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Automobile Leasing in the United States:
Why Do Consumers Lease Cars?

by

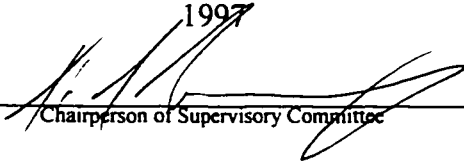
William Scott Starkey

A dissertation submitted in partial fulfillment
of the requirements for the degree of

Doctor of Philosophy

University of Washington

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Chairperson of Supervisory Committee

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Doctoral Dissertation

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Abstract

Automobile Leasing in the United States:
Why Do Consumers Lease Cars?

By William Scott Starkey

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Department of Civil Engineering

This dissertation examines the process by which consumers decide which automobile to purchase and how to finance their decision. Although prior research of automobile leasing assumed a sequential process in which household's first decided which vehicle to buy and then decided how to pay for it, empirical estimates from this paper indicate the process should be modeled as simultaneous. A nested multinomial logit vehicle type choice model which considers payment options is used to gain insight into why consumers lease cars. Specifically, evidence supports the hypothesis that consumers lease to avoid binding credit constraints which permit them to drive a higher quality car than they otherwise would have chosen and avoid the disposal costs associated with purchasing a new vehicle every three years. Furthermore, accurate survey information enabled the inclusion of previously unexplored vehicle and socioeconomic attributes in the vehicle type choice estimation. For example, it is shown that the residual value of a vehicle, defined as the percentage of MSRP a vehicle is expected to retain after three years of use, does have a significant impact on the selection of which vehicle to purchase. An endogenous lease pricing model which allows automobile manufacturers to

price discriminate depending upon a household's choice of financing is then used to develop short term forecasts of the automobile industry. The endogenous pricing model allows for empirical enumeration of two opposing incentives faced by automobile manufacturers. Results indicate that in many cases manufacturers have incentives to charge lease prices higher than the Manufacturer's Suggested Retail Price would suggest. Automobile demand estimates and endogenous lease pricing results are then used to explain the dramatic increase in consumer leasing over the past fifteen years and predict future leasing trends. As real household income and automobile prices stabilize, consumer leasing is predicted to peak at approximately 30% of all vehicle purchases.

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Chapter 1. Introduction

Automobiles comprise a significant sector of the American economy. In 1992 alone, consumers spent \$424 billion to purchase and operate their motor vehicles, a figure exceeding over 10% of all personal consumption expenditures. (American Automotive Manufacturer's Association, Facts and Figures '93). Over 810,000 American workers were employed to produce the 9,311,734 passenger cars and commercial vehicles produced in the United States that year. Understanding why consumers choose to purchase a particular make and model of vehicle has far-reaching political and economic implications. This dissertation critically examines past estimates of automobile demand and sheds light on previously unanswered questions regarding the leasing of cars and light trucks in the United States.

Before introducing new research, a summary of the current state of the U.S. automobile market is in order. As shown in Table 1, sales of cars and light trucks were strong in the 1995 model year. Over 14.75 million vehicles of the 1995 model year were sold in the United States, a figure approaching the sales record of 16 million vehicles in 1986 (Automotive News, Market Data Book). The big three U.S. automobile companies (Ford, General Motors, and Chrysler) posted strong profits, with net income for 1995 being 4.139, 6.881, and 2.025 billion dollars, respectively. Domestically produced cars

TABLE 1. U.S. Automobile Sales

Year	Car Share ^a	Truck Share ^a	Total Share ^a	Car Sales ^b	Truck Sales ^b	Total Sales ^b
80					2227472	
81					2035528	
82					2391746	
83					2995822	
84	2.9	0.9	2.5	2227472	3878263	
85	4.2	1.1	3.5	2227472	4418583	
86	3.6	1.1	3	2227472	4617506	
87	5.3	1.1	4.4	2227472	4709359	
88	8.5	1.1	6.8	2227472	4922339	
89	10.1	1.1	7.9	2227472	4779192	
90	9.7	1.1	7.3	2227472	4591077	
91	11.7	1.1	9.1	2227472	4159421	
92	15.2	1.1	13.5	2227472	4674589	
93	19.3	1.1	17.9	2227472	5398483	
94	25.6	1.1	23	2227472	6097787	
95	27.2	1.1	24.2	2227472	6130406	
96	29.5	1.1	27.2			
97	32.6	1.1	29.3			
98	35.1	1.1	31.5			
99	35.2	1.1	31.6			
00						

a) Car Share, Truck Share, and Total Share represent the pure consumer lease shares and were obtained from CNW Marketing/Research, Bandon, OR. 1996-99 lease shares are based on proprietary CNW forecasting models.

b) Sales figures obtained from Automotive News: The 100 - Year Almanac. 1996 - 2000 sales figures were projected using the Binary Logit purchase/not purchase estimates shown in Table 8 and assuming a 3% increase in real household income.

also regained some lost market share, accounting for almost 74% of total sales (See Figure 1).

The U.S. auto industry in recent years is characterized by two distinct trends. The last fifteen years have shown a pronounced change in the composition of the fleet. A shift in consumer demand, mostly due to lower gasoline prices, has caused a resurgence in popularity of larger cars and light trucks. In 1980, truck sales accounted for 19.9% of total sales in the United States. Vastly increased sales of minivans and sports utility vehicles caused this figure to rise to 41.5% in 1995 (Figure 2).

The second trend, the sudden popularity of consumer leasing, is much more difficult to explain. The leasing of cars in the United States has risen substantially in the past decade. As recently as 1984, consumers chose to lease only 2.9% of new cars. This percentage increased gradually to 11.7% in 1991. Thereafter, the percentage of consumers leasing increased dramatically (as shown in Figure 3).¹ Current leasing exceeds 27% of all new cars acquired

¹ A survey of automobile dealerships in the Seattle area found few supply side leasing incentives. Dealerships said leasing was not pushed upon consumers while commissions were often independent of a consumers method of financing. Demand side leasing explanations proposed by dealerships include 1) Consumers are not sure if they will like a particular model and value the option to change models after just a few years, and 2) Leasing allows for a lower downpayment and lower monthly payment. One manager had a strong belief that the increase in consumer leasing was highly correlated to the increase in automobile prices partially due to recent increases in litigation expenses (~\$500/vehicle). A salesman felt that the increase in leasing had to do with the changing structure of lease contracts. Many lease contracts in the early 1980's were open ended contracts which required consumers to bear all of the risk when the vehicle was resold. Nearly all consumer leases are now closed end leases.

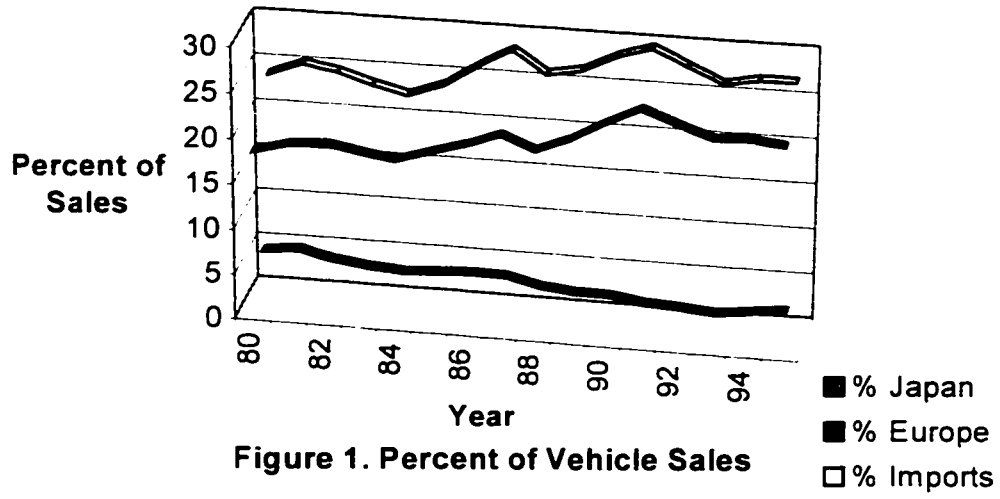


Figure 1. Percent of Vehicle Sales

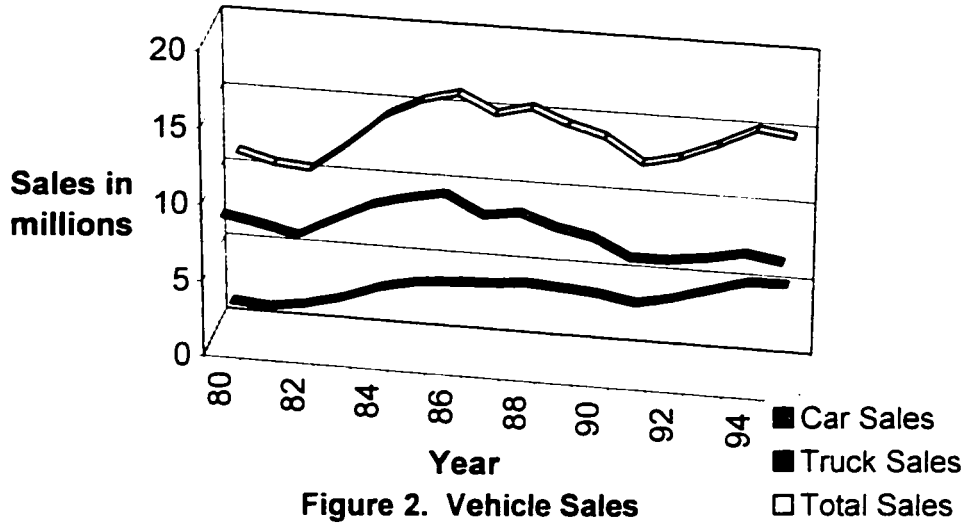
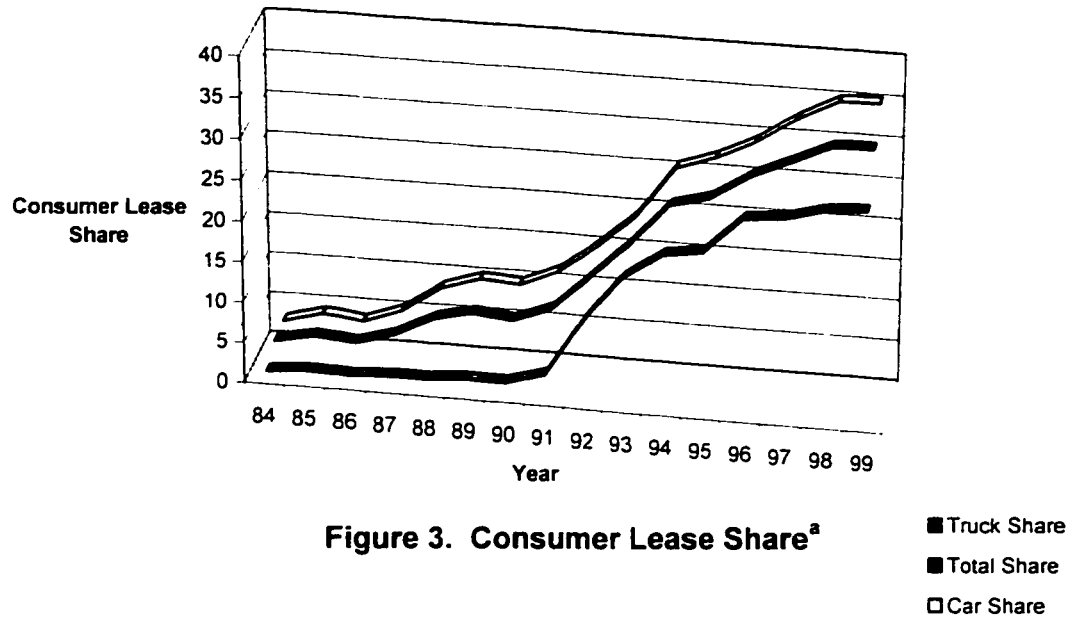


Figure 2. Vehicle Sales



^a Car Share, Truck Share, and Total Share represent the pure consumer lease shares and were obtained from CNW Marketing/Research, Bandon, OR. 1996-99 lease shares are based on proprietary CNW forecasting models.

by households, and forecasts show no sign of waning. An independent research firm² predicts that over 1/3 of all new vehicle purchases will be leased by the year 1998. The leasing of light trucks has increased as well, rising from 3.5% to 19.7% in the decade from 1985 - 1995 (See Table 1).

The increase in the popularity of leasing occurred despite the elimination of many tax benefits in the tax reform act of 1986. Most consumers can no longer deduct vehicle lease payments from taxable income. Only unusual circumstances permit individuals earning income as employees to deduct any amount of personal vehicle lease payments (Nunnally & Plath, 384).³ Moreover, the phase out of the personal interest deduction associated with vehicle installment purchases was completed in 1990. These changes, which should have led to a decrease in the popularity of consumer leasing, make its increase even more perplexing.

Any comprehensive analysis of automobile demand should be able to explain these recent changes in consumer behavior. The first objective of this work is to explicitly analyze the decision process by which consumers choose which new vehicle to purchase and how to pay for it. It is empirically shown that previous analysis of the leasing question has not adequately described consumer behavior, leading to biased and unreliable conclusions. A model is proposed which allows for the derivation of unbiased estimates of automobile demand and yields valuable insight as to why people lease a given car.

² CNW Marketing/Research

³ Sales tax implications do make leasing an attractive financing option. If a vehicle is leased, sales taxes are paid monthly along with the lease payment and are only paid on the amount leased. Nevertheless, this is unlikely to explain the change in consumer leasing.

In terms of its econometric estimation of automobile demand, this work shows that previously unexamined variables are important determinants in vehicle choice. These variables include expected automobile insurance, a household's annual debt, and the number of miles it expects to drive per year.

The application of the estimated econometric models to forecasting was undertaken giving full consideration to the dynamics of brand loyalty. For example, a person who has previously purchased a Ford is more likely to purchase a Ford in the future. Previous research has ignored this brand loyalty when forecasting how automobile manufacturers set their prices for future model years. This is an important consideration because a profit maximizing firm should realize that setting lower prices on some of their models today will enable them to capture a larger share of the market and increase their brand loyalty for future years (making their demand curve for a given model more inelastic in the future at any given price). Forecasting in this paper is done by endogenously determining lease prices through numerical enumeration. Results from the enumerations explain important phenomena such as why companies offer lease incentive programs and why lower end vehicles are priced much closer to marginal cost than more expensive models.

The following chapters explore the increasing attraction of leasing contrary to what economic theory would predict. Chapter 2 presents a review of relevant past literature and research. It lays the groundwork for a new, more accurate approach to the analysis of leasing trends in the United States. Chapter 3 discusses the econometric model of automobile demand, gives the

results of various specification tests, and discusses insights into the decision to lease. Chapter 4 develops a new forecasting technique which allows for endogenous lease pricing and predicts what is likely to happen in the industry over the 1997 - 2000 period. The final chapter restates the conclusions of the dissertation and gives suggestions for future research.

Chapter 2. Literature Review

When consumers enter a new car dealership, they are immediately confronted by a plethora of choices. Decisions must be made between vehicles with different attributes, options, and prices. When consumers decide to purchase a vehicle, they must decide on whether to lease, finance, or find another way to pay for their purchase. Both vehicle price and financial arrangements are negotiable, while the leasing and financing terms offered to customers often differ by both the model of the vehicle and the chosen method of financing.⁴

A numerical example helps to illustrate the vehicle choice and financing options available to the consumer. Suppose you were interested in purchasing a \$20,000 automobile (including state license and registration fees). To purchase the vehicle, you would need to make a \$4,000 downpayment plus state and local sales taxes. To finance the remaining \$16,000 for four years at a 9% interest rate, your monthly payment would be \$398.16. The net present value of the stream of payments required to purchase the vehicle, using a

⁴ Leases typically require a 10% downpayment, while a 20% downpayment is required if the vehicle is purchased. In August, 1997, Chevrolet was charging customers a 9% interest rate to lease all vehicles and finance *some* vehicles. For example, the interest rate for a Chevrolet Lumina was 1.9% for a 36 month loan, 2.9% for a 48 month loan, and 3.9% for a 50 month loan. Interest rate discounts were not offered on the more popular Malibu models. The fact that manufacturers may price discriminate based on the method of financing is addressed later in the paper.

9% discount rate, is \$20,000. Leasing that same vehicle would require a \$1,000 downpayment, a security deposit, and an agreement to pay \$223.97 per month for the length of the lease.⁵ If you expect to sell your financed vehicle in four years for a price of \$10,000 current dollars, the net present value of the stream of payments using a 9% interest rate is \$10,000, regardless of the method of payment.⁶

It is not the case that consumers and automobile salesmen negotiate in terms of the present value of an automobile. Because negotiations take place on monthly payments, downpayment, and interest rates, the present value of the payment stream differs on the household's choice of payment. In particular, consumers often choose to lease even when the present value of payments is greater.

An example helps to show that the lease/finance decision of a consumer goes beyond simple cost minimization. Suppose two consumers decide to acquire (either lease or finance) a Nissan Altima. Also assume the two households face identical (lease and finance) downpayments, monthly payments, and interest rates. Minimizing the net present value of payments, the consumers should both choose to lease or finance. If different methods of acquisition are chosen, one of the consumers must have chosen a more expensive method.

Economists have long wondered why many consumers choose a payment method even when it is not in their best financial interest. The brief

⁵ The standard lease contract is 3 years in length, although many options are available.

answer is that the choice of whether to lease or purchase is not a simple accounting decision. The stream of benefits associated with leasing a vehicle is not the same as if the vehicle was purchased. Leasing yields benefits for which many households are willing to pay a premium. In particular, this dissertation shows that leasing reduces the transactions costs associated with vehicle disposal and replacement and allows households to avoid otherwise binding credit constraints.⁷

To show that leasing confers benefits not associated with vehicle purchase, it is worthwhile to review suggested reasons for consumer leasing found in the literature. Hinsberg (1988) suggests that vehicle leasing might be preferred to alternative methods of financing because: 1) lease financing requires a lower downpayment and monthly payment for a given car; 2) leasing allows consumers to acquire a more costly vehicle for a given monthly payment; and 3) leasing simplifies the disposal of used vehicles upon maturity.

In addition, the majority of retail lease contracts are closed-end leases, whereby upon expiration of the lease the household simply returns the automobile to the dealer. Risk averse consumers might lease in order to transfer risk to automobile dealerships. Another explanation could be that as

⁶ As mentioned in footnote 3, leasing is a more attractive payment option in the presence of local and state sales taxes.

⁷ Alternatively, leasing could allow a household to borrow at a lower interest rate.

cars become more difficult and expensive to maintain, the length of time a household wants to own its car decreases, and leasing lowers the transaction costs of disposing of a used car. Similarly, if driving a new car is a normal good, an increase in real income would lead consumers to purchase new automobiles more frequently. Leasing would increase in popularity because it decreases the transaction costs of vehicle disposal and replacement.

I. CONDITIONAL MODELS

Although numerous articles have been written on the advantages and disadvantages of leasing, research has focused exclusively on what should be considered a subset of the leasing literature. Articles to date have solely considered the optimal financing of an asset. The implicit assumption in these conditional models (i.e. conditioned on the decision to acquire a particular vehicle) is that the lessee will obtain a given piece of capital equipment regardless of the terms of the lease or cost of purchase. These types of studies range from "The Lease-Purchase Decision for Agricultural Assets" (Ford and Musser, 1994), to the decision to purchase or lease oil refineries, to how households should finance their automobiles. While the conditionality assumption is realistic (or at least reasonable) for heterogeneous goods with few substitutes (like many pieces of large capital equipment), it becomes questionable in the context of consumer leases of cars and light trucks. For

example, a Ford Taurus should be considered an excellent substitute for a Chevrolet Corsica because it provides many of the same benefits to consumers.

Conditional models evaluate the financing decision by comparing the present value of the stream of cash flows associated with leasing and financing (Ford and Musser, 1994). Examples in the literature include "*Leasing versus Borrowing: Evaluating Alternative Forms of Consumer Credit*" (Nunnally & Plath, 1989), "*A Proposed Procedure for Facilitating the Analysis of Lease-Purchase Decisions by Consumers*" (Patrick, 1984), and "*Economics of Automobile Leasing: The Call Option Value*" (Miller, 1995). Summaries of articles such as these are frequently written to aid consumers in their leasing decision when purchasing a car and have been found in publications as diverse as Consumer Reports and Parenting.

Because the attributes of both a leased car and financed car are the same, conditional models assume that the benefits from driving a vehicle over a given time of period are also the same. The financing decision can only be explained by differences in the costs households face. Nunnally and Plath (1989) explain consumer leasing by examining the opportunity cost of capital for various households, while Ford and Musser (1994) study how changes in the discount rate and marginal tax rate (among others) affect the leasing decision.

Other potential reasons for leasing could be similarly discussed and tested empirically. If one reason consumers lease is either to make a lower downpayment and/or a lower monthly payment, people facing liquidity

constraints should be more apt to lease. A model with liquidity constraints could examine the hypothesis that people lease to get into a better vehicle than they could otherwise afford. Similarly, consumers who are more risk averse should be more likely to lease if a primary reason has to do with transference of risk from consumers to dealers. Some insight into consumer leasing may also be found in literature regarding the lease/debt relationship (e.g. Branson, 1995, Smith and Wakeman, 1985). Companies with higher debt ratios have been found to be more likely to lease. If this relationship holds true for consumers, the likelihood of a consumer leasing should increase with debt. The conditional models (conditioned on the decision to acquire an asset) common in the corporate finance literature have drawbacks. The conditional aspect of the models precludes them from addressing the decision whether or not to purchase a given piece of capital equipment (or consumer durable in the case of automobiles). Because their purpose is to aid consumers in their financing decision, the models have no predictive value, limiting both their applicability and their usefulness. Nor can conditional models explain any of the other trends that have occurred in the automobile industry (like the increased demand for sports utility vehicles and minivans). Furthermore, in order to compare the present value of leasing to other means of financing, the researcher needs to assume the consumer either 1) sells their purchased vehicle at the end of the lease term, or 2) purchases the leased vehicle when the lease expires. It is also difficult for conditional models to deal with the transaction costs of disposing of vehicles in a reasonable manner.

II. AUTOMOBILE DEMAND

A more encompassing class of models is one in which households are allowed to simultaneously decide which vehicle to buy and how to pay for it. The leasing decision could be examined in this context by extending the extensive literature on automobile demand to accommodate the lease-purchase choice. Note that in conditional models it is impossible to analyze the question of which vehicle a consumer will decide to finance or purchase. Unconditional models subtly change the nature of the leasing question. The question becomes, "what characteristics of consumers and vehicles make it more likely that a consumer will decide to lease". Although there have been no empirical tests to date on the process by which consumers make their vehicle financing/leasing decisions, manufacture incentive programs like lease rebate programs (in which the manufacturer charges a price different than the manufacturer suggested retail price if a vehicle is leased) suggest that automobile companies believe that consumers' decisions are not conditional on financing/leasing choice.

Econometric estimation of automobile demand initially emphasized aggregate models describing the entire automobile market. Recent estimation, however, has seen a shift away from these early time-series, stock adjustment models (Chow, 1957) to models which emphasize analysis at the household level. At the disaggregate, or micro level, researchers are able to study the

underlying decision-making process of consumers as well as make extensive use of microeconomic theory to interpret their results. Furthermore, the consumer demand functions which are the core of these models are based on discrete consumer choices.

A. Holdings Models

Two classes of disaggregate, discrete choice models have been used to analyze a consumer's decision of which type of vehicle to buy (vehicle type choice models) and how many automobiles to own. One such class of models, holdings models, looks at how many and what type of vehicle(s) a consumer (usually assumed to be a household) will choose to own at any given point in time. Early examples include studies by Train and Lohrer (1982), and Mannering and Winston (1985). Holdings models assume that households, facing low transaction costs for vehicle replacement, periodically evaluate their automobile ownership decision, and choose the number and type of vehicles which give them the most satisfaction. The benefits a household derives from owning particular vehicles is a function of the attributes or characteristics of the vehicles. A typical example of an early type choice holdings model was that of Berkovec and Rust in 1985. Berkovec and Rust estimated the make and model one-automobile households were likely to own using vehicle characteristics (purchase price, operating cost, number of seats, horsepower to weight ratio, turning radius, age of vehicle) and characteristics of the

household (income, number of people in the household, age, rural vs. urban dummy variable) as explanatory variables. Good summaries of early discrete choice models can be found in Train (1986), Mannering and Train (1985) and Hensher et.al. (1992).

Early holdings models contained many drawbacks which have been corrected in the past fifteen years. Researchers realized that the type and number of vehicles households choose to own should depend upon how much the household expects to drive. Many early holdings models included vehicle miles traveled as an exogenous variable to explain the household's decision. Similar models examined the household's decision of how much to drive conditional upon owning a certain number and type of vehicles. The decision of how many and what type of vehicles to own is related to how much a household expects to drive and should be modeled simultaneously. Recent research has extended the discrete/continuous framework introduced by Dubin and McFadden (1984) to correct for the endogeneity of vehicle miles traveled in the vehicle selection decision. The household's vehicle quantity and type choice has been estimated either through the use of instrumental variables (e.g. Train & Lohrer, 1982) or two-stage estimation (e.g. Mannering & Winston, 1985).

Another advancement in holdings models came when researchers combined the decision of how many vehicles to own (quantity choice) with what types of vehicles to own. Combining quantity and type choice allowed researchers to ask more relevant policy questions than were previously

possible. As in most applications, data limitations frequently pose significant problems to a researcher estimating a holdings model. For example, because few households typically own more than two vehicles, only an extremely large data set will enable a researcher to get reasonable parameter estimates with households with three or more vehicles. To overcome this problem, researchers either have to 1) assume the parameter estimates for three vehicles are the same as the estimates for four or more vehicles, or 2) assume no households own more than a specified number of vehicles. Depending on the question being addressed, these assumptions can significantly bias empirical results.

B. Transaction Models

The second method of estimating automobile demand using disaggregate, discrete choice models is through the use of a transaction model. “Transaction models differ from holdings models in that they first assess the household's decision to enter the vehicle market and then consider the choice of a vehicle conditional on the decision to purchase a new vehicle” (Mannering & Train, 1985). Whereas a holding model might tell a researcher that a new policy would cause a family to increase its vehicle holdings from two to three vehicles, a transaction model would estimate the probability of the household purchasing a vehicle, thus increasing its vehicle holdings. Once the household decides to enter the vehicle market, the vehicle type choice of the household

can then be examined. For example, Mannering and Winston (1994) used a transaction model to estimate consumers marginal willingness to pay for air bags.

Many of the data problems present in holdings models can be avoided by reformulating the analysis as a transaction model. No longer are researchers required to make an assumption regarding the number of vehicles a household will own. The only assumption that transaction models require regarding the number of vehicles owned by a household is that it is greater or equal to zero. However, empirical estimation of transaction models is not without problems. Often an implicit assumption is made regarding the substitutability of new and used cars. As previously mentioned, transaction models first examine whether or not the consumer will enter the automobile market. Often the automobile market is defined as the market for new automobiles. Because new and used automobiles provide many of the same benefits to the consumer, they should be treated as substitutes. The Marshallian demand functions for new cars should be a function of the price of used cars and visa versa. In order to determine how many cars a household owns at any given point in time, a general equilibrium model of the automobile market is necessary. Berkovec (1985a, 1985b) introduced such a model by combining a model of vehicle scrappage (Parks, 1979) with an estimated demand model with a simple model of vehicle supply. One drawback of general equilibrium models is that they are computationally burdensome even by today's standards.

The optimal solution in choosing between a holdings model and a transaction model often depends upon what question the researcher is trying to address. If the goal of the estimation is to determine the number of vehicles owned by the household at any point in time, holdings models simplify the analysis (because general equilibrium estimation is not necessary), while intuitively leading to more precise estimates of the parameters. Analyzing any question in the new car market, however, often makes transaction models more appealing. Transaction models can incorporate the dynamic aspects of automobile demand more readily than holdings models, because holdings more are essentially a snapshot (static) of the dynamic process at any point in time.

C. Dynamic Considerations

The vehicle ownership decision is best thought of as a dynamic process. Changing market conditions (e.g. interest rates, demographics), household characteristics (e.g. expectations, preferences, socioeconomic characteristics), and vehicle attributes (e.g. introduction of a new model) lead a household to periodically update its vehicle holdings. When a household scraps, replaces, or purchases an additional vehicle it incurs both monetary and psychological costs which make frequent updatings of vehicle holdings impractical. “The challenge of modeling vehicle demand in this dynamic setting is to capture the true costs of not only entering the vehicle market but also of making decisions

regarding the replacement or purchasing of specific vehicles” (Mannering & Train, 1985).

Researchers have incorporated dynamic elements into models of vehicle quantity and type choice in a number of ways. Berkovec and Rust (1985) included a transaction cost indicator variable in their vehicle type choice transaction model and found it to be highly significant. This result suggests that households incur significant transaction costs when changing their vehicle holdings. Alternatively, Mannering and Winston (1985) incorporated the concept of brand loyalty in vehicle type choice models. Automobile companies have long known that consumers develop “loyalty” toward a particular make of car. For example, a household which has purchased a Ford Taurus in the past is much more likely to purchase one in the future. By owning and operating a particular make of vehicle (e.g. Ford), households acquire costly information and develop habits which affect future decisions relating to vehicle type choice. Commonly specified as the number of consecutive purchases of the same make, brand loyalty coefficients are frequently significant and are now firmly embedded in models of vehicle type and quantity choice.

The difficulties of incorporating consumer durable demand has limited research. Berkovec (1985a) noted that when transaction costs are minimal and there are no information discrepancies between agents, consumers act as if maximizing a single-period utility function. Ignoring durability in this situation still allows for unbiased parameter estimates. Transaction models

implicitly address the durability of automobiles by examining the household's decision to enter the new vehicle market. If the researcher correctly specifies and estimates the process by which a household enters the vehicle market, the fact that automobiles are a consumer durable is implicitly taken into account. Although estimation of such a transaction model can lead to unbiased parameter estimates, future research should attempt to make the durability explicit. More specifically, estimation of a transaction model will yield unbiased parameter estimates as long as the used car market has not changed fundamentally (e.g., the proportion and composition of new cars to used cars remains relatively stable, etc.).

III. MULTINOMIAL LOGIT

All disaggregate, discrete choice studies in the automobile demand literature use essentially the same random utility framework in which households are assumed to maximize their utility. More formal descriptions of discrete choice modeling can be found in both Train (1986) and Maddala (1993), while Train (1986) and Mannering and Train (1985) summarize the early applications of automobile demand. The following discussion of discrete choice models in general and automobile holdings models in particular relies heavily on Train (1986).

Denote the decisionmaker in a qualitative choice situation by n and the set of alternatives she faces by J_n . Define the utility from alternative i in J_n as

U_{in} . Note that the utility decisionmaker n receives from choice i is a function of the characteristics of the decisionmaker (r_n) and the characteristics of the alternative (x_{in}). The decisionmaker then chooses the alternative in J_n from which the largest utility is derived. In the context of holdings models, the household decides to own a certain number of vehicles and type of vehicles if and only if

$$U_{in} > U_{jn} \text{ for all } j \text{ in } J_n, j \neq i \text{ or} \quad (2.1)$$

$$U(x_{in}, r_n) > U(x_{jn}, r_n) \text{ for all } j \text{ in } J_n$$

If a researcher had perfect information on all (household and vehicle) characteristics which affected the household's decision as to how many and what type of vehicles to own, predictions of vehicle choices would be comparatively easy. Unfortunately, neither all relevant characteristics nor how much each household values each characteristic are known. To estimate the probability of the household choosing a particular vehicle alternative, it is necessary to decompose the utility of each alternative into factors which are known to the researcher and aspects of utility which are not known to the researcher. Formally,

$$U_{in} = U(x_{in}, r_n) = V(z_{in}, s_n, \beta) + \varepsilon_{in} \quad (2.2)$$

where z_{in} represents observed characteristics of alternative i to decisionmaker n . s_n represents observed characteristics of decisionmaker n . β is a vector of estimated parameters, and ε_{in} is the difference between true and observed utility.

Note that the choice of which alternative the decisionmaker will select is not deterministic from the standpoint of the researcher (although it might be from the standpoint of the decisionmaker). The best a researcher can hope to accomplish is to make an informed decision based upon the observed portion of utility. All discrete choice models are derived by specifying some distribution for the unobserved portion of utility. Different assumptions regarding the specification of ε_{in} lead to different functional forms of the choice probabilities. The two most common assumptions regarding ε_{in} are that ε_{in} is distributed normally, leading to probit choice probabilities, and ε_{in} has a generalized extreme value distribution, leading to logit probabilities. The assumption that the unobserved portion of indirect utility is distributed extreme value leads to the following logit choice probabilities.

$$P_{in} = \frac{e^{V_{in}}}{\sum_{j \in J_n} e^{V_{jn}}}, \text{ for all } i \text{ in } J_n. \quad (2.3)$$

where P_{in} represents the probability of decisionmaker n choosing alternative i , and V_{in} represents the characteristic component of indirect utility corresponding to alternative i . Indirect utility is used in discrete choice models

because prices and incomes are included as arguments in the utility specification.

IV. EXTENSIONS OF MULTINOMIAL LOGIT

The number of alternatives in any model of vehicle type choice is large. The 1996 model year alone contained 168 different vehicle types, each alternative consisting of numerous attributes (e.g., front shoulder room, horsepower, turning radius, operating cost, braking distance, air bag dummy variables). Estimation of probit probabilities is computationally intractable when the number of alternatives becomes large because probit probabilities are not closed form. For this reason, previous estimates of vehicle type choice have assumed the unobserved portion of utility has an extreme value distribution, leading to the closed form, multinomial logit choice probabilities. The distributional assumption regarding the unobserved portion of indirect utility (generalized extreme value) allows researchers to further ease the computational burden in type choice estimation. McFadden (1980) showed that consistent (though not efficient) parameter estimates may be obtained using a subsample of alternatives as the entire choice. This enables researchers to estimate a previously intractable problem containing potentially thousands of mutually exclusive alternatives.

The multinomial logit (MNL) model readily lends itself to estimation of both holdings and transaction models of vehicle type choice. MNL choice

probabilities have the desirable properties of 1) ranging from zero to one, 2) summing to one for all finite, mutually exclusive, and exhaustive alternatives, and 3) having an S-shaped function of representative utility. However, the choice probabilities have a well known and well documented undesirable property, that of the independence of irrelevant alternatives (IIA). "Stated succinctly, the IIA property holds that for a specific individual the ratio of the choice probabilities of any two alternatives is entirely unaffected by the systematic utilities of any other alternatives" (Ben-Akiva & Lerman, 1995, p.108). For example, the ratio of two MNL probabilities is as follows:

$$\begin{aligned}
 P_{in} &= \frac{e^{V_{in}}}{e^{V_{kn}} \frac{\sum_{j \in J} e^{V_{jn}}}{n}} & (2.4) \\
 &= \frac{e^{V_{in}}}{e^{V_{kn}}}
 \end{aligned}$$

Consider the independence of irrelevant alternatives in the vehicle type choice model. Suppose 2% of all consumers purchase a Mercedes E-Series and 2% purchase a Ford Escort. If BMW decided to raise its price on a luxury automobile, the IIA would predict that households shifting from BMW would be equally likely to purchase the Mercedes and the Ford. Although the IIA property might be valid in this context, researchers should at the very least

examine whether consumers would be more likely to purchase a Mercedes than a Ford. In other words, the ratio of the probabilities between Mercedes E-Series and Ford Escort might be affected by what alternatives are included.

The independence of irrelevant alternatives arises from the extreme value distribution of the unobserved portion of utility which assumes the errors are independent and identically distributed (IID). However, this IID assumption, which causes problems in model structure, also gives the MNL model its closed form solution and allows for the subsampling of alternatives discussed above.

In a significant generalization of multinomial logit, McFadden (1980) showed that models which do not exhibit the IIA structure can be reformulated in the form of logit models. One such generalization is if the unobserved portion of utility is distributed generalized extreme value. This assumption leads to the most commonly used generalization, the nested logit formulation. Nested logit models allow for the unobserved portion of utility to be correlated across groups (e.g. foreign/domestic, size or class of car, luxury/non-luxury vehicles) while still allowing for ease of estimation by assuming errors are independent and identically distributed within groups.

Nested Multinomial Logit models have the useful empirical property that consistent estimates can be obtained through sequential estimation. Parameter estimates of the lower nests are consistent (due to their IIA property), enabling the construction of a systematic component of random utility commonly called the inclusive value. McFadden has shown that the use

of this inclusive value term in subsequent estimations in the upper nests yields consistent parameter estimates.⁸ More formally, the conditional nested logit probabilities shown in Equation 2.5 (conditioned on the household choosing a

$$P_{in:n} = \frac{e^{V_{in:n}}}{\sum_{j \in J_n} e^{V_{jn:n}}} \quad (2.5)$$

particular form of financing) are estimated in the first stage.

Where $V_{in:n}$ represents the indirect utility of selecting vehicle i conditional on a method of financing (lease/finance/cash). Estimation of Equation 2.5 allows construction of the inclusive value term, representing the expected maximum utility obtained from a vehicle choice in the lower nest.⁹ The probability of selecting a particular method of financing can now be estimated using the probabilities shown in Equation 2.6.

$$P_n = \frac{e^{V_n + \lambda L_n}}{\sum_{j \in J_n} e^{V_j + \lambda L_n}} \quad (2.6)$$

Where λ is a parameter and L_n is the inclusive value term calculated from Equation (2.5). To be consistent with utility maximization, coefficients on the parameter estimates of the inclusive value term must lie between zero

⁸ Sequential estimation does not lead to efficient estimates. Empirical estimates (e.g. Hensher et al., 1990) suggest a 10% - 20% loss on efficiency using sequential as opposed to Full Information Maximum Likelihood (FIML) methods.

⁹ The inclusive value term is defined as the log of the denominator of the choice probabilities in the lower nest of the sequential estimation.

and one. As parameter estimates of the inclusive term approach zero, the nested multinomial logit model disintegrates into the multinomial logit model while a parameter estimate on the inclusive value term approaches one the model becomes deterministic from the standpoint of the researcher.

The straightforward interpretation of results and the tractability of estimation even with a large number of alternatives in the choice set, has led researchers to focus on sequential estimation in nested multinomial logit models. Applications of the nested logit model will be discussed later in this dissertation, while a thorough discussion can be found in Ben-Akiva and Lerman (1985).

Chapter 3. Model Structure and Estimation

I. THE DATA

Chapter 2 noted the correct model formulation of the consumer leasing/financing decision depended critically upon empirical estimates. A brief discussion of the data upon which the estimates are based is now in order.

The model was estimated on a sample of 654 households which purchased 714 new cars or light trucks from the 1993 - 1995 model years. The survey was administered by National Family Opinion, Inc., in September of 1995. Households were sampled nationwide and the following information was obtained from each household:

1. Socioeconomic data, including annual household income, age of household members, location of main residence (e.g. urban, rural) by zip code, population size of residential location, education level of each household member, and detailed financial information on the household.
2. A detailed inventory of all vehicles the household currently or previously owned, including the make, model, and model year of all vehicles.
3. Information on the recent vehicle acquisitions, including how much the household expected to drive the vehicle, expected automobile insurance, and how the household decided to pay for their recent vehicle purchase. The

method of acquisition was not known on only 14 of the 714 vehicles. Of the remaining 700 vehicles in the sample, 361 were financed (51.57%), 142 were leased (20.29%), and 197 had another form of financing (hereon referred to as cash) (28.14%). The 20.29% lease share is relatively close to the actual lease share (28.3%) over the same time period. Moreover, the rate of leasing in the sample mirrored the actual rate of change previously shown in Figure 3.

Before model estimation could begin, it was necessary to augment the household sample with data on the characteristics of cars and light trucks for the 1993 -1995 model years. Vehicle attribute information was obtained for the 511 different makes, models, and model years available for purchase during the sample period. Information on turning radius, weight, horsepower, front shoulder room, repair record, and whether the vehicle had a standard passenger side air bag were obtained from *Consumer Reports*. The manufacturer's suggested retail price (MSRP) was obtained from the *National Automobile Dealer's Association (NADA) Used Car Guide*. Fuel efficiency and vehicle class specifications were obtained from the *EPA Gas Mileage Guide for New Car Buyers*. Finally, the expected residual value of a vehicle after three years of use (as a percentage of its initial value) was obtained from *Edmund's Used Car Guide*. The construction of other vehicle and household characteristics was also necessary. Other vehicle characteristics were constructed to either correct for endogeneity (e.g. annual fuel cost, automobile insurance) or allow for dynamic models of vehicle choice (e.g. brand loyalty, lease loyalty, and brand preference variables)

II. MODEL STRUCTURE

After augmenting the make, model, and vehicle year information with their corresponding vehicle attributes, it became possible to represent the indirect utility a household attains from the purchase of a particular vehicle as a function of household characteristics, vehicle characteristics, and a component unknown to the researcher as discussed in Chapter 2. Only the choice of the distribution of the unobserved component of indirect utility and the decision to use a holdings or transaction model remained before the cash/financing/leasing decision could be examined. The previous chapter notes the optimal choice between holdings and transaction models is dependent upon the question the researcher is analyzing. Because the primary goal of this analysis is to examine the increase of consumer leasing in the new car market, a transaction model was chosen. This will also allow more precise parameter estimates in the new car market while allowing for treatment of dynamic considerations. Finally, the errors were assumed to have a generalized extreme value structure, leading to a nested multinomial logit model. Figure 4 shows two alternate model structures.

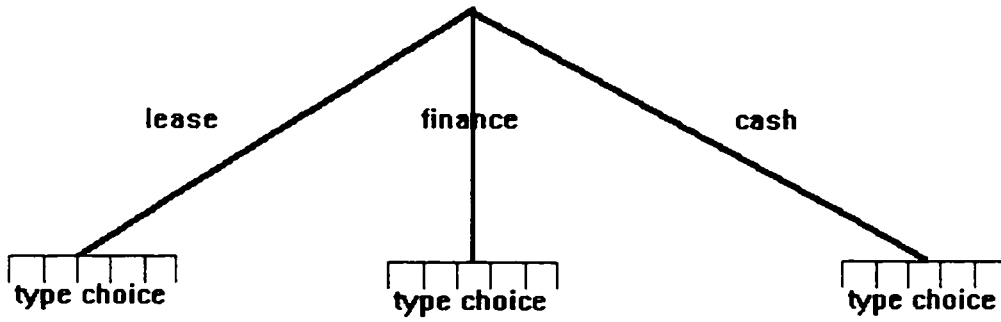
Model 1 in this figure illustrates the nested logit formulation. Households simultaneously choose the vehicle and method of financing which gives them the most utility, conditional on their decision to purchase a new vehicle. The unobserved portion of utility is assumed to be independent and

identically distributed within groups, but allowed to vary across groups. If the errors are independent and identically distributed (IID) across groups then the model reduces to Model 2 in Figure 4, the multinomial logit model. It is possible to test the validity of the nested logit structure. If the multinomial logit model is correct (Model 2 in Figure 4), parameter estimates of the three subgroups (Cash/Finance/Lease) in Model 1 should be equivalent. A likelihood ratio test can be used to test the null hypothesis $H_0: \beta_{\text{Lease Subsample}} = \beta_{\text{Finance Subsample}} = \beta_{\text{Cash Subsample}}$.

Appendix A shows the parameter estimates using a multinomial logit model to estimate the indirect utility function of the 700 households in the sample. The same specification was then used to obtain parameter estimates for the three subsamples represented by the nested multinomial logit model. Empirical analysis reveals that the null hypothesis of equivalent parameter estimates is rejected even at levels of significance exceeding 99.999%. The χ^2 (58 d.o.f.) test statistic of 155.4 far exceeds the critical value of 76.77791 at a 95% level of significance. The multinomial logit model is rejected in favor of the nested logit model. This is a critical contribution to the existing literature, suggesting that previous estimates of automobile demand yielded biased and inconsistent estimates by inaccurately constraining coefficients to be the same.¹⁰

¹⁰ Other specification tests were also performed on the final model structure, including empirical tests of stability of the parameter estimates across model years and testing for violations of the independence of irrelevant alternatives assumption.

Model 1: Nested Multinomial Logit Model



Model 2: Multinomial Logit Model

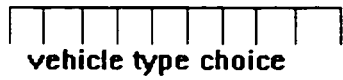


Figure 4. Alternate Model Structures

Similarly, research which tries to explain consumer leasing through conditional models (conditioned on the cash/finance/lease decision) yields inaccurate results. A complete analysis of leasing requires the simultaneous consideration of vehicle choice and cash/finance/lease choice.

The model specification used in this study is illustrated in Figure 5. This is a slight variation of the nested multinomial logit model previously discussed. Like the straightforward MNL model, errors are assumed to be IID within the lease, finance, and cash submodels. This specification was chosen due to the possible presence of shared unobserved effects among the non-cash options (lease and finance).

III. RESULTS

Sequential estimation of nested multinomial logit models begins by first estimating each of the bottom nests using the subsample of observations that chose that nest (i.e. cash, finance, or lease) and treating the subsample as if it were the entire choice set. For example, all of the consumers who leased were grouped and a multinomial logit model was estimated on the subset to determine parameter estimates for the household and vehicle characteristics which make up the indirect utility function. The dependent variable is a dummy variable which equals one if the household chose a given vehicle from the choice set, 0 otherwise. Right hand side (RHS) variables vary across

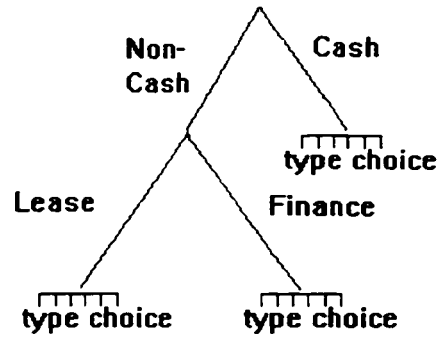


Figure 5. Nested Logit Model Structure

vehicle choices and may be interacted with household characteristics to more accurately describe a households' indirect utility function. The complete list of explanatory variables and the accompanying summary statistics for each of the submodels (households who leased, financed, and paid cash) are shown in Tables 2 to 4.

Before directly addressing the lease/cash/finance decision of the household, it is worthwhile to discuss results of the three submodels. Results from the lease submodel will be summarized and interpreted in detail, followed by a brief discussion of how the finance and cash models differ. To facilitate understanding, explanatory variables of the submodels are separated into the following groups: 1) general vehicle characteristics, 2) vehicle cost variables, and 3) brand preference and brand loyalty variables.

A. Lease Submodel

1. General Vehicle Characteristics

Any vehicle attribute which affects the comfort, safety, performance, or reliability of a vehicle should influence the utility a household receives from its use. Although many general vehicle characteristics were examined to see if

TABLE 2.

**Multinomial Logit Coefficient Estimates for 1993, 1994, and 1995:
New-Vehicle Choice - Lease Submodel**

Variable	Coefficient (Standard Errors)
<u>Vehicle Attributes:</u>	
Passenger side airbag dummy (= 1 if passenger side airbag standard on vehicle model, 0 otherwise)	1.045 (.356)
Turning radius (in feet)	.152 (.0591)
Natural log of vehicle price divided by the natural log of household income (in thousands of dollars)	-9.536 (2.484)
Annual fuel cost (in dollars)	-.00182 (.00137)
Vehicle Horsepower (defined for households with income > \$25,000)	.00746 (.00385)
<i>Consumer Report's</i> repair index ^a	.317 (.133)
Vehicle residual value if domestic (defined as the percentage of the manufacturer suggested retail price the vehicle will retain during its first three years of use)	.0917 (.0261)
Vehicle residual value if non-domestic (defined as the percentage of the manufacturer suggested retail price the vehicle will retain during its first three years of use)	.0652 (.0265)
Subcompact class dummy if domestic ^b (=1 if vehicle is a subcompact and domestic, 0 otherwise)	.835 (.678)
Subcompact class dummy if non-domestic ^b (=1 if vehicle is a subcompact and non-domestic, 0 otherwise)	-2.208 (1.236)
Compact class dummy ^b (=1 if compact vehicle, 0 otherwise)	1.845 (.573)
Mid-size vehicle dummy ^b (=1 if mid-size vehicle, 0 otherwise)	2.188 (.58)
Large vehicle dummy ^b (= 1 if large vehicle, 0 otherwise)	1.342 (.654)
Minivan dummy if domestic ^b (=1 if vehicle is defined as a domestic minivan and the household has 3 or more members, 0 otherwise)	1.496 (.635)

TABLE 2. (continued)

Sports Utility Vehicle dummy if domestic ^b (= 1 if vehicle is a domestic SUV and the household has 3 or more members, 0 otherwise)	2.71 (.735)
Sports Utility Vehicle dummy if non-domestic ^b (= 1 if vehicle is a domestic SUV and the household has 3 or more members, 0 otherwise)	2.215 (.768)
<u>Brand Loyalty and Preference:</u>	
Ford manufacturer dummy (= 1 if Ford make, 0 otherwise)	-.827 (.807)
GM manufacturer dummy (= 1 if produced by GM, 0 otherwise)	-1.673 (.826)
Chrysler manufacturer dummy (= 1 if produced by Chrysler, 0 otherwise)	-2.605 (.864)
Japanese manufacturer dummy (= 1 if produced by Japanese manufacturer, 0 otherwise)	-.137 (.384)
Number of previous consecutive GM purchases	1.659 (.449)
Number of previous consecutive Ford purchases	1.649 (.546)
Number of previous consecutive Chrysler purchases	1.041 (.6)
Number of previous consecutive Japanese manufacturer purchases	1.123 (.403)
Number of previous consecutive purchases for vehicles produced by non-Japanese or American manufacturers	4.656 (1.307)
Number of previous consecutive leases of the same make of vehicle	.668 (.394)
<u>Summary statistics</u>	
Number of Observations	142
Estimation by maximum likelihood:	
Log likelihood at zero	-340.5
Log likelihood at convergence	-203.43

^a Consumer report's repair index is a measure of reliability that uses integer values from 1 to 5. A value of 1 indicates the vehicle has a "much below average" repair record, 3 is "average", while 5 represents a "much better than average" reliability.

^b Vehicle class sizes (e.g. subcompact, compact) are defined by the EPA.

TABLE 3.

**Multinomial Logit Coefficient Estimates for 1993, 1994, and 1995:
New-Vehicle Choice - Finance Submodel**

Variable	Coefficient (Standard Errors)
Age of consumer (defined for domestic cars)	.0164 (.0108)
Population dummy (1 if Honda, Nissan, or Toyota and population size \geq 500,000)	.598 (.312)
<u>Vehicle attributes:</u>	
Passenger side airbag dummy (= 1 if passenger side airbag standard on vehicle model, 0 otherwise).	.573 (.183)
Turning radius if domestic auto, 0 otherwise (in feet)	.248 (.0395)
Turning radius if non-domestic auto, 0 otherwise (in feet)	.107 (.0433)
Natural log of vehicle price divided by natural log of household income (in thousands of dollars)	-9.468 (1.67)
Annual fuel cost (in dollars)	-.00105 (.000771)
<i>Consumer Report's</i> repair index ^a	.342 (.0734)
Expected automobile insurance (in dollars)	-.0104 (.00518)
Vehicle residual value if domestic (defined as the percentage of the manufacturer suggested retail price the vehicle will retain during its first three years of use)	.041 (.0156)
Vehicle residual value if non-domestic (defined as the percentage of the manufacturer suggested retail price the vehicle will retain during its first three years of use)	.0964 (.0172)
Subcompact class dummy if non-domestic ^b (=1 if vehicle is a subcompact and domestic, 0 otherwise)	.916 (.334)
Compact class dummy ^b (=1 if compact vehicle, 0 otherwise)	1.316 (.24)
Mid-size vehicle dummy ^b (=1 if mid-size vehicle, 0 otherwise)	1.58 (.278)
Large vehicle dummy ^b (= 1 if large vehicle, 0 otherwise)	.71 (.341)

TABLE 3. (continued)

Minivan dummy if domestic ^b (= 1 if vehicle is defined as a domestic minivan and the household has 3 or more members, 0 otherwise)	1.74 (.346)
Sports Utility Vehicle dummy if domestic ^b (= 1 if vehicle is a domestic SUV and the household has 3 or more members, 0 otherwise)	1.385 (.468)
Sports Utility Vehicle dummy if non-domestic ^b (= 1 if vehicle is a domestic SUV and the household has 3 or more members, 0 otherwise)	.758 (.491)
<u>Brand Loyalty and Preference:</u>	
Ford manufacturer dummy (= 1 if Ford make, 0 otherwise)	-3.549 (.76)
GM manufacturer dummy (= 1 if produced by GM, 0 otherwise)	-4.11 (.786)
Chrysler manufacturer dummy (= 1 if produced by Chrysler, 0 otherwise)	-3.935 (.763)
Japanese manufacturer dummy (= 1 if produced by Japanese manufacturer, 0 otherwise)	-1.359 (.273)
Number of previous consecutive GM purchases	.98 (.188)
Number of previous consecutive Ford purchases	1.617 (.332)
Number of previous consecutive Chrysler purchases	.645 (.388)
Number of previous consecutive Japanese manufacturer purchases	1.202 (.378)
Number of previous consecutive purchases for vehicles produced by non-Japanese or American manufacturers	.644 (.392)
Number of previous consecutive leases of the same make of vehicle	-1.123 (.509)
<u>Summary statistics</u>	
Number of Observations	361
Estimation by maximum likelihood:	
Log likelihood at zero	-865.64
Log likelihood at convergence	-569.48

^a Consumer report's repair index is a measure of reliability that uses integer values from 1 to 5. A value of 1 indicates the vehicle has a "much below average" repair record, 3 is "average", while 5 represents a "much better than average" reliability.

^b Vehicle class sizes (e.g. subcompact, compact) are defined by the EPA.

TABLE 4.

**Multinomial Logit Coefficient Estimates for 1993, 1994, and 1995:
New-Vehicle Choice - Cash Submodel**

Variable	Coefficient (Standard Errors)
Population dummy (1 if Honda, Nissan, or Toyota and population size \geq 500,000)	1.659 (.463)
<u>Vehicle attributes:</u>	
Passenger side airbag dummy (= 1 if passenger side airbag standard on vehicle model, 0 otherwise).	.524 (.262)
Turning radius if domestic auto, 0 otherwise (in feet)	.278 (.037)
Natural log of vehicle price divided by household income (in thousands of dollars)	-8.036 (2.292)
Annual fuel cost (in dollars)	-.00153 (.00104)
Vehicle Horsepower (defined for households with income $>$ \$25,000)	.00344 (.00348)
Expected automobile insurance (in dollars)	-.00518 (.00588)
Vehicle residual value if non-domestic (defined as the percentage of the Manufacturer suggested retail price the vehicle will retain during its first three years of use)	.116 (.0221)
Subcompact class dummy ^a (= 1 if vehicle is a subcompact and domestic, 0 otherwise)	.142 (.441)
Compact class dummy ^a (= 1 if compact vehicle, 0 otherwise)	1.129 (.405)
Mid-size vehicle dummy ^a (= 1 if mid-size vehicle, 0 otherwise)	1.746 (.373)
Large vehicle dummy ^a (= 1 if large vehicle, 0 otherwise)	1.546 (.416)
Minivan dummy if domestic ^a (= 1 if vehicle is defined as a domestic minivan and the household has 3 or more members, 0 otherwise)	1.563 (.624)
Sports Utility Vehicle dummy ^a (= 1 if vehicle is a domestic SUV and the household has 3 or more members, 0 otherwise)	.531 (.463)
<u>Brand Loyalty and Preference:</u>	
Ford manufacturer dummy (= 1 if Ford make, 0 otherwise)	-4.567 (1.162)

TABLE 4. (continued)

GM manufacturer dummy (= 1 if produced by GM. 0 otherwise)	-5.387 (1.215)
Chrysler manufacturer dummy (= 1 if produced by Chrysler. 0 otherwise)	-6.124 (1.224)
Japanese manufacturer dummy (= 1 if produced by Japanese manufacturer. 0 otherwise)	-.882 (.425)
Number of previous consecutive GM purchases	.735 (.225)
Number of previous consecutive Ford purchases	1.212 (.371)
Number of previous consecutive Chrysler purchases	2.877 (.628)
Number of previous consecutive Japanese manufacturer purchases	1.095 (.451)
Number of previous consecutive purchases for vehicles produced by non-Japanese or American manufacturers	1.726 (.916)
<u>Summary statistics</u>	
Number of Observations	197
Estimation by maximum likelihood:	
Log likelihood at zero	-472.39
Log likelihood at convergence	-316.6

^a Vehicle class sizes (e.g. subcompact, compact) are defined by the EPA.

they affected vehicle choice, only four were significant and included in the final specification of the lease submodel. The most reliable measure of performance was found to be the horsepower of a vehicle, defined for households with incomes greater than \$25,000 (illustrating that consumers with higher incomes value horsepower more). The positive and significant result (at the 90% level of significance) illustrates that *ceteris paribus*, increasing the horsepower of a vehicle makes it more attractive to consumers. Within any class of vehicle (e.g. small car, midsize), turning radius is highly correlated both with variables which capture interior and exterior comfort (e.g. front and rear shoulder room, luggage space), as well as safety (e.g. weight). The positive and significant effect on the turning radius parameter reflects how much household's who decided to lease value additional comfort and safety associated with vehicles with larger turning radii.

Following Mannering and Winston (1995) in *Automobile Air Bags in the 1990's: Market failure or Market Efficiency*, a second safety variable was included in the indirect utility function. A dummy variable was created which equaled one if a passenger side airbag was standard in a given model, 0 otherwise. Parameter estimates were again found to be positive and highly significant, showing that consumers value the increased safety an airbag provides. Passenger side airbags were found to be a much better indicator than a standard driver side airbag, most likely due to lack of variation among vehicle alternatives caused by automobile industry standards which required driver side air bags by the 1996 model year. For example, over 80% of 1995

model year vehicles had a standard driver side airbag, making it a poor measure of vehicle choice.

The final category of vehicle characteristics is reliability. A measure of reliability was obtained from Consumer Reports, which generates a repair index on automobiles consisting of integer values from 1 (well below average) to 5 (well above average). As in all of the submodels, the parameter estimate on this of reliability was found to be positive and highly significant, indicating a strong preference for reliable automobiles.

2. Vehicle Cost Variables

The initial and ongoing costs of owning and operating an automobile should affect the purchase decision of a household. A variable capturing initial capital costs was created by dividing the log of vehicle price by the log of household income, illustrating that as income increases, price becomes less important and prices are more relevant at lower price levels. This variable was negative, highly significant, and found to significantly influence the household's indirect utility function.

Ongoing operating costs such as insurance costs, maintenance costs, and accident repair costs which are presumed to influence the vehicle choice decision are often impossible to measure due to the unavailability of data. Two different operating cost variables were examined in all three submodels; annual fuel costs and the expected cost of insurance. In both cases, these

variables were instrumented for logit-model estimation because they depend on vehicle usage which has been shown to be endogenous with vehicle choice (Mannering and Winston, 1985). In the lease submodel, annual fuel costs had a negative impact on vehicle choice (as expected) while expected insurance costs were found not to have a significant impact on type choice.

Vehicle depreciation is another important concern in the vehicle choice decision. If households consider the possibility of disposing of a vehicle before its useful life has expired (as is likely the case), the selling price of the vehicle when sold is an important consideration. Edmund's Used Car Guide was used to create a variable representing a vehicle's residual value (defined as the expected percentage of the Manufacturer's Suggested Retail Price the vehicle will retain during its first three years of use). Defined for both domestic and foreign autos, a positive and significant coefficient shows that residual value is an important component of consumer behavior which has been previously omitted in models of automobile demand.

3. Brand Loyalty and Preference

As in recent automobile demand analysis (e.g. Mannering and Winston, 1995), a distinction is made between brand loyalty and brand preference. Brand preference captures the tendency of households to purchase a given brand of vehicle everything else being equal. Brand preference was captured in the estimation by creating dummy variables for vehicles produced by

General Motors, Ford Motor Company, Chrysler Corporation, and Japanese manufacturers. Separate from brand preference is brand loyalty, a variable which captures a consumer's accumulated knowledge about a particular brand of vehicle. Ownership of an auto allows a household to acquire valuable information regarding its reliability, comfort, and safety. A positive parameter estimate on the brand loyalty variables indicates that this information makes households more likely to buy the same make of vehicle as that previously owned. Though the purpose of this paper is not to foresee future problems of the automobile industry, the Chrysler Corporation in particular should be concerned about the low parameter estimates of its brand loyalty and brand preference variables. Not only do people prefer other brands to Chrysler (as indicated by brand preference estimates), consumers who currently own a vehicle produced by the Chrysler corporation are less likely to make repeat purchases. To recapture or retain current market share Chrysler will most likely have to lower vehicle prices and/or improve their previously lower than average repair record (which is the likely reason for the lower loyalty and preference variables in the first place).

As previously noted, past estimates of automobile demand have shown a tendency for households to make repeat purchases of a vehicle make. This study expands the concept of brand loyalty and examines whether or not brand loyalty is independent of how the household financed the vehicle. A lease loyalty variable was defined as the number of consecutive leases of the same make. The positive coefficient on this variable (in the lease submodel)

indicates that a consumer who has previously leased a particular brand (e.g. Ford) is more likely to lease that same brand again if they decide to lease. The lease loyalty coefficient is positive in the lease submodel even with the inclusion of the regular brand loyalty variable (defined as the number of consecutive acquisitions of the same make), again showing the importance of unconditional vehicle type choice models.

Even a thorough nested multinomial logit estimation with general vehicle characteristics, vehicle costs, and brand preference and loyalty variables is unlikely to capture all of the relevant characteristics consumers consider when making their new vehicle purchase decision. Trandel (1991), shows that studies that do not consider quality in addition to physical characteristics may produce significantly downwardly biased elasticity estimates.¹¹ In addition to testing many variables which were found not to be significant (e.g. luxury dummy variable, turning radius, antilock brakes), vehicle class dummy variables were constructed to capture residual consumer behavior not captured by vehicle attributes previously mentioned. The resulting parameter estimates indicate a strong preference during the sample period (1993-1995) for Sports Utility Vehicles, a preference supporting the stylized facts of the period discussed in Chapter 1.

¹¹ A luxury dummy variable was created in an attempt to capture this effect. The variable equaled one if the vehicle was considered a luxury automobile by Consumer Reports, 0 otherwise. The parameter estimate was found to be insignificant.

B. Finance and Cash Submodels

A few notable differences exist between the finance, cash, and lease submodels, again illustrating the necessity of a joint modeling approach. Of lesser significance is the inclusion of additional socioeconomic variables in the finance and cash submodels. Older consumers who financed were found to have a preference for cars from domestic manufacturers. In addition, households living in metropolitan areas with populations greater than 500,000 people were more likely to purchase Japanese vehicles (in both the finance and cash submodels) than consumers who lived in areas with smaller populations. Of greater significance is that households were less likely to obtain a vehicle which they expected to have high automobile insurance costs (recall this variable was instrumented to avoid endogeneity). The significant estimate in the finance submodel illustrates that future research should account for the effects this ongoing cost has on automobile demand.

The final dissimilarity between the finance and lease submodels is of great importance to the automobile industry. The parameter estimate of lease loyalty was found to be negative and highly significant. The number of consecutive leases of the same make was shown to negatively impact the probability that consumers would make a purchase, given that they finance their vehicle. This significant result illustrates one of the reasons consumers lease; it allows them to avoid otherwise binding credit constraints and drive a

higher quality car. For example, a household leasing an Infiniti might not be able to afford the same car if it had to pay cash or finance the vehicle.

The fact that lease prices set by the manufacturer have a different effect on future demand (through brand loyalty) than cash/finance prices suggests that manufacturers face different pricing incentives depending on a household's choice of financing.¹² The negative lease loyalty coefficient suggests that a policy of charging low lease prices in order to capture market share and increase future cash/finance prices would be misguided. This suggests that manufacturers have some long-term incentives to limit the growth of leasing.

IV. WHY DO CONSUMERS LEASE?

The unconditional structure of the nested multinomial logit models allows for the analysis of more than vehicle type choice parameters. Real insight as to why consumers lease automobiles can be found by examining a household's decision whether to lease or alternatively to finance an automobile. Parameter estimates from the binary logit estimation (Table 5)¹³ show that a household's propensity to lease increases with its income.

¹² The pricing decision of manufacturers is addressed in Chapter 4.

¹³ Results of the Binary Logit Cash/Not Cash estimation (upper nest) indicate that consumers who own their homes, males, and households with high education levels are more likely to pay cash for vehicles. Alternatively, the probability of paying cash for a vehicle decreases with the miles a household expects to drive and with increasing debt levels. The inclusive value term is between zero and one as required for utility maximization.

education, and debt levels.¹⁴ This supports the hypotheses that leasing both reduces the transaction costs of vehicle disposal and replacement and allows a household to avoid binding credit constraints. The positive and significant coefficient on yearly household income indicates that households lease in order to avoid binding credit constraints and drive a higher quality car than they otherwise would have chosen. As incomes increase, households choose to acquire a more expensive vehicle through leasing rather than make larger finance payments on a less expensive model. Similarly, an indebted household could choose to purchase a less expensive vehicle. Rather than do this, the positive debt coefficient suggests that many households choose to lease.¹⁵

The belief that driving a "newer" car is a normal good is also supported by the results of the binary logit estimation. As incomes increase, a household desires to keep its new vehicle purchases for a shorter period of time. By reducing the transaction costs of vehicle disposal and replacement, leasing should increase in popularity with household incomes, a result supported by the positive income coefficient.¹⁶ The increased popularity of leasing in the 1990's could partially be explained by the increasing household incomes

¹⁴ Debt levels were obtained from household information on socioeconomic characteristics, monthly credit card payments, homeowners and medical insurance, alimony and child support payments, mortgage payments, and utilities. Age and sex were found not to have a significant impact on the probability of leasing.

¹⁵ An alternative explanation of the positive debt coefficient is that debt is positively correlated to wealth. If the debt variable is capturing household wealth instead of allowing the household to avoid binding credit constraints, the positive debt coefficient should be interpreted in a manner similar to the positive income coefficient.

¹⁶ The positive residual value coefficient in model two also indicates that significant transaction costs of vehicle disposal and replacement exist. If transaction costs were minimal and perfect capital markets existed, the residual value coefficients would be zero.

during this time period. Note that the positive income coefficient does not support the hypothesis that households lease in order to enter the new vehicle market. If leasing was primarily used to enable households to purchase a new vehicle, an increase in household income should decrease the likelihood of leasing, a result contradicted by the analysis.

Ongoing costs were also found to influence a household's leasing decision. A standard consumer lease contains a per mile surcharge if the number of miles driven exceeds a certain level (usually 12,000 miles/year). Predictably, the number of miles per year a household expected to drive in excess of 12,000 miles/year had a negative impact on the probability of leasing. Households that had previously leased were also found to be much more likely to lease in the future, as they are more likely to have characteristics which enable them to avoid costs of excess wear and tear at the end of the lease.

Two more interpretations can be drawn from the binary logit estimation of Table 5. The first is that the coefficients on the inclusive value terms from the lower nests lie between 0 and 1 which is needed for the model to be consistent with utility maximization. Preclusion of these inclusive value terms would lead to biased and inconsistent results, as would estimating a model which did not jointly consider a household's vehicle type choice and cash/lease/finance decision. The final interpretation from Table 5 is that everything else being equal, leasing became less onerous (or more attractive)

TABLE 5.

**Binary Logit Coefficient Estimates for Determining
the Probability of Leasing/Financing**

Variable	Coefficient (Standard Errors)
1993 model year dummy (=1 if lease-finance choice was made on a 1993 vehicle. 0 otherwise. defined for leasing alternative)	-3.375 (.772)
1994 model year dummy (=1 if lease-finance choice was made on a 1994 vehicle. 0 otherwise. defined for leasing alternative)	-2.41 (.746)
1995 model year dummy (=1 if lease-finance choice was made on a 1995 vehicle. 0 otherwise. defined for leasing alternative)	-2.248 (.741)
Inclusive value term from vehicle type/finance submodel (defined for financing alternative)	.181 (.104)
Inclusive value term from vehicle type/lease submodel (defined for financing alternative)	.15 (.0957)
Household Income (defined for leasing alternative)	.0118 (.00435)
Yearly household debt (in dollars. defined for leasing alternative)	.0000883 (.0000091)
Dummy variable if household has previously leased a vehicle (defined for leasing alternative)	2.08 (.365)
Education dummy (1 if respondent graduated from college. 0 otherwise. defined for leasing alternative)	.769 (.312)
Miles the household expected to drive over 12,000 ^a (0 if under 12,000. defined for leasing alternative)	-.0000655 (.0000262)
<u>Summary Statistics</u>	
Number of observations	503
Estimation by maximum likelihood	
Log likelihood at zero	-348.65
Log likelihood at convergence	-212.18

^a To avoid endogeneity, socioeconomic characteristics were used to instrument for the number of miles over 12,000 households expected to drive their vehicle.

over the sample period (1993 - 1995).¹⁷ One explanation for the increased popularity in consumer leasing is that economies of scale exist in the leasing industry.¹⁸

To some extent, the increased popularity of consumer leasing in the past decade (see Figure 3) may also be explained by a change in the structure of many lease contracts. Many lease contracts in the mid-1980's were "open-ended". An open-ended lease is one in which the residual value of the vehicle is determined when the vehicle is sold at the end of the lease contract. If the selling price is less than the expected residual value, the consumer is obligated to pay the difference. Overstating a vehicle's residual value creates the illusion of a low present value of payments. The low downpayment and low monthly payments made possible by the high residual value must be supplemented by a final installment at the end of the lease contract. This final unexpected payment is often cited by dealerships as why leasing was unpopular in the early 1980's.

Current consumer lease contracts are almost exclusively "closed-ended" (i.e., a contract in which the residual value is determined at the initial sale). Closed-ended lease contracts increase the attractiveness of automobile leasing by allowing a risk averse household to transfer risk to automobile dealerships. A household clearly prefers a closed-ended lease if a vehicle sells below its *ex-ante* expected value. Results of the binary logit estimation of

¹⁷ A likelihood ratio test rejected the null hypothesis that the model year coefficients were the same over the sample period.

¹⁸ Other suggested reasons include the increasing consumer familiarity and comfort with automobile leasing and supply side effects such as promotion by manufacturer.

whether or not to pay cash for a vehicle (Table 6) also highlight the need for unconditional demand models. Men, homeowners, and households with less debt and more education were found to be much more likely to pay for a vehicle outright. The negative and significant impact the number of expected miles driven over 12,000 (per year) shows the net benefits a household receives from a vehicle is dependent on the lease/finance/cash decision.¹⁹

Additional insight as to why a household chooses to lease a particular vehicle may be obtained by comparing parameter estimates across the lease, finance, and cash submodels.²⁰ Such a comparison can be made only after accounting for the impact of related exogenous variables on indirect utility.²¹ One such method is through the use of conditional elasticity estimates as illustrated in Table 7.^{22,23}

¹⁹ Leases typically have surcharges for excess mileage as this decreases a vehicle's resale value and residual value.

²⁰ Parameter estimates can be compared within submodels but not across models. Although a larger coefficient does mean that a change in an attribute will effect indirect utility more, other variables which vary across submodels also effect indirect utility. For example, even though the price coefficient of -9.536 in the lease submodel is greater in absolute value than the coefficient of -8.036 in the cash submodel, you cannot conclude from this fact alone that consumers who purchase their cars using cash are less responsive to a change in price than those who lease.

²¹ An alternative method is to use likelihood a ratio test to test the a-priori expectation that the parameter estimates differ across submodels. Disadvantages of this approach include: 1) the results are not as readily interpretable as the conditional submodels shown in Figures 1-3, and 2) the inability to estimate and interpret the upper nests of nested multinomial logit models is limited because the inclusive value term becomes ambiguous. For these reasons, this approach was used to give empirical credence to the formulation of the model, but not used in the final interpretation.

²² In discrete choice models, elasticity is defined as how the probability of purchasing a vehicle changes when an attribute changes, or $\partial P_{in} / \partial Y_{in} * Y_{in} / P_{in}$ where P_{in} represents the Probability that decisionmaker n chooses alternative i and Y_{in} represents an attribute of alternative i.

²³ Comparing marginal rates of substitution (MRS) is also common in vehicle type choice models. The problem of comparing MRS is that, unlike elasticity, the marginal rate of substitution is dependent upon model specification. Specifically, the specification of how vehicle price enters the indirect utility function (e.g. $\log(\text{price})/\log(\text{income})$ vs. $\log(\text{price})/\text{income}$) changes MRS results.

A general interpretation of the elasticity estimates is that the impact that a vehicle attribute has on the probability of purchase differs depending on how the vehicle is purchased. For example, households that choose to lease are more responsive to the addition of a passenger side airbag than households who do not lease. The fact that elasticity estimates differ across models suggests that automobile companies can offer attributes in certain models to alter proportions of vehicles that are leased, financed, and bought with cash.

More specific interpretations of the elasticity estimates are extremely useful in evaluating the possible reasons why consumers decide to lease their automobiles. Consider the repair index estimates of 0.9801 and 1.05789 for the lease and finance elasticities, respectively. The closeness of the estimates does not support the hypothesis that consumers lease to avoid potential repair costs. If leasing consumers were more concerned with repair costs than those who did not, they would be more responsive to the reliability of an automobile.

A similar interpretation gives credence to the theory that leasing enables households facing credit constraints to drive a higher quality car for the same monthly payment. Under this assumption, vehicle attributes positively correlated with vehicle quality should have higher lease elasticity estimates. This hypothesis was supported by the analysis, as the elasticities for passenger side airbag, vehicle horsepower, and annual fuel cost were much higher in the leasing submodel. Elasticity estimates also indicate that a vehicle's residual value has a much larger effect on vehicle type choice when leasing. The larger

TABLE 6.

**Binary Logit Coefficient Estimates for determining the
probability of Cash/Non-Cash**

Variable	Coefficient (Standard Errors)
Constant	3.315 (.747)
Inclusive value term from non-cash submodel (defined for non-cash alternative)	.291 (.209)
Inclusive value term from cash submodel (defined for cash alternative)	.0278 (.0646)
Yearly household debt (in dollars, defined for cash alternative)	-.0000434 (.00000973)
Gender dummy variable (1 if male, 0 otherwise, defined for cash alternative)	1.139 (.211)
Education dummy (1 if respondent graduated from college, 0 otherwise, defined for cash alternative)	1.664 (.265)
Homeowner dummy (1 if respondent owned home, 0 otherwise, defined for cash alternative)	.783 (.348)
Miles (per year) the household expected to drive at purchase ^a (defined for cash alternative)	-.000406 (.0000501)
<u>Summary Statistics</u>	
Number of observations	700
Estimation by maximum likelihood	
Log likelihood at zero	-485.2
Log likelihood at convergence	-343.93

^a To avoid endogeneity, socioeconomic characteristics were used to instrument for the number of miles over 12,000 households expected to drive their vehicle.

TABLE 7. Conditional Elasticity Estimates of Lease, Finance, and Cash Submodels²⁴

Variable	Lease Submodel	Finance Submodel	Cash Submodel
	.959831		.48137
	.9801		N/A
	1.23258		.568433
	-1.7642		-1.4831
	N/A		-.780057
	-2.51092		-2.11596
	4.25278		N/A
	3.29064		5.86713
	6.23		11.3777
	5.81104		N/A

²⁴ Conditional elasticities are obtained by calculating individual household elasticities and enumerating over the sample.

the residual value of a vehicle, the lower the monthly lease payment, and the more credit constraints may be avoided.²⁵

Two additional results can be obtained by examining the conditional elasticity estimates.²⁶ Consumers who lease and finance their vehicle purchases are more responsive to a change in vehicle price than those who do not.²⁷ The own price elasticity of demand ranges from -2.11 in the cash submodel to -2.51 in the lease submodel. These results are consistent with the range of reasonable estimates between -.5 and -2.5 in previous studies of automobile choice.

Three case studies help to simplify the interpretation of who is likely to lease their new vehicle purchase. First consider one of the households in the data set. A married couple in their late thirties with one child, household A has an income in excess of \$200,000 per year. Both spouses graduated from college and they live in a city with a population greater than 500,000 people. Having leased their last vehicle purchase from the Ford Automobile Company, there is an 83.9% chance couple A will lease their next vehicle purchase. Secondly, consider Couple B, an educated couple in their mid forties with two children living in a city with a combined income of \$67,500 per year. Their last three purchases have all been Chevrolets, and they have never previously

²⁵ A high residual value also captures unobserved desirability and durability of the car, indicating that leasing enables acquisition of a higher quality vehicle. Different residual value elasticity estimates also indicate the transaction costs of vehicle disposal must be significant. If transaction costs were minimal, the residual value of a vehicle would not matter to households, as they could sell and replace vehicles at low cost.

²⁶ It is possible to obtain elasticities which are not conditional. However, such elasticities are not readily interpretable if the objective is to compare nests of the multinomial logit model.

²⁷ A previous likelihood ratio test rejected the null hypothesis that the vehicle price coefficients were equal to each other at a 95% confidence level.

leased a vehicle. The probability of Couple B leasing, financing, and paying cash for their next vehicle purchase is 42.1%, 33.7%, and 24.2% respectively. The final example is a seventy eight year old woman living alone with a reported income of \$11,250 per year. Living in a rural area with a high school education, the woman did not lease her last vehicle, an Oldsmobile. Tables 1 through 5 predict only a 16% this woman will lease should she choose to make a new vehicle purchase. Alternatively, there is a 65.1% chance she will find another method of paying for her purchase.

V. TESTS OF MODEL SPECIFICATION

Because true model specification is critical to understanding consumer behavior, it is imperative that the model be correctly specified. For this reason, a number of specification tests were conducted in order to evaluate the validity of the final nested multinomial logit structure. Violations of the Independence of Irrelevant Alternatives (IIA) assumption and the stability of the parameter estimates across time were both examined and rejected as a possible source of model misspecification.

Recall the inherent assumption regarding the unknown component of indirect utility in multinomial logit models. Errors were assumed to independent and identically distributed (IID) within groups. A number of statistical tests are available to examine the validity of the multinomial logit structure and its corresponding IID assumption. For this work, the asymptotically unbiased likelihood ratio test suggested by Small and Hsiao

(1982) was used.²⁸ Using the sample of households who chose to finance their vehicle²⁹, the IID assumption was tested for violations using both the country of origin (foreign vs. domestic cars) and vehicle class specifications (defined by the EPA) as possible sources of violations. It was not possible to reject the null hypothesis that the errors were independent and identically distributed.

Finally, the finance subsample was again used to test for the stability of parameter estimates over time (the 1993, 1994, and 1995 model years). Parameter estimates should be stable in order to either draw inferences outside the sample or to use estimation results in forecasting future behavior. A likelihood ratio test could not reject the null hypothesis that the parameter estimates were stable over the time period. To summarize, no statistical inference could be found to suggest a misspecification of the automobile demand models.

The model specification and automobile demand estimates presented in this chapter give new insight as to why consumers choose their method of automobile financing. Before the estimates can be used to predict future sales and lease shares in the automobile market, however, an improved forecasting technique needs to be discussed. Chapter 4 presents a technique which explains the forecasting problem in more detail and presents a solution.

²⁸ A thorough discussion of the Small-Hsiao test can be found in Ben-Akiva and Lerman (1993).

²⁹ The finance subsample was used due to the asymptotic nature of the Small - Hsiao test as it was the subsample with the greatest number of observations (361).

Chapter 4. Lease Share Forecasts

Automobile demand estimation techniques developed and discussed earlier in this paper are important to both the U.S. economy and the 800,000 plus workers in the automobile industry. Accurate automobile demand estimates, combined with good forecasting techniques, give critical information on future sales and the prevalence of consumer leasing. Previous automobile industry forecasts using micro data have inherent internal inconsistencies. The assumptions researchers have made to forecast results were often contradicted by the empirical estimates found in the models themselves. This chapter overcomes this inconsistency by introducing an innovative forecasting technique to predict consumer leasing behavior through the turn of the century.

Consider the models discussed Chapter 3. For the demand estimates to predict future consumer behavior, it is necessary to have future information on both consumer attributes (e.g., future household income, demographics, education levels), and attributes of the vehicle fleet (e.g. available makes and models with their corresponding characteristics). If the data set is a representative subset of the general population, a researcher need only make an assumption regarding the growth in real income to find the necessary consumer attributes. Similarly, information on what vehicles will be available in future years is widely available in trade magazines such as Motor Trend and Car and

Driver. It is the prediction of future automobile prices which causes the greatest concern to the forecaster.

The most common assumption regarding future automobile prices is that all models will increase in price at some constant rate over the length of the forecast.³⁰ The real rate of price increase illustrates the historical trend of average real vehicle prices steadily increasing over the past decade. The forecasters' dilemma is that both empirical estimates and economic theory refute the ex-post expectations that automobile prices will increase at the same rate.³¹

Consider first the empirical automobile demand estimates in Tables 2,3, and 4. Brand loyalty variables were found to be statistically significant and vary across manufacturers (recall brand loyalty is defined as the number of consecutive purchases of the same make). This means that automobile manufacturers face consumers with different brand loyalties. The price elasticity of demand for consumers with high brand loyalty is more inelastic because they are more likely to make a repeat purchase of that brand. Corporations with high loyalty levels face short-term incentives to increase

³⁰ For example, Berkovec (1985) assumed automobile prices to remain at pre-forecasted 1983 levels.

³¹ Some anecdotal evidence also contradicts the hypothesis that automobile prices increase at the same rate. Vehicles introduced at the low end of the price spectrum often become more popular and develop loyalty. These vehicles are often upgraded in quality as new lower priced vehicles are introduced as low end models. For example, the Volkswagon Jetta has increased in quality and price while the Fox and Golf were introduced to capture its previous market niche.

prices at a rate exceeding the mean. Of course, a price increase would lead to a decrease in short term sales and a corresponding decrease in brand loyalty. Similarly, manufacturers with low loyalty need to sacrifice current profits to increase loyalty, market share, and future profits. How a firm should price future models is an empirical question that depends upon the strength of these two dynamically opposed effects.

I. SUPPLY SIDE

The automobile industry is best characterized as an oligopoly with multiproduct firms. Supply decisions can be accurately characterized as having a long-run and a short-run stage (Breshnahan, 1981). Vehicle models are developed and tested, and decisions regarding product mix and quality are made in the long-run. After a vehicle has been developed and produced, however, a manufacturer must take these long-term decisions as given. The short-run stage is characterized by firms, unable to alter product type, competing through vehicle price. Because the intent of this paper is to derive accurate short term forecasts of the automobile industry, long-run decisions can be taken as exogenous and the choice of vehicle price can be emphasized.

More formally, automobile manufacturers choose vehicle prices to

maximize their stream of discounted profits.³² The suppliers' decision is of the form:

$$\text{Max} \sum_{t=0}^{\infty} B_t \left[\sum_{i=1}^n (P_{it} - C_{it}) E_t [S_{it}] \right] \quad (4.1)$$

w.r.t. $P_{it}, \forall i \in H_k$.

$$S_{it} = \text{fn}(L_{it}, P_{it}, P_{jt}, X_t) \quad (4.2)$$

where H_k represents all vehicles produced by manufacturer k .

P_{it} = Price of vehicle i in period t .

C_{it} = Cost of vehicle i in period t .

B_t = Discount rate in period t .

S_{it} = Sales of vehicle i in period t .

S_{jt} = Sales of vehicle j in period t .

E_t = Expected value in period t .

X_t = Household characteristics and vehicle attributes in period t .

L_{it} = Brand Loyalty for vehicle i entering period t .

Also note :

$$L_{it+1} = \text{fn}(L_{it}, P_{it}, P_{jt}, X_t) \quad (4.3)$$

With full information regarding aggregate consumer demand, and

³² Goldberg (1995) also allowed for vehicle prices to be chosen endogenously. However, her vehicle type choice demand estimates did not include any brand loyalty variables. This oversimplifies the inherently dynamic nature of the endogenous pricing problem by ignoring the incentive of firms to charge lower prices in order to capture future loyalty. Similarly, Berry, Levinsohn, and Pakes (1995) estimate supply and demand interactions using endogenous prices without brand loyalty effects.

excess capacity in production, the dynamic maximization problem of the firm becomes

$$\text{Max} \sum_{t=0}^{\infty} B_t \left[\sum_{i=1}^n (P_{it} - C_{it}) E_t [D_{it}] \right] \quad (4.4)$$

w.r.t. $P_{it}, \forall i \in H_k$.

$$D_{i,t+1} = \text{fn}(D_{it}, P_{t+1}, X_{t+1}) \quad (4.5)$$

where D_{it} = Quantity of vehicle i demanded in period t .

Equation (4.5) explicitly illustrates the incentive of firms to increase future demand for vehicles by charging low current prices. Low current prices increase current sales, thereby increasing the brand loyalty for future periods. It is this aspect of endogenous pricing behavior which has not been adequately addressed in the literature.

Note the separative value function shown in Equation (4.4) and the recursive constraints represented by Equation (4.5). If the aggregate consumer demand functions were tractable, dynamic optimization techniques could be used to solve for the optimal vehicle price path.³³ In the circumstance where firms have a Nash conjecture regarding the pricing behavior of competing firms, the prices of automobile models produced by a given manufacturer would be control variables, while the loyalty of all models in the vehicle fleet would be state variables. Optimal endogenous prices could be found by the

³³ The aggregate consumer demand functions are obtained by calculating individual household probabilities and enumerating across households.

simultaneous solution of k first order conditions and n envelope conditions, where n represents the number of models produced by all manufacturers.³⁴

Unfortunately, the logit distribution used in estimating a household's indirect utility function makes the corresponding aggregate demand curves highly non-linear (see Equation 2.1), and the simultaneous solution of $k + n$ equations impossible. However, difficulties in finding closed-form solutions should not deter analysis of the dynamic endogenous pricing problem. Recent technological advances in the speed of computer processors allow for optimal prices to be found using numerical optimization techniques. Numerical optimization techniques are discussed after answering two additional questions. First, is it necessary to model a household's decision of which vehicle to purchase simultaneously with its decision to purchase a new vehicle? Second, is it possible for automobile companies to charge different prices to different consumers?

II. EXAMINING THE HOUSEHOLD'S DECISION TO ENTER THE NEW VEHICLE MARKET

Finding the optimal endogenous price path for each firm requires the use of the automobile demand estimates from Chapter 3. The probability that

³⁴ In the situation where brand loyalty is defined as the number of consecutive purchases of the same make, n would equal the number of automobile producers.

each household in the sample will lease, finance, or pay cash for each vehicle in the fleet (given current and future household characteristics, vehicle attributes, and long run supply decisions) may be combined with current and future vehicle prices to determine automobile market demand, conditional on the household entering the new vehicle market. To obtain the unconditional market demand estimates necessary for accurate short-run forecasts, the conditional automobile demand estimates must be combined with the decision of a household to enter the new vehicle market.

The probability that a household will purchase a new vehicle in any given year may be found by estimating the length of time between vehicle purchases as recommended by Raymond, Beard, and Gropper (1993) in "Modeling the Consumer's Decision to Replace Durable Goods: a Hazard Function Approach", or through qualitative choice analysis (e.g., Mannering and Winston, 1995).³⁵ Binary logit parameter estimates of a household transaction decision (whether or not to buy a 1992 model year vehicle) are shown in Table 8. The dependent variable is a qualitative choice variable which equals one if a household purchased a 1992 model year vehicle, and zero otherwise. Independent variables include socioeconomic characteristics

³⁵ The data in this study was obtained by questioning people who decided to purchase a new car of the 1993 - 1995 model years and should be treated as censored data. The fact that there were years in which households did not make vehicle purchases allows for the binary logit estimates in this study. The corresponding sample was treated as random to ensure that household probabilities are non-negative and less than 1 (through qualitative choice analysis), and to examine whether it is necessary to include vehicle attributes and financing options when estimating purchase probabilities.

of the household and information regarding the size and composition of a household's vehicle fleet. For example, the length of time between previous household purchases significantly decreases the probability of purchasing a new car in a given year. The binary logit estimates are included in this paper to emphasize the positive, but not significant, parameter estimates of the inclusive value term calculated from the nested multinomial logit model illustrated in Figure 5.³⁶ If the inclusive value term were significant, it would have been necessary to jointly estimate the purchase/not purchase decision with the conditional vehicle type choice estimates of which vehicle to purchase and how to pay for that vehicle.³⁷ Predicted automobile sales using Table 8 estimates are illustrated in Figure 6.³⁸

III. CAN AUTOMOBILE COMPANIES PRICE DISCRIMINATE?

Automobile manufacturers have the ability to increase the suggested retail prices of their models at different rates. It is not as clear whether companies charge different prices based upon observable socioeconomic characteristics of buyers, such as race or gender, or upon a household's choice

³⁶ The inclusive value term does lie between zero and one as required for utility maximization.

³⁷ For estimation purposes, it would be necessary to add an additional nest to the top of Figure 5 representing the household's decision to enter the new vehicle market.

³⁸ Actual sales figures used through the 1995 model year.

TABLE 8.

**Binary Logit Parameter Estimates for the Choice to Acquire a New Vehicle or Not To
Acquire a New Vehicle, for the 1992 Model Year**

Variable	Coefficient (Standard Errors)
Constant	-1.558 (.947)
Inclusive value term from the nested model (See Figure 5)	.0677 (.0744)
Yearly household income (in dollars, defined for acquire alternative)	.00310 (.00295)
Gender dummy variable (1 if male, 0 otherwise, defined for acquire alternative)	-.227 (.248)
Head of household age (defined for acquire alternative)	.00797 (.00827)
Population dummy variable (1 if household lives in demographic area with population size > 500,000 people, 0 otherwise, defined for acquire alternative)	-.279 (.250)
High School education dummy (1 if respondent graduated from high school and did not graduate from college, 0 otherwise, defined for acquire alternative)	.671 (.770)
College education dummy (1 if respondent graduated from college, 0 otherwise, defined for acquire alternative)	.957 (.773)
Number of new and used vehicle transactions during the last five years (defined for acquire alternative)	-2.11 (.141)
Average age of the vehicle(s) owned by the household (defined for acquire alternative)	-.0471 (.429)
Average time between vehicle purchases (defined for acquire alternative)	-.315 (.0822)
First time buyer dummy (1 if household has never purchased a new vehicle, 0 otherwise) (defined for acquire alternative)	-.298 (.362)
<u>Summary Statistics</u>	
Number of observations	654
Estimation by maximum likelihood	
Log likelihood at zero	-453.32
Log likelihood at convergence	-250.6

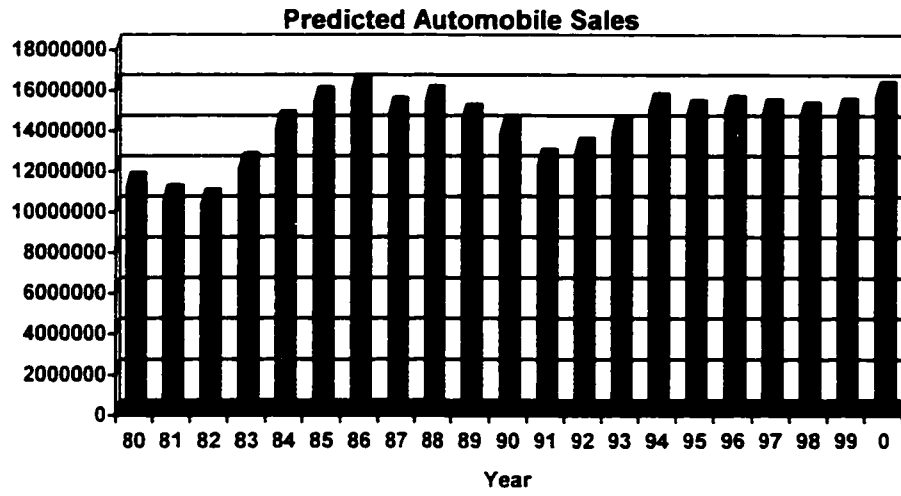


Figure 6. Predicted Automobile Sales

of financing.³⁹ Ayres and Siegelman (1995) focus on the relationship between dealer prices and buyer specific attributes, finding evidence of gender and race discrimination in the new car market. In a controlled experiment, initial price offerings to minorities and women were substantially higher than offerings to white males. Goldberg (1996) shows that when consumers differ by mean willingness to pay and by higher moments of the discount distribution, consumer specific characteristics fail to explain dealer discounts. Rather, “[m]odel, market specific, and purchase transaction variables (e.g., first time purchase, trade-in, and financing through dealer) do explain them.”(Goldberg, 1996)

While auto dealerships certainly try to differentiate a consumers' true willingness to pay, manufacturers have few instruments to price discriminate across consumers.⁴⁰ Manufacturers can control the Manufacturer's Suggested Retail Price (MSRP), recommended dealer markups, and manufacturer incentive programs (e.g. first-time buyer programs, cash back incentives) to price discriminate across consumers. For example, first-time car buyers are more responsive to a change in price than consumers who have developed loyalty toward a product (Goldberg, 1996). First-time buyer programs tend to

³⁹ A distinction should be made between the price suggested by the manufacturer and the price actually paid by the consumer. The prices might differ due to price discrimination on the part of the dealer, transportation costs, local or state taxes, or dealer specific discounts (Goldberg, 1995). Because the transaction price paid by the consumer is neither observable nor exogenous (as it depends upon the negotiating power of the household), manufacturer's prices were used in both the demand estimation and forecasting.

⁴⁰ Define price discrimination across consumers as charging different prices to different households based upon characteristics specific to that household.

charge lower prices to first time car buyers in order to increase current sales and develop future brand loyalty.

Instruments also exist which enable automobile manufacturers to price discriminate within a given household. In particular, control over interest rates (through lease incentive and dealer financing programs) gives firms the ability to offer different prices, depending on how a household decides to pay for its vehicle purchase.^{41,42} This is the paradox which has intrigued economists for the past decade. Why would a household choose a method of financing which is not in its financial best interest? In order to price discriminate, it is commonly assumed that two things must exist: 1) firms must be able to distinguish between customers at a relatively low cost, and 2) consumers must not be able to resell their product.⁴³ The second assumption is an arbitrage condition, which in the automobile market means that

⁴¹ For example, Chevrolet recently offered 2.9% financing on Cavalier purchases, but standard financing on the Malibu model.

⁴² An automobile dealer noted that the lower downpayment and lower monthly payment associated with leasing requires consumers to have better credit than consumers who finance. Of course, if this were the only explanation, one would see lessors paying a lower price for vehicle(s).

⁴³ A third, often unmentioned condition, is that the goods sold to each consumer are identical. Because the stream of attributes associated with automobile leasing is not the same as the stream of attributes associated with financing, this condition merits further examination. Define price discrimination as charging different prices to different consumers, when the costs of supplying goods to each consumer is identical. Using this definition, automobile manufacturers might be price discriminating when they charge different prices based upon a household's method of financing, or they might be charging consumers for the higher costs of selling a leased vehicle. For example, as manufacturers shifted toward using exclusively closed-ended lease contracts, risk was transferred from consumers to manufacturers. If the residual value of a vehicle is lower than expected, manufacturers cannot recoup the difference between actual and expected residual value. The costs of selling a vehicle by leasing are greater than the costs of selling a vehicle through financing. If all of the costs are passed on to the consumer in the form of higher lease prices, the higher lease prices can no longer be called price discrimination. Under these circumstances, the current section should be entitled, "Can

consumers must be effectively prevented from reselling to themselves.⁴⁴ The solution to the paradox lies in the fact that the method of financing a household uses affects the stream of benefits a household receives over the vehicle's life. In particular, the first three chapters of this paper suggest that leasing enables households to reduce the transaction costs of vehicle replacement and to avoid binding credit constraints or obtain credit at a lower interest rate than otherwise possible.

IV. THE NUTS AND BOLTS OF ENDOGENOUS LEASE PRICING

The ability of firms to price discriminate should be addressed in any short term forecasting model. This paper examines the incentive of automobile manufacturers to charge lease prices which differ from the manufacturer suggested retail price. As a practical matter, a few simplifying assumptions are required to estimate the system of equations represented by (4.4) and (4.5). First, note the solution to the system of equations would yield current lease price P_{it} as a function of all current and future prices of the same model, different models produced by the same manufacturer, and competing models. Tractable estimates require assumptions regarding both manufacturer

Automobile Manufacturer's Charge Different Prices Based Upon a Household's Choice of Financing?"

⁴⁴ There is a corresponding market arbitrage condition. If the cost of leasing were substantially higher than the cost of purchase, a secondary lease market would arise. For this reason, the forthcoming numerical estimation constrained lease prices to be no more than 10% greater than the cost of purchase.

costs and the pricing behavior of competing firms^{45,46}, while the number of time periods in the objective function must be assumed finite. Because this paper examined leasing incentives of manufacturers, cash and finance prices were assumed fixed in real terms at the manufacturer's suggested retail price. If the objective function is restricted to three time periods, the maximization problem becomes:⁴⁷

$$\text{Max } \sum_{t=0}^2 B_t \left[\sum_{i=1}^n (P_{it} - C_{it}) E_t [D_{it}] \right] \quad (4.6)$$

$$\text{w.r.t. } P_{it}, \forall i \in H_k.$$

$$D_{it+1} = \text{fn}(D_{it}, P_{t-1}, X_{t+1}) \quad (4.7).$$

Optimal endogenous lease prices may be found by choosing numerous current and future lease price vectors. Current and future sales, and discounted expected profits may then be calculated for each price vector, with the optimal price in period t representing the price that maximizes the present value of profits. Note that current prices both affect and are affected by future sales through brand loyalty and the demand functions calculated from Tables 2 through 6, and 8. Optimal period t prices are then used to calculate loyalty

⁴⁵ Following Breshnahan (1986), a rough approximation based upon vehicle classification was used to calculate manufacturer costs. A more data intensive procedure suggested by Berry, Levinsohn, and Pakes (1995) would likely yield better cost estimates.

⁴⁶ The assumption in this paper is that the pricing behavior of other firms is independent of the pricing decision of a given manufacturer. As processing speed increases, an iterative solution would be more likely to yield a Nash equilibrium.

⁴⁷ If computational time is a factor, the objective function could consist of two time periods with interest rates adjusted (decreased) accordingly. A real interest rate of 5% was assumed for the purposes of this paper.

entering period $t+1$ with optimal lease prices in period $t+1$ found through re-estimation of the optimization program.⁴⁸

V. ENDOGENOUS LEASE PRICING RESULTS

Output of the endogenous pricing program consisted of the present value of profits to the manufacturer under each price vector.⁴⁹ Cursory examination of the results indicate that manufacturers have incentives to charge lease prices higher than the MSRP. Of the 855 endogenous prices estimated for the 1996 through 2000 model year vehicles, only 21.1% of optimal lease prices did not exceed the finance or cash price of the vehicle. On average, lease prices exceeded the MSRP by 14.76%. Results also indicate the importance of using a dynamic objective function (i.e. Equation 4.6) when finding optimal prices. When current period profits only were maximized, lease prices were found to be 30% higher than the MSRP. Endogenous pricing analysis which does not consider the inherent dynamics of brand loyalty in the automobile market (e.g. Goldberg, 1995) yields upwardly biased prices. Myopic pricing upwardly biases results because it does not take into account the incentive of manufacturers to charge lower

⁴⁸ Efficiency is critical in the optimization program. In the case where 10 prices are chosen in each time period, there are 172 vehicle models, 654 households, the program is iterated 20 times, and there are 1000 calculations necessary to calculate each household probability, each run of the program requires 3.44 billion calculations. The extensive number of calculations made simultaneous enumeration of endogenous lease, finance, and cash prices prohibitively expensive.

⁴⁹ The price vectors tested ranged from -30% to +30% of expected MSRP.

prices in current periods in order to increase brand loyalty and profits in future periods. An ordinary least squares regression of the optimal "Lease Markup" on vehicle attributes (Table 9) is useful in explaining other findings of the endogenous pricing model.⁵⁰

First note that optimal lease markups vary by manufacturer. In particular, manufacturers that produce a large number of models are less likely to charge a larger lease markup. Statistical analysis supports this hypothesis, as the number of models produced by the same manufacturer has a significant, negative impact. As a consumer's characteristics change (e.g. change in income, demographics), the vehicle a consumer would like to drive is also likely to change. A manufacturer producing a wide variety of vehicles is more likely to produce a vehicle with the characteristics that the consumer now desires. There is a larger incentive to develop brand loyalty because the effects on future profits are great.

The manufacturer dummy variables for American and Japanese models also indicate that European manufacturers are more likely to charge high lease markups. This result may be understood by examining the dynamics of the endogenous lease pricing problem. The large European lease

⁵⁰ Lease markup is defined as the optimal lease price suggested by the endogenous lease pricing model minus the MSRP. Lease markup may be positive or negative.

TABLE 9.
Least Squares Regression
Dependent Variable: Endogenous Lease Price minus
Manufacturer's Suggested Retail Price

Variable	Coefficient (Standard Errors)
<u>Vehicle attributes:</u>	
Constant	-262.629 (2004.435)
1997 model year dummy (=1 if vehicle 1997 model year, 0 otherwise)	-908.586 (319.851)
1998 model year dummy (=1 if vehicle 1998 model year, 0 otherwise)	2010.152 (322.225)
1999 model year dummy (=1 if vehicle 1999 model year, 0 otherwise)	2072.8 (322.225)
2000 model year dummy (=1 if vehicle 2000 model year, 0 otherwise)	2030.243 (322.225)
Number of models produced by manufacturer	-164.328 (46.379)
Horsepower	14.672 (4.069)
Passenger Side Airbag dummy(=1 if passenger side airbag is standard, 0 otherwise)	904.889 (425.438)
<i>Consumer Report's</i> repair index ^a	182.209 (106.896)
Vehicle fuel consumption in miles per gallon	62.987 (43.77)
Vehicle residual value (defined as the percentage of the Manufacturer Suggested Retail Price the vehicle will retain during its first three years of use)	75.425 (16.312)
Luxury dummy variable (=1 if vehicle is defined a luxury vehicle, 0 otherwise)	942.734 (350.062)
Vehicle weight (in pounds)	1.097 (.359)
<u>Manufacturer and class variables:</u>	
Ford manufacturer dummy (= 1 if Ford make, 0 otherwise)	-699 (463.321)
GM manufacturer dummy (= 1 if produced by GM, 0 otherwise)	-106.968 (406.855)

TABLE 9. (continued)

Chrysler manufacturer dummy (= 1 if produced by Chrysler, 0 otherwise)	-537.011 (428.785)
Honda manufacturer dummy (= 1 if produced by Honda, 0 otherwise)	-221.777 (519.245)
Nissan manufacturer dummy (= 1 if produced by Nissan, 0 otherwise)	-579.366 (502.69)
Toyota manufacturer dummy (= 1 if produced by Toyota, 0 otherwise)	-811.498 (518.208)
Japanese manufacturer dummy (= 1 if produced by Japanese manufacturer other than Honda, Nissan, or Toyota, 0 otherwise)	-1014.189 (416.938)
Small vehicle dummy ^b (= 1 if vehicle is a subcompact, 0 otherwise)	563.353 (510.997)
Midsize vehicle dummy ^b (= 1 if vehicle is defined as compact, midsize, or large vehicle, 0 otherwise)	1902.628 (482.127)
Large vehicle dummy ^b (= 1 if vehicle is a Sports Utility Vehicle or minivan, 0 otherwise)	830.526 (597.694)

Summary Statistics

Number of observations = 855

F(22, 832) = 29.59

R-squared = 0.4389

Adj R-squared = 0.4241

^a Consumer report's repair index is a measure of reliability that uses integer values from 1 to 5. A value of 1 indicates the vehicle has a "much below average" repair record, 3 is "average", while 5 represents a "much better than average" reliability.

^b Vehicle class sizes (e.g. subcompact, compact) are defined by the EPA.

markup may be understood by realizing that high brand loyalty currently exists for most European makes. Because the demand for European models is more inelastic than non-European models, there is a greater incentive for European manufacturers to increase current prices.⁵¹ As European manufacturers reap the benefits of existing brand loyalty by charging higher prices, one would expect the market share to fall. In fact, the market share for European manufacturers has decreased, as illustrated previously in Figure 3.

Vehicle attributes positively correlated with price and quality (e.g. dummy variables for luxury automobiles and standard passenger side airbags, Consumer Reports repair index, gas mileage, and vehicle weight) also indicate that more expensive vehicles are more likely to have higher lease markups. Recall that leasing enables households to avoid risk and avoid binding credit constraints while decreasing the transaction costs of vehicle disposal and replacement. Because the value of these leasing attributes likely increases with the purchase price of the vehicle, consumers are willing to pay a higher lease premium. For example, the costs of vehicle disposal and replacement include both monetary costs and search costs. High income households face search costs greater than low income households due to greater opportunity

⁵¹ Berry, Levinsohn, and Pakes (1995) estimate changes in price markups by manufacturer and find the counter-intuitive result that firms which produce the fewest models (e.g. BMW) will have lower dealer markups than firms which produce many models. Their counter-intuitive result is contradicted by endogenous lease pricing estimation.

costs, making leasing more attractive to high income consumers. Also, note the residual value of a vehicle (defined as the expected percentage of initial price a vehicle maintains after three years of use) has a positive and significant effect on lease prices. Because a large residual value corresponds to low monthly payments, the hypothesis that many consumers lease to avoid binding credit constraints is supported.⁵²

VI. FUTURE LEASE SHARE FORECASTS

This chapter introduced a lease pricing model that allows prices to vary both across and within manufacturers, while allowing price discrimination based upon a household's choice of vehicle payment. Optimal endogenous lease prices may now be used to predict short-term changes in the automobile industry. Short-term forecasts of lease share (Table 10) are shown in Figures 7-10, while predicted lease shares by manufacturers (Table 11) are illustrated in Figure 11.

Short-term forecasts indicate that slightly over 30% of all new consumer automobile acquisitions will be leased by the year 2000. The forecasts suggest that automobile leasing will become more prevalent, but at an ever decreasing rate. Forecasts also predict a moderate increase in the leasing of American models, with a decrease in the European lease share.

⁵² An alternative explanation would be that households consider monthly payment instead of vehicle price when making their vehicle purchase decision.

Lease markup predictions, based upon endogenous lease pricing models, are slightly lower than the common myopic forecasts. Myopic lease pricing forecasts, entitled rational expectation forecasts, assume that households accurately predict future real automobile prices. Regardless of the prices used to predict consumer lease share, consumer leasing is expected to stabilize between 30% and 33% of all new vehicle consumer purchases. Possible explanations for this stabilization are discussed in Chapter 5.

TABLE 10 - Predicted Lease Share.

Year	Predicted Endogenous	Rational Expectations ^a	Predicted CNW ^b
1996	2.5		2.5
1997	3.5		3.5
1998	3		3
1999	4.4		4.4
2000	6.8		6.8
2001	7.9		7.9
2002	7.3		7.3
2003	9.1		9.1
2004	13.5		13.5
2005	17.9		17.9
2006	23		23
2007	24.2		24.2
2008	28.71		27.2
2009	29.33		29.3
2010	29.89		31.5
2011	30.13		31.6
2012	29.94		

^a The rational expectation model assumes a 3% real increase in consumer income, 0% increase in real automobile prices, and that households accurately predict inflation over the course of the forecasts. Myopic lease pricing forecasts are titled as a rational expectations model since they assume households accurately predict future real automobile prices.

^b Car Share, Truck Share, and Total Share represent the pure consumer lease shares and were obtained from CNW Marketing/Research, Bandon, OR. 1996-99 lease shares are based on proprietary CNW forecasting models.

Table 11.
Predicted Lease Share by Manufacturer
using Endogenous Prices

Year	GM	Ford	Chrysler	Japanese
	21.46		21.94	
	25.65		24.27	
	24.53		23.65	
	26.3		24.49	
	26.97		24.5	
	27.06		24.52	
Year	Honda	Loyota	Nissan	European
	35.88		32.6	
	51.91		32.33	
	51.75		34.19	
	52.43		33.51	
	52.02		33.51	
	52.95		33.93	

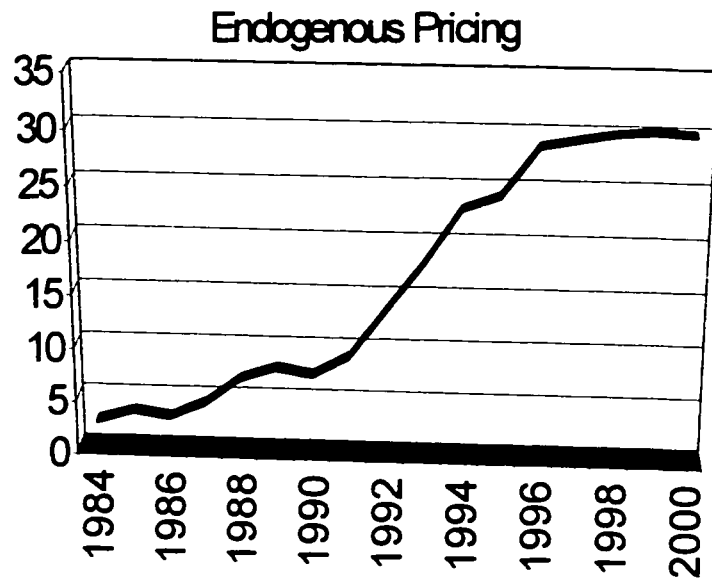


Figure 7. Overall Lease Share using Endogenous Prices

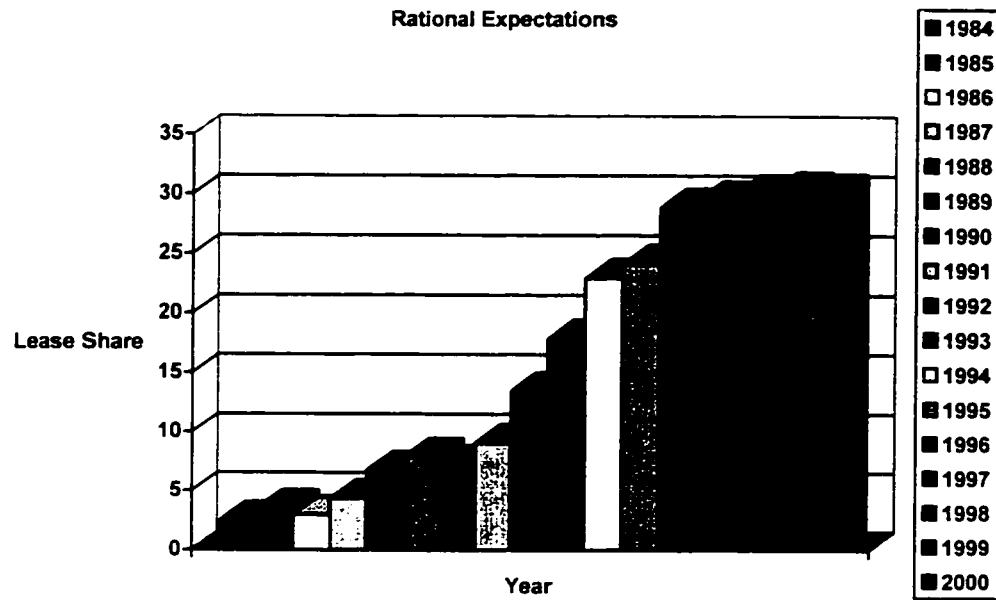


Figure 8. Rational Expectations Lease Share ^a

^a The rational expectation model assumes a 3% real increase in consumer income, 0% increase in real automobile prices, and that households accurately predict inflation over the course of the forecasts. Myopic lease pricing forecasts are titled as a rational expectations model since they assume households accurately predict future real automobile prices.

CNW Predicted

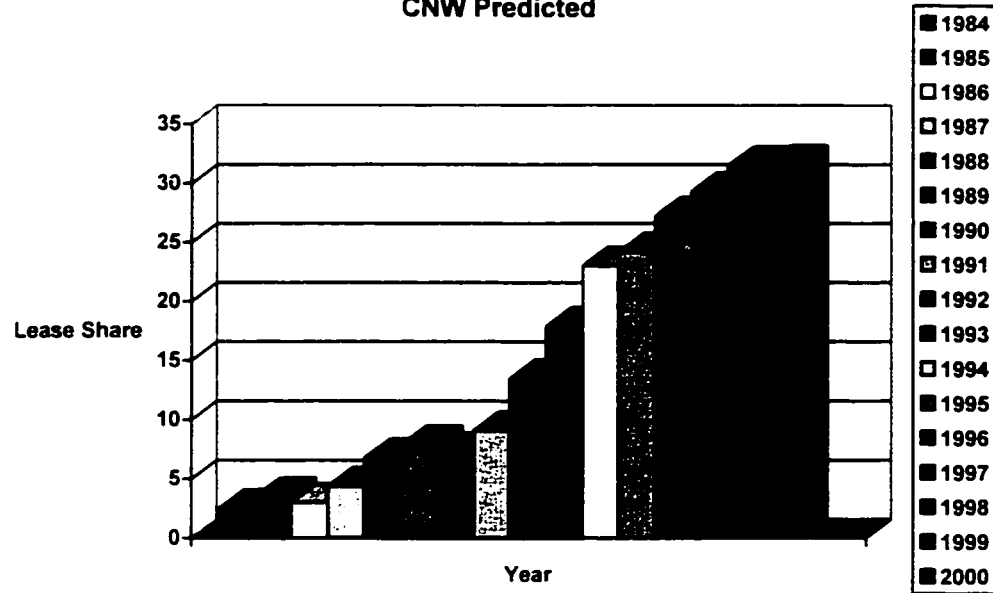


Figure 9. Independent Lease Share Predictions^a

^a Car Share, Truck Share, and Total Share represent the pure consumer lease shares and were obtained from CNW Marketing/Research, Bandon, OR. 1996-99 lease shares are based on proprietary CNW forecasting models.

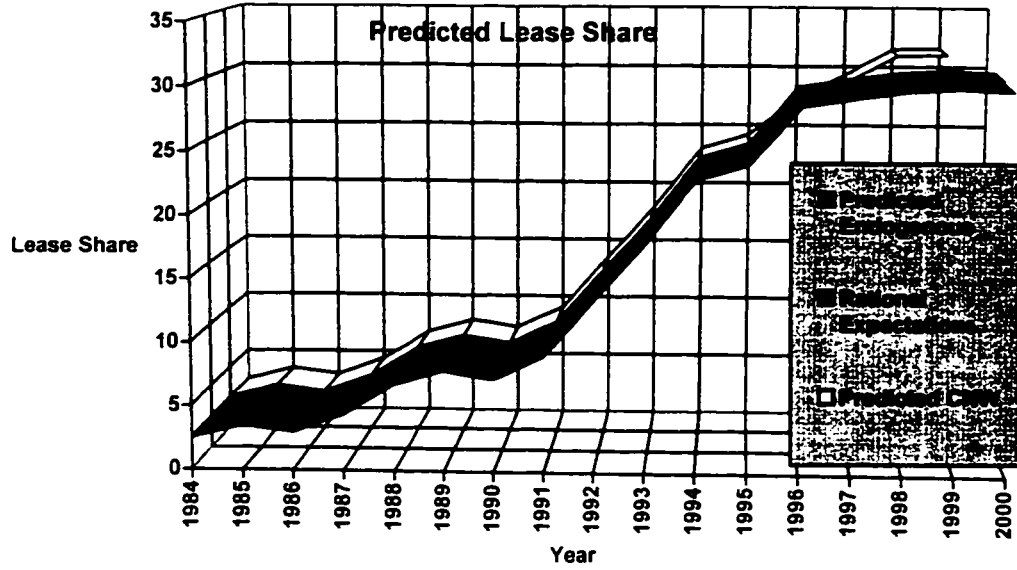


Figure 10. Overall Lease Share Predictions^a

^a Car Share, Truck Share, and Total Share represent the pure consumer lease shares and were obtained from CNW Marketing/Research, Bandon, OR. 1996-99 lease shares are based on proprietary CNW forecasting models.

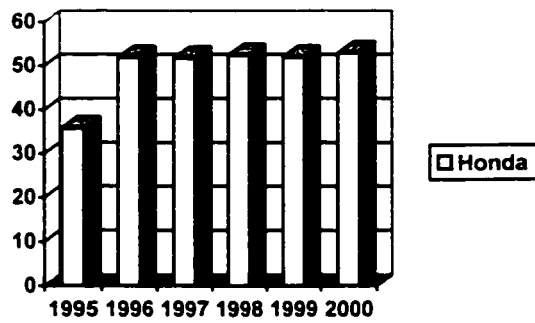
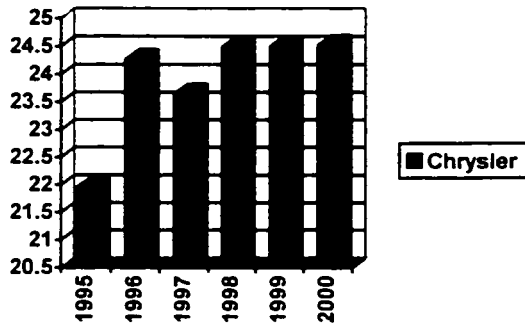
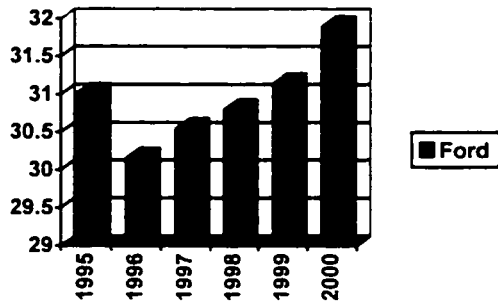
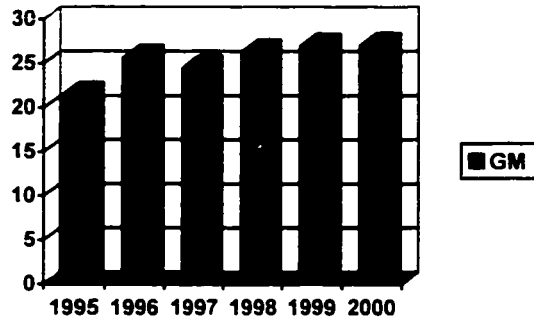


Figure 11. Lease Share Predictions by Manufacturer

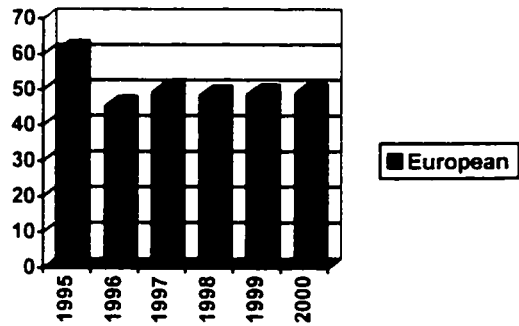
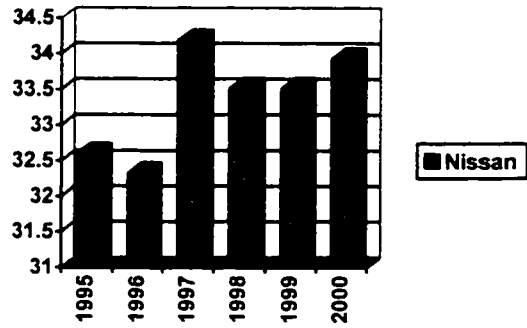
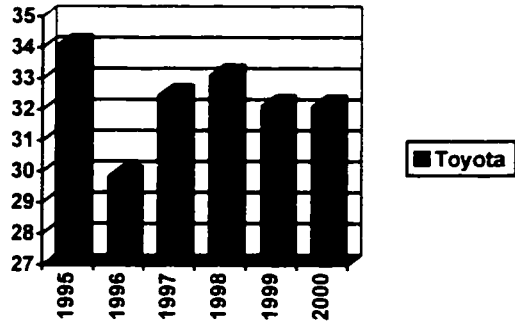


Figure 11 (cont.). Lease Share Predictions by Manufacturer

Chapter 5. Conclusions and Suggestions for Further Research

This study provides a comprehensive analysis of automobile demand. It has shown that a household's decision to pay cash, finance, or lease can not be separated from the type of vehicle acquired. This methodological improvement cannot be overstated; research that does not allow for simultaneous estimation will yield biased and inconsistent results. Moreover, previously unaddressed independent variables were excluded in the vehicle type choice estimation.

Estimates from the nested multinomial logit model give insight as to why consumers lease automobiles even when it is not in their financial best interests to do so. Results indicate that the choice of how to finance a vehicle should not be treated as a simple accounting decision. A household's choice of financing influences the stream of benefits it receives from a vehicle's use. Leasing allows a household to avoid otherwise binding credit constraints or borrow money at a lower interest rate than otherwise possible. This enables a household to drive a higher quality vehicle. Secondly, leasing reduces the transaction costs associated with vehicle disposal and replacement. Similarly, if consumers are unsure about the model or make they wish to purchase, leasing allows them to commit to a vehicle for a short period of time. No support was found for the hypothesis that consumers lease to avoid future

repair costs, and it was shown that consumers who use different methods of financing value vehicle attributes differently.

Because the stream of benefits a household receives from the purchase of a new vehicle is dependent on its choice of financing, households are often willing to pay more for a leased vehicle. An arbitrage condition no longer prevents manufacturers from charging different prices based on a household's choice of payment. A dynamic, profit maximizing, endogenous lease pricing model examines the incentive of automobile manufacturers to price discriminate using manufacturer rebates and interest rate programs. The dynamic model captures the incentive to charge high current period prices in order to maximize current profits, and the incentive to increase market share and future profits (through brand loyalty) by charging low current period prices. Manufacturers which produce many models have a larger incentive to charge low lease prices in an attempt to increase future market share by establishing brand loyalty. As the socioeconomic characteristics of households change, companies with many models are more likely to produce a vehicle in the new market niche and are more likely to have a repeat purchase. Alternatively, the recent decrease in European market share may be explained by European manufacturers charging high current period prices to capture high existing brand loyalty. The dynamic endogenous lease pricing results also provide additional support for the hypothesis that leasing enables a household to avoid otherwise binding credit constraints. Attributes positively correlated to high quality automobiles (e.g. repair index, horsepower, residual value,

standard passenger side airbag dummy) were shown to have a positive impact on the optimal vehicle lease price.

Two factors likely contributed to the increased popularity of consumer leasing shown in Figure 3.⁵³ First, the structure of leasing contracts has evolved so that current leases are almost exclusively closed-ended. Having the residual value of a vehicle determined at the time of the vehicle purchase increases the value of attributes associated with vehicle leasing. In particular, a household assumes less risk and faces lower transactions costs of vehicle replacement under a closed-ended lease contract.

The increase in consumer leasing may also be explained by the recent increases in real consumer income as shown in Table 12 and Figure 12. As a household's income increases, so should the value of attributes associated with leasing. One benefit of leasing is that it reduces the transaction costs (both monetary and opportunity costs) of vehicle disposal and replacement. If driving a "newer" car is a normal good, an increase in household income would lead to more frequent purchases of new automobiles. As the time between vehicle purchases decreases, leasing should become a better financial alternative as more costs may be avoided.

⁵³ Alternatively, the increase in consumer leasing could be explained by lease incentives given by manufacturers. Because leasing lowers the transaction costs associated with vehicle disposal and replacement, lease incentives encourage frequent replacement of new automobiles. However, the dynamic endogenous pricing model shows that manufacturers have incentives to charge higher lease prices.

**Table 12. Percent of Households with an annual income exceeding
\$75,000 (1994 dollars)**

Year	% of Households
1970	8
1975	9.1
1980	11.8
1985	14.3
1990	16.9
1992	15.7
1993	16.4
1994	17.2

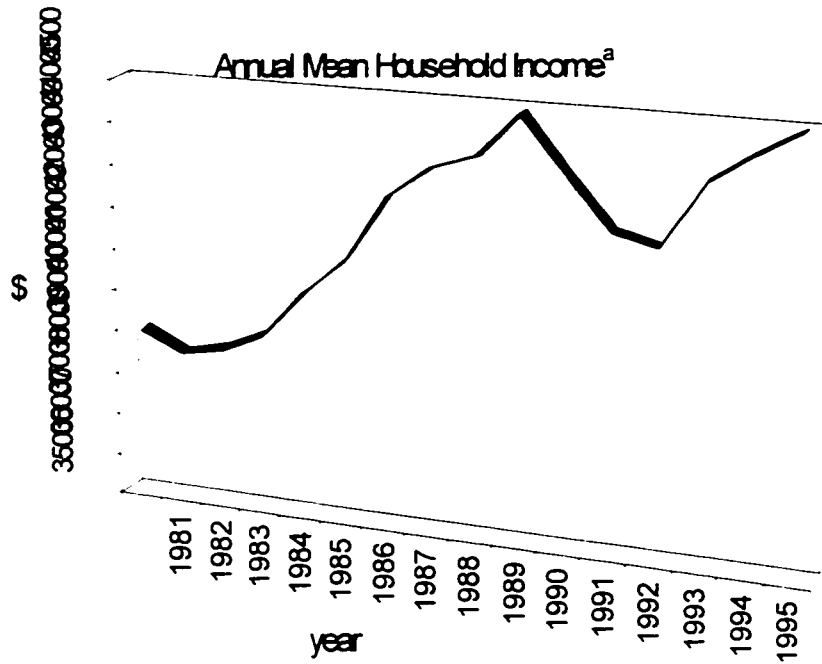


Figure 12. Annual Mean household income

^a Source: U.S. Department of Labor, Bureau of Labor Statistics
 1995 CPI-U-X1 adjusted dollars

The real increase in household income could also explain the recent popularity of consumer leasing if the income elasticity of demand for luxury cars is greater than one. As income increases, a household's desire to purchase a more luxurious vehicle increases at a greater rate. Because the price of a vehicle has increased faster than income, it is increasingly likely that a household will choose to lease to avoid binding credit constraints. The low downpayment and lower monthly payments associated with leasing enable the household to pay higher interest bearing debts instead of its automobile payments. Figure 13 shows the average annual increase in automobile prices to be 5.26% during the 1993 to 1997 model years.

Automobile demand forecasts give important clues to the future popularity of consumer leasing in the United States. Using endogenous lease price estimates, consumer leasing should stabilize at just over 30% in the next five years. If the economy remains strong and real incomes continue to increase, the predictions should be viewed as a lower bound. A stabilizing economy should decrease the rate of increase of household incomes and stabilize future lease share. A residual value effect may also explain lease share stabilization. As previously leased vehicles enter the used car market in larger numbers, the price of used models will decrease. The residual value of the model will decrease and the monthly lease payments and downpayment

New Car Prices

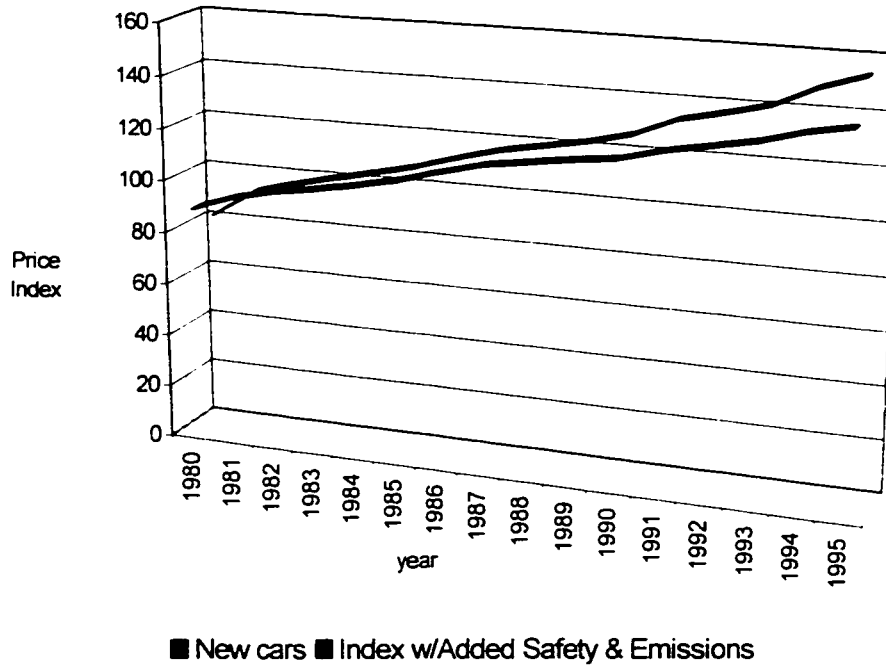


Figure 13. New Car Prices

⁴ Calculated using CPI-U-X1 adjusting for Congressionally Mandated improvements in safety and equipment. Adjustments calculated by the American Automobile Manufacturer's Association (see Motor Vehicle Facts and Figures, 1996 ed.). The CPI was weighted using the average of 170, 1995 model year prices obtained from the National Automobile Dealers Association.

will rise.

Despite the accomplishments of this paper, some major issues in automobile demand estimation still need to be overcome before consumer behavior may be fully understood. The greatest theoretical problem with empirical automobile demand estimation lies in the treatment of automobiles as a consumer durable. The durability of automobiles in the demand estimation has yet to be explicitly addressed. Specifically, an empirical test of whether or not new and used cars are close substitutes for each other would clarify the need for more encompassing vehicle type choice models. If new and used cars are close substitutes, a fundamental change in consumer behavior, such as the increase in consumer leasing addressed in this paper, would have additional implications for future new automobile demand.

The incorrect use of price information in demand estimation should also be addressed. The true price that should be included in demand estimation is the net present value of payments over the period of time a household expects to own a vehicle. Data limitations to this point have led researchers to include MSRP as a proxy for the true vehicle price. The importance of this omission is highlighted by the results of this paper which indicate that households consider the residual value of a vehicle when making purchase decisions.

Finally, improving empirical techniques could also lead to a greater understanding of consumer behavior. Estimates to date have stressed the importance of consistent estimates at the expense of efficiency. Full

Information Maximum Likelihood (FIML) will soon be available to researchers at a relatively low computational cost (though the large number of vehicle alternatives will still pose many problems).

It is my hope that this dissertation improves the understanding of why consumers choose to lease their vehicles and leads to more accurate estimates of automobile market demand in future studies.

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APPENDIX A.

**Multinomial Logit Coefficient Estimates for 1993, 1994, and 1995:
New-Vehicle Choice - Entire Data Set**

Variable	Coefficient (Standard Errors)
Vehicle attributes:	
Passenger side airbag dummy (= 1 if passenger side airbag standard on vehicle model, 0 otherwise)	.552 (.136)
Turning radius if domestic auto. 0 otherwise (in feet)	.235 (.0275)
Turning radius if non-domestic auto. 0 otherwise (in feet)	.0739 (.029)
Natural log of vehicle price (in thousands of dollars)	-2.231 (.332)
Annual fuel cost (in dollars)	-.00169 (.000576)
<i>Consumer Report's</i> repair index ^a	.256 (.0526)
Horsepower	.00436 (.00171)
Expected automobile insurance (in dollars)	-.00379 (.00326)
Vehicle residual value if domestic (defined as the percentage of the manufacturer suggested retail price the vehicle will retain during its first three years of use)	.0325 (.0117)
Vehicle residual value if non-domestic (defined as the percentage of the manufacturer suggested retail price the vehicle will retain during its first three years of use)	.0986 (.0132)
Subcompact class dummy if domestic ^b (=1 if vehicle is a subcompact and domestic, 0 otherwise)	.179 (.28)
Subcompact class dummy if non-domestic ^b (=1 if vehicle is a subcompact and non-domestic, 0 otherwise)	.36 (.292)
Compact class dummy ^b (=1 if compact vehicle, 0 otherwise)	1.241 (.233)
Mid-size vehicle dummy ^b (=1 if mid-size vehicle, 0 otherwise)	1.675 (.251)
Large vehicle dummy ^b (= 1 if large vehicle, 0 otherwise)	1.088 (.274)
Minivan dummy if domestic ^b (=1 if vehicle is defined as a domestic minivan, 0 otherwise)	1.81 (.264)

APPENDIX A. (continued)

Minivan dummy if non-domestic ^b (=1 if vehicle is defined as a non-domestic minivan, 0 otherwise)	-416 (.648)
Sports Utility Vehicle dummy if domestic ^b (= 1 if vehicle is a domestic SUV, 0 otherwise)	1.827 (.33)
Sports Utility Vehicle dummy if non-domestic ^b (= 1 if vehicle is a non-domestic SUV, 0 otherwise)	.758 (.491)
Brand Loyalty and Preference:	
Ford manufacturer dummy (= 1 if Ford make, 0 otherwise)	-2.84 (.483)
GM manufacturer dummy (= 1 if produced by GM, 0 otherwise)	-3.503 (.499)
Chrysler manufacturer dummy (= 1 if produced by Chrysler, 0 otherwise)	-3.681 (.488)
Japanese manufacturer dummy (= 1 if produced by Japanese manufacturer, 0 otherwise)	-.732 (.17)
Number of previous consecutive GM purchases	1.009 (.138)
Number of previous consecutive Ford purchases	1.361 (.221)
Number of previous consecutive Chrysler purchases	1.168 (.248)
Number of Previous consecutive Japanese manufacturer purchases	1.066 (.211)
Number of previous consecutive purchases for vehicles produced by non-Japanese or American manufacturers	1.146 (.306)
Number of previous consecutive leases of the same make of vehicle	.958 (.258)
Summary statistics	
Number of Observations	700
Estimation by maximum likelihood:	
Log likelihood at zero	-1678.5
Log likelihood at convergence	-1179

^a Consumer report's repair index is a measure of reliability that uses integer values from 1 to 5. A value of 1 indicates the vehicle has a "much below average" repair record, 3 is "average", while 5 represents a "much better than average" reliability.

^b Vehicle class sizes (e.g. subcompact, compact) are defined by the EPA.

APPENDIX A. (continued)Appendix A estimated on Finance subsample

auxiliary statistics	at convergence	initial
log likelihood	-575.59	-865.64
number of observations	361	

Appendix A estimated on Lease subsample

auxiliary statistics	at convergence	initial
log likelihood	-205.43	-340.5
number of observations	142	

Appendix A estimated on Cash subsample

auxiliary statistics	at convergence	initial
log likelihood	-320.28	-472.39
number of observations	197	

Testing the null hypothesis that the finance, lease, and the cash submodels have the same coefficients:

The test statistic = 155.4 ~ (χ^2 with 58 d.o.f.)

The critical value = 76.77791

Reject H_0 : same specification at 95% level of significance

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University of Washington
Ph.D. in Economics, October, 1997
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Experience

Teaching:

Visiting Professor. *University of Puget Sound, Tacoma, Washington.* January, 1997 – present. Course instructor for introductory microeconomics, macroeconomics, environmental economics, industrial organization, and transportation economics.

Lead Teaching Assistant. *University of Washington, Seattle, Washington.* September, 1994 to June, 1996. Coordinated, evaluated, instructed, and advised teaching assistants for the Department of Economics.

Teaching Assistant. *University of Washington, Seattle, Washington.* Instructed, graded, and performed other duties related to teaching undergraduates. Teaching assistant and course grader for introductory microeconomics, introductory macroeconomics, and natural resource economics. Course instructor for public finance and introductory macroeconomics. Recipient of the 1995 Langton Award, presented to the outstanding teaching assistant in the Department of Economics. September, 1992 to June, 1996.

Research:

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"Why do Consumers Lease Cars?" Written with co-authors Cliff Winston (Brookings Institute) and Fred Mannering (University of Washington). To be submitted December, 1997.

Current and Future Research.

"The cost effectiveness of reducing automobile emissions through registration fees."

"Using litigation to solve environmental problems."