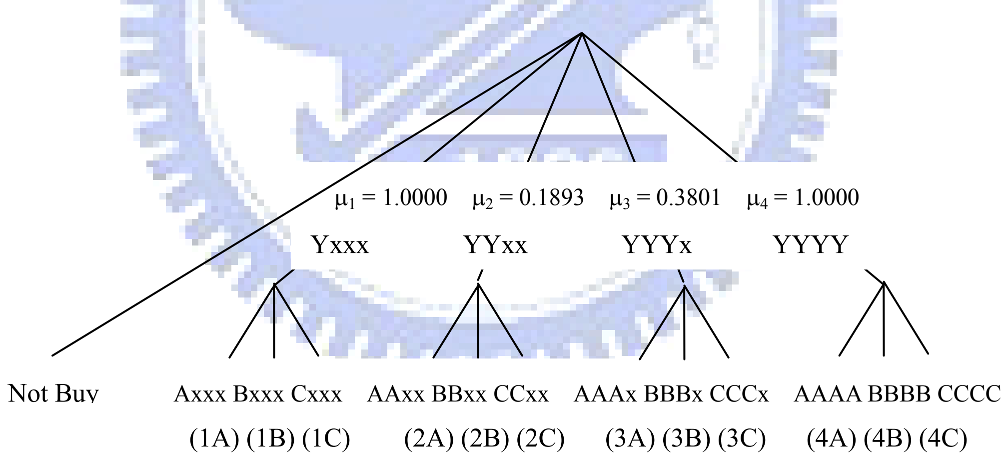


Figure 5.4 Estimation Result of Nested Structure (II) – Four-year samples

Table 5.6 reports estimation results of nested logit models using five-year samples. The NL5 model illustrated in Figure 5.5 includes the physical damage coverage choice at the upper level and the number of consecutive years at the lower level. The estimates of the logsum parameters for all three nests (Types A, B and C) lied within the reasonable range and were significantly different from one at the 5% level. By contrast, most of the estimates of the logsum parameters in the NL6 model fell outside the zero to one range.

The NL5 model statistically rejected the multinomial logit model, using the likelihood ratio test with the value of chi-square 21.36, larger than the critical value 7.81 with three degrees of freedom. The NL5 model statistically outperformed the NL6 model, implying a high correlation between unobserved utilities of the number of consecutive year alternatives. In this case, the substitution effects within the same coverage type are significant.

In most cases, the nested logit model statistically rejected the multinomial logit model. It demonstrates the statistical and structural superiority of the nested logit model in analyzing the insured's repeated choices of physical damage coverage types and the number of consecutive years. Most importantly, the choice behaviors, particularly the hierarchical structures implied by nested logit models, are likely to vary across sampled groups.

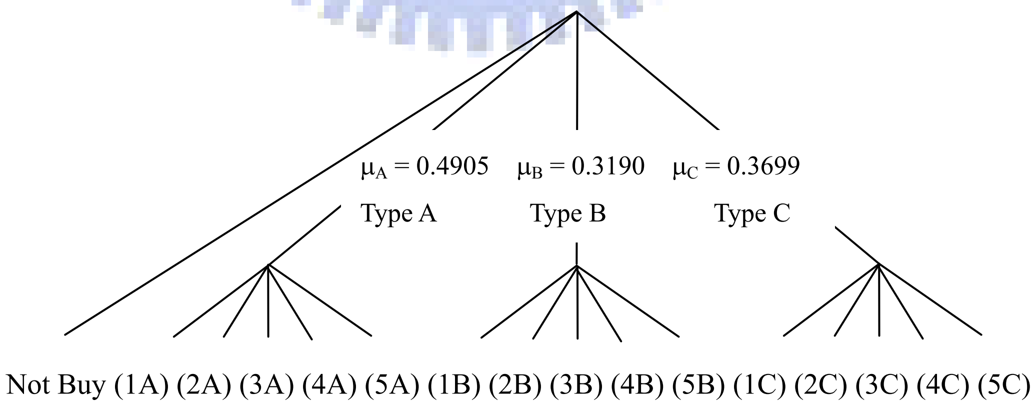


Figure 5.5 Estimation Results of Nested Structure (I) – Five-year samples

Table 5.6 Estimation Results of Nested Logit Models
Using Five-year Samples

Variables4	NL5		NL6	
	Coefficient	t-value	Coefficient	t-value
Alternative Specific Constants				
1A	-2.7734	-7.78	-2.4524	-3.70
2A	-5.0550	-4.09	-1.6530	-1.23
3A	-6.9919	-3.80	-3.7758	-3.77
4A	-10.8524	-3.49	-13.0700	-1.26
5A	-10.6253	-4.19	-6.6138	-4.85
1B	-0.2072	-0.32	0.3494	1.91
2B	-5.4064	-2.47	-1.2275	-4.77
3B	-9.7603	-2.71	-3.0815	-7.05
4B	-9.1052	-2.53	-3.3794	-2.94
5B	-6.4462	-2.74	-1.9864	-6.65
1C	-1.1723	-1.02	-0.7361	-1.57
2C	-4.5132	-1.35	-1.1834	-5.98
3C	-10.0445	-1.54	-4.0745	-3.70
4C	-9.7699	-1.52	-7.9113	-1.20
5C	-3.8418	-1.74	-1.9721	-7.19
Age of the Insured				
1A	0.0209	3.20	0.0180	2.54
5A	0.0423	1.89	0.0281	2.16
3B	0.0590	2.45	0.0249	3.14
5B	0.0183	1.59	0.0104	2.10
1C	-0.0116	-1.10	-0.0135	-1.90
2C	-0.0645	-1.56	-0.0115	-0.40
Vehicle Make (1 = imported, 0 = domestic)				
5A	1.5568	2.61	0.7971	2.67
1B	-1.2615	-2.50	-0.4432	-4.59
4B	1.3291	1.80	0.4439	2.24
5B	2.1979	2.37	0.6324	5.84
Engine Capacity				
4A	1.4739	1.76	1.8404	1.39
5A	1.3577	3.05	0.9461	3.30
1B	-0.6748	-4.54	-0.3403	-3.49
1C	-0.9320	-1.43	-0.3166	-2.07
3C	1.0338	1.22	0.4647	1.72
5C	0.5587	1.40	0.2966	2.73
Logsum parameter (t value vs. 1)				
Type A	0.4905	3.41		
Type B	0.3190	5.65		
Type C	0.3699	2.44		
1 year (Yxxxx)			0.8870	0.53
2 years (YYxxx)			3.6848	-0.29
3 years (YYYxx)			1.1207	-0.22
4 years (YYYYx)			0.3124	1.92
5 years(YYYYY)			0.9953	0.02
Log-likelihood value				
At convergence	-15150.77		-15158.37	
At market share	-15299.41		-15299.41	
At zero	-19885.01		-19885.01	
Likelihood ratio index				
At market share	0.0097		0.0092	
At zero	0.2381		0.2377	

5.3 Discussions

As identified by the multinomial logit models, important explanatory variables affecting the choice of physical damage coverage and number of consecutive years consist of age of the driver, vehicle made and engine capability. Older adults, the insured with imported vehicles and owners of large engine vehicles are likely to purchase expensive bundles of AIP for several consecutive years. The insurer can develop strategies towards targeting two distinct types of insured. One type is the older adult with a large engine capacity or imported vehicle. To encourage this type of insured to repurchase expensive physical damage coverage, the insurer could offer them additional services, such as consulting service of tax saving, wealth management or other risk managements, without extra charges. The other type of the insured is the young adult with a small engine capacity or domestic vehicle. They are reluctant to pay higher premium to cover their risks. Thus, the insurer could offer them more premium discounts or free gifts to increase repurchase intention of physical damage coverage.

We also found that the majority of the insured who purchased physical damage coverage for three consecutive years is the status of a person who deliberate their needs and premium cost to make a selection. Likewise, the status of a "legal person" (such as organization, corporate, society) is likely to purchase expensive physical damage coverage for five consecutive years. The status of a legal person pays more attention on employer liability by law, and the premium of auto insurance can be categorized as expenses to save their corporate profit tax. Choice behaviors between the status of a legal person and the status of a person are fairly different. The finding is new to the insurers because they are not aware of this phenomenon.

The NL1 and NL2 models had approximately the same goodness-of-fit values but different hierarchical structures and behavioral interpretations. The use of more flexible discrete choice models such as the paired combinatorial logit model may be required. The estimation results of four groups of NL3 of the logsum parameters for two nests (Type A and B) fell within the zero to one range and were significantly different from one. The estimation results of NL4 of the logsum parameters for two nests (two and three consecutive years) were significantly different from one at 5% level. It implied that different types of physical damage coverage are closely substituted in the case of the insured buying AIP for two or three consecutive years. To avoid the insured purchasing cheaper coverage, the insurer could offer higher deductible or free charge of additional coverage for the insured choosing the expensive physical damage coverage, such as Type A or Type B, during the second and third years.

CHAPTER 6 ESTIMATION RESULTS OF PAIRED COMBINATORIAL LOGIT MODELS

In this chapter, two different samples are attempted for the paired combinatorial logit models: Three-year samples and Four-year samples. Section 6.1 presents the estimation results for three-year samples. Section 6.2 reports the estimation results from four-year samples. Section 6.3 discusses the findings.

6.1 Estimation Results Using Three-year Samples

Table 6.1 reports the estimation result of the paired combinatorial logit model using three-year samples. As the number of alternatives increases, the estimation and interpretation of the paired combinatorial logit model becomes relatively difficult. The total number of possible alternatives is 10, and the maximum number of logsum parameters is equal to 45 (=10×9/2). The estimation result indicates that only two logsum parameters were within the zero-one range; these include the 1A and 1B nest and the 2A and 2B nest. The logsum parameter for the 2A and 2B nest is set to 0.1, and thus the t-value is not shown.

The paired combinatorial logit cannot reject the multinomial logit model at the 5% level of significance. Furthermore, the paired combinatorial logit did not have a better goodness of fit compared with the nested logit model. Thus, in the context of physical damage coverage choice with three consecutive years, the use of the paired combinatorial logit model is not required.

Table 6.1 Estimation Results of Paired Combinatorial Logit Model Using Three-year Samples

Variables	Coefficient	t-value
Alternative Specific Constants		
1A	-2.2165	-6.42
2A	-4.4721	-6.65
3A	-4.6197	-9.02
1B	0.5410	2.40
2B	-1.1913	-16.51
3B	-1.6441	-6.02
1C	-1.8606	-19.80
2C	-2.6354	-19.55
3C	-1.8141	-17.21
Age of the Insured		
1A	0.0174	2.08
2A	0.0348	2.28
3B	0.0136	2.05
Vehicle Make (1 = imported, 0 = domestic)		
3A	0.8336	2.60
3C	0.4519	2.55
Engine Capacity		
3A	0.7647	2.99
1B	-0.4383	-3.55
Logsum Parameter		
(1B, 1A)	0.2250	1.73
(2B, 2A)	0.1000	-
Log-likelihood value		
At convergence	-4814.22	
At market share	-4842.43	
At zero	-5917.64	
Likelihood ratio index		
At market share	0.0058	
At zero	0.1817	

6.2 Estimation Results Using Four-year Samples

Table 6.2 reports the estimation result of the paired combinatorial logit model using four-year samples. The total number of possible alternatives is 13, and the maximum number of logsum parameters is equal to 78 (=13×12/2). Six logsum parameters had the reasonable range and indicate high degrees of similarity between pairs of AIP alternatives. The paired combinatorial logit model statistically rejected the multinomial logit model, using the likelihood ratio test with the value of chi-square 29.96, larger than the critical value (14.07) with 7 degrees of freedom at the 0.05 level of significance. The log-likelihood value of the paired combinatorial logit model is better than that of the nested logit model. The paired combinatorial logit model also rejected the nested logit model using the non-nested test. Therefore, it demonstrates the statistical and structural superiority of the paired combinatorial logit model in analyzing insured choice when facing different AIP bundles.

Table 6.2 Estimation Results of Paired Combinatorial Logit Model Using Four-year Samples

Variables	Coefficient	t-value
Alternative Specific Constants		
1A	-1.6319	-18.44
2A	-3.3069	-17.57
3A	-7.2222	-6.79
4A	-5.9955	-9.53
1B	-0.2026	-0.72
2B	-2.1049	-7.07
3B	-2.0695	-19.20
4B	-2.2281	-6.45
1C	-1.7324	-18.50
2C	-1.2682	-2.11
3C	-5.5399	-5.27
4C	-1.8607	-11.17
Age of the Insured		
3A	0.0808	3.63
1B	0.0096	1.98
2B	0.0226	3.18
3C	0.0424	1.77
Vehicle Make (1 = imported, 0 = domestic)		
4A	1.1884	2.79
1B	-0.4087	-3.37
4B	0.5201	3.00
Engine Capacity		
4A	1.0706	3.64
1B	-0.2145	-1.75
4B	0.3373	1.97
2C	-0.6624	-2.05
Logsum Parameter		
(1C, 1B)	0.1000	-
(1B, 2B)	0.1000	-
(1B, 4B)	0.1000	-
(1B, 1A)	0.1000	-
(2C, 3B)	0.1000	-
(3C, 3B)	0.1000	-
Log-likelihood value		
At convergence	-4978.60	
At market share	-5045.92	
At zero	-6514.97	
Likelihood ratio index		
At market share	0.0133	
At zero	0.2394	

We found that the paired combinatorial logit in some cases did not have a better goodness of fit compared with the nested logit model. The total number of possible alternatives of five-year samples is 15, and the maximum number of logsum parameters is equal to 105 (=15×14/2). However, the total number of AIP alternatives in our choice problem relatively large, especially as the number of the logsum parameters becomes large. In addition, estimation of the paired combinatorial logit model became very difficult as the number of alternatives increases. To simplify the complex estimation problem, the choice behavior of two groups (three- year samples and four-year samples) is adopted to develop.

6.3 Discussions

The estimation result of the paired combinatorial logit model with three-year samples indicates that the paired combinatorial logit model cannot reject the multinomial logit model at the 5% level of significance. The paired combinatorial logit model did not have a better goodness of fit compared with the nested logit model. It shows that the use of the paired combinatorial logit model is not necessary in this case. In contrast, the estimation result of paired combinatorial logit model with four year samples reveals that six logsum parameters had the reasonable range and indicated high degrees of similarity between pairs of bundled AIP alternatives. It illustrates the statistical and structural superiority of the paired combinatorial logit model in analyzing insured's choice when facing different AIP bundles in this case.

When we estimated the paired combinatorial logit model with five-year samples, the total number of available alternatives is 15, and the maximum number of logsum parameters is equal to 105 (=15×14/2). The total number of AIP alternatives becomes extremely large. We did estimate the utility function and all pairs of logsum parameters but found that none of the logsum parameters fell within the reasonable range. Although the paired combinatorial logit model is more flexible than the multinomial logit or nested logit model, the estimation of such model becomes very difficult when the number of alternatives is large, which limits its applicability under this circumstance.

CHAPTER 7 CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

7.1 Conclusions

This dissertation has made important contributions to the understanding of the insured's choice of bundled AIP by developing a model system that comprises two main components: the first component, which is the main focus of the study, includes the decision to choose physical damage coverage types; the second component consists of the choice of non-physical damage coverage involving third party liability with additional coverage. A discrete choice modeling framework including the choices of physical damage coverage types and the number of consecutive years that the insured has purchased the same type of coverage is further developed. The use of various discrete choice models including multinomial logit, nested logit, and paired combinatorial logit enable us to compare different model structures and select a preferred model that better represents the choice situation.

The multinomial logit models were initially estimated to identify important explanatory variables associated with the choice of physical damage coverage and number of consecutive years. The parameter coefficients of the age of the driver, vehicle make, and engine capacity were different from zero at a high level of significance. The results indicate that older adults, the insured with imported vehicles and owners of large engine vehicles prefer to purchase expensive bundles of AIP for several consecutive years.

The results of nested logit models imply high correlations between unobserved utilities of different coverage types and the number of consecutive years. In most cases, the nested logit model statistically rejected the multinomial logit model, using the likelihood ratio tests. It demonstrates the statistical and structural superiority of the nested logit model in analyzing the insured's repeated choices of physical damage coverage types and the number of consecutive years. More importantly, the choice behaviors implied by the nested structures are likely to vary across sampled groups.

The paired combinatorial logit that allows for differential correlation between pairs of alternatives has a flexible covariance structure. However, we found that the paired combinatorial logit in some cases did not have a better goodness of fit compared with the nested logit model. In addition, estimation of the paired combinatorial logit model became very difficult as the number of alternatives increases. In the context of physical damage coverage choice with Three-year samples, the use of paired combinatorial logit model is not required. Using Four-year samples, the log-likelihood value of the paired combinatorial logit model is better than that of the nested logit model. Moreover, the paired combinatorial logit model rejected the nested logit model, using the non-nested test. In this case, the structural superiority of paired combinatorial logit model over the nested logit model in analyzing insured choice when facing different AIP bundles is recommended.

Based on our findings, young adults, owners of domestic vehicles and owners of vehicles with a small engine size should be the target markets for promoting long-term purchases of physical damage policy, because the insured in these segments typically purchase physical damage coverage in the first year but are more likely to decrease their automobile insurance expenditures by purchasing reduced coverage or not buying any physical damage coverage in succeeding years. Therefore, steeper discounts may be given in the second or third year to those insured buying long-term physical damage coverage to increase the company's profits and to maintain cash flow for the next few years.

In addition, the preferred nested logit model implies high substitution patterns among the number of consecutive year alternatives. For the insured who only purchase one or two years of physical damage coverage, the insurer may develop loyalty programs or offer sufficient incentives to encourage the insured to purchase the same physical damage coverage in subsequent years. We can make some strategy during the second or third year, for example higher deductible or free charge of additional coverage to maintain they choose the same type of policy, if insured adhere to change their AIP into cheaper policy, insurer can adjust the insurance amount of non-physical damage coverage to reduce the degree of cash flow away.

In practice, car dealers have the extraordinary and important role in automobile insurance market in Taiwan. Car dealers have strong incentives to promote more expensive coverage because most of the insured are not concerned about the details of the insurance policies; as such, they very much rely on the dealers to make the selection decisions for them, or at least to provide recommendations on such issues as insurance limits, deductibles and other coverage (Wang, 2004). Car dealers or car manufacturers would also encourage the insured to buy expensive insurance policies for consecutive few years by offering them additional maintenance presents or free of charge insurance policies such as theft loss coverage or other cheaper policies to obtain long term contracts. During the first two or three years of new car, car dealers would limit the insurer through a contract to prevent their customers from directly purchasing AIP from the insurer, and the period of contract was the same as the maintenance contract to the new car owners.

Since car dealers in Taiwan are rewarded by a commission with a fixed percentage of the insurance premium, the loss ratio under Type A and Type B has been extremely high, and is continuing to increase. However, the dealers control the new cars business only for three years. After that, if the insured no longer buy any physical damage coverage, the dealers will have no commissions coming in. Consequently, the insurers may offer some incentives to the insured to make them keep purchasing the physical damage coverage in the consecutive four and five years. The insurers may also consider other distribution channels for their insurance products, such as e-commerce or direct marketing.

7.2 Directions for Future Research

Several possible directions are identified here for further exploration.

1. This study only focuses on the first component of the model system. The future research could develop a comprehensive methodological framework that incorporates the second component into the first component to formulate an integrated model. However, estimations of such complex model system could be difficult when the number of alternatives is extremely large. There is also a need of developing more efficient estimation approach for a large and integrated model system.
2. The empirical study includes only the insured with non-commercial automobiles and excludes motorcycles and other types of privately owned vehicles. Future research could apply the proposed modeling approach to analyze the insured with different vehicle types.
3. The data set consists of the new car owners who have repeatedly purchased bundled AIP from a specific insurance company since 2000. The insured purchasing new cars before and after year 2000 were excluded. Future work could enlarge the sample size by analyzing the new car owners starting from different time horizons.
4. The data source used for empirical analysis was from a non-life insurance company that has the largest market share among all non-life insurance companies in Taiwan. Although this research has successfully applied the discrete choice modeling approach in

analyzing the insured choice behaviors, comparison of behavioral differences across insurance companies would be desirable.

5. The insurers should distinguish status of a "legal person" from status of a person in their databank so as to further analyze the choice behaviors of five-year and three-year individuals. This would help the insurers make good strategies for market segmentation.

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APPENDIX A : ABBREVIATIONS

AIP : Automobile Insurance Policies

IIA : the property of Independence from Irrelevant Alternatives

L1 : Property damage

L2 : Bodily injury

L3 : Intoxicated driver

L4 : Spousal liability

L5 : Family's personal injury

L6 : Passenger's (personal accident) or liability

L7 : Drivers' personal injury

L8 : Uninsured motorists

L9 : Additional PIP (No-Fault) benefits

L10 : Other special coverage

MNL : Multinomial Logit Model

NL : Nested Logit Model

NL1 : the physical damage coverage choice at the upper level and the number of consecutive years at the lower level (Three-year Samples)

NL2 : number of consecutive years at the upper level and physical damage coverage choice at the lower level (Three-year Samples)

NL3 : the physical damage coverage choice at the upper level and the number of consecutive years at the lower level (Four-year Samples)

NL4 : number of consecutive years at the upper level and physical damage coverage choice at the lower level (Four-year Samples)

NL5 : the physical damage coverage choice at the upper level and the number of consecutive years at the lower level (Five-year Samples)

NL6 : number of consecutive years at the upper level and physical damage coverage choice at the lower level (Five-year Samples)

PCL : Paired Combinatorial Logit Model

P1 : Collision

P2 : Fire

P3 : Lightning, struck by lightning

P4 : Explosion

P5 : Missiles or fall objects

P6 : Vandalism

P7 : Any unidentified reasons other than the exclusions

P8 : Theft loss

P9 : Windscreen damage

PA : Physical Damage Coverage Type A (Type A)

PB : Physical Damage Coverage Type B (Type B)

PC : Physical Damage Coverage Type C (Type C)

PL : Passenger Liability

T : Theft Loss Coverage

TP : Third Party Liability

APPENDIX B : NOTATIONS

V_{ytn} : represents the deterministic (observable) components of utilities for alternative (*y*, *t*)

ε_{ytn} : represents the random (error) components of utilities for alternative (*y*, *t*)

t : physical damage coverage type

y : number consecutive years

α_{yt} : a constant term specific to the alternative (*y*, *t*)

X_{ytkn} : the explanatory variable *k* for alternative (*y*, *t*)

β_k : an unknown parameter reflecting the relative importance of the variable *k*

$P_n(y \mid t)$: the conditional probability of insured *n* selecting a number of consecutive years *y* among choice set N_t conditional on choosing coverage type *t*

$P_n(t)$: the marginal probability of insured *n* choosing coverage type *t*

Γ_{tn} : the logsum variable for insured *n* choosing coverage type *t*

μ_t : the logsum (or inclusive value) parameter for coverage type nest *t*

μ_{ij} : the logsum parameter associated with paired alternatives *i* and *j*

N : the number of alternatives

$LL(\hat{\beta}_R)$: the log likelihood at convergence of the restricted model

$\hat{\beta}_U$: and $\hat{\beta}_R$: vectors of parameters in the unrestricted and restricted

ρ^2 : the fraction of an initial log likelihood value explained by the model

$\bar{\rho}^2$: similar to ρ^2 but corrected for the number of parameters (*K*) estimated

$\bar{\rho}_h^2$: the adjusted likelihood ratio index for model, *h* = 1, 2

K_h : the number of parameters in model *h*

Φ : the standard normal cumulative distribution function

APPENDIX C : VITA

姓　名	王明智　(Ming-Jyh Wang)	姓　別	女
教　育	民國 90 年 8 月-97 年 1 月　國立交通大學交通運輸研究所博士 民國 79 年 8 月-81 年 1 月　逢甲大學保險學研究所碩士 民國 74 年 8 月-77 年 6 月　逢甲大學銀行保險學系學士		
現　職	朝陽科技大學保險金融管理系專任教師		
經　歷	朝陽科技大學保險金融管理系 僑光商專銀行保險科 台灣省政府財政廳第二科 財政部保險司財產保險科 台灣人壽保險公司 京華證券股份有限公司 中國人壽保險股份有限公司		
兼　職 經　歷	財政部保險司「保險公司設立審查小組」 內政部營建署「公寓大廈管理條例」審查小組 財政部「保險審議委員會」成員 財政部保險司「財產保險新種商品審查小組」成員 行政院消費者保護委員會「保險宣導計劃」諮詢委員 僑光技術學院兼任講師 僑光技術學院「保險諮詢服務暨研究中心」諮詢委員 中華民國風險管理學會風險管理師考試中區主考官 中華民國產物保險商業同業公會損害防阻系列講座講師 現代保險雜誌「信望愛獎」評審委員 國立台中技術學院兼任講師		
國　家 考　試	民國 79 年全國公務人員高等考試，金融保險職系 民國 81 年財政部保險業務發展基金管理委員會 　「保險從業人員出國進修考試」及格 民國 82 年行政院所屬公務人員出國進修考試及格 產險代理人考試及格		

歷任重要工作項目	**1.財政部任內** ★財政部保險司品質圈成員 ★保險教育宣導五年中程計劃之規劃與執行 ★新保險公司設立審查小組 ★新種保單審查小組 ★強制汽車責任保險暨相關子法及議題 ★國內產物保險公司(包含外商公司)財務、業務之監理 ★保險合作社與相互保險公司設立及相關問題之研究 ★財政部所屬公營保險公司民營化之規劃執行 **2.財政廳任內** ★省屬金融保險機構業務監理，營業預決算之審核暨組織人事章則 ★省轄農漁會信用部業務之監理 ★公益彩券發行相關事宜之規劃 ★省屬金融機構民營化之規劃 ★日據時代金融機構債權債務之處理 ★省轄農漁會信用部合併之可行性研究