Consumer perception of warranty as signal of quality: An empirical study of powertrain warranties

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Abstract

This paper empirically explores the degree to which consumers perceive a manufacturer's warranty as a signal of unobservable product quality. Data on household purchases of new automobiles from the Consumer Expenditure Survey are used to estimate both conditional and mixed logit models of consumer demand, with the indirect utility specification extended to incorporate the impact of manufacturer provided warranties. To distinguish between the two main motives underlying consumer preference for warranties, signaling and risk aversion, the impact of warranty length is allowed to differ by proxies for [1] household risk aversion and [2] amount of product information available to the household. Our results suggest, at most, a modest role for risk aversion but an important one for signaling. We find warranty length especially appealing for brands that consumers have not previously experienced and for recently introduced models not yet rated in *Consumer Reports* – precisely the type of automobiles for which asymmetric information is the greatest and signals of product quality the most valuable.

1 Introduction

The length of an automobile manufacturer's powertrain warranty – the warranty insuring a new automobile's engine, transmission, and drive system from product defect – has been a prominent aspect of modern automobile advertisements. In July 2007, Chrysler stirred the industry by announcing a "lifetime" powertrain warranty, effectively eliminating the risk of major product defect for the original owner. The warranty extension was reportedly spurred by Chrysler's belief that their 2007 models were among the highest quality they had ever produced and that powertrain warranty was a chief consideration for their target consumers.[1] Sales data from the U.S. automobile market during the late 1990s and early 2000s provide some suggestive evidence supporting the latter contention.

In 1999, Hyundai Motors extended their powertrain warranty from 5 years / 60,000 miles to 10 years / 100,000 miles. After the warranty change, Hyundai's U.S. market share increased from 1.1% to 4%. Dodge saw a 5% increase in sales, between November 2001 and July 2002, after extending their powertrain warranty from 3 to 7 years. Other firms have shortened their warranty. In 2002, Volkswagen reduced their powertrain warranty from 10 years / 100,000 miles to 5 years / 60,000 miles. In the 3 years after the warranty change, U.S. sales of Volkswagen cars declined 30%.[2] These examples suggest the importance of warranty coverage on consumer demand for new automobiles. This raises the question: do consumers value an automobile manufacturer's warranty as a signal of product quality, as theorized in the information economics literature?

Although there are many theoretical papers that study warranties and signaling, only a few papers empirically examine warranties as a form of signaling.[3] One reason for this may

[1] *Consumer Reports* (2007)

[2] Figure 1, in the appendix, illustrates these changes.

[3] Riley (2001) writes "Despite the plethora of theories arguing that introductory prices, advertising, and warranties can signal high quality, there is remarkably little applied work seeking empirical support."

be the difficulty in obtaining the necessary data set that combines the appropriate product, manufacturer, and consumer information. Another reason may be the difficulty in measuring the relevant economic concepts, such as risk aversion and asymmetric information. The measurement of such concepts requires an explicit model of consumer behavior. The ability to address each of these concerns makes the automobile industry a natural candidate for an empirical study of warranties as signals. The recent changes in automobile warranty terms help identify the impact of warranties on consumer demand for new automobiles. Additionally, the necessary product, manufacturer, and consumer information are readily available for this industry. These data can be combined with existing, well developed econometric specifications to model directly the consumer utility underlying new automobile demand.[4]

In this paper, conditional and mixed logit models are applied to household level data from the *Consumer Expenditure Survey* to model new automobile purchasing behavior. Data from *Automotive News, Consumer Reports* and *Warranty Direct* are used to measure the degree to which warranties are valued as signals of product quality. The estimated models indicate that a longer warranty significantly increases the likelihood of a product being chosen. Moreover, we find evidence supporting signaling, not risk aversion, as the main motive for the observed consumer preference for longer warranties. Consistent with the signaling motive is the finding that longer warranties appear to be valued most for automobile models on which the consumer has the least *a priori* information – such as those yet to be rated by *Consumer Reports* and those offered by brands with which the consumer has no prior purchase experience.

[4]Prominent examples include Goldberg(1995), Berry(1994), Berry, Levisohn, and Pakes(1995), Brownstone and Train(1998), and Train and Winston(2007)

2 Signaling and warranty

In the information economics literature, adverse selection and moral hazard show how asymmetric information can complicate market operation; Akerlof (1970) provides the classic argument on how asymmetric information may hinder markets. Signaling theory argues that some informed agents may try to reduce this hinderance by sending signals to the uninformed agents. Spence (1977) argues that signaling facilitates the functioning of a perfectly competitive market when there is a lack of information. Grossman (1981) finds a similar result for single supplier markets. Gal-Or (1989) focuses on duopoly markets and argues the possibility of multiple equilibria. Warranties, such as those offered by automobile companies, are considered a common type of signal sent by "high quality" firms to reduce the consumers' information gap on the quality of their products.

Here, the term "quality" indicates unobservable product characteristics and, specifically, product durability. With the assumption that offering a warranty is more costly for firms producing "low quality" products, a warranty can be a credible signal of unobservable product durability. In the automobile industry, product failures are correlated with product quality. Therefore, the cost of offering a longer warranty will be higher for lower quality cars. Auto manufacturers offer two different types of warranties, "basic" and "powertrain." The former covers any part of an automobile and the latter the key components, namely the engine and transmission. For some brands, the basic warranty also covers maintenance costs, such as oil changes. The length of the two types of warranties, within a brand, are highly correlated each other. We use the powertrain warranty as it is the warranty most advertised by auto manufacturers.

The information asymmetry between consumer and manufacturer is high in the automobile industry due in large part to the significant number of new products released in

the market each year. When products are new, consumers have less information about product quality as they have much more limited access to past experience, word of mouth, and third party reviews for the new products. The combination of costly warranties and sizable asymmetric information suggests that warranties may serve as important signals of product quality in the automobile industry.

However, warranties are effective as signals only if manufacturers actually offer different warranty lengths based on their product quality, as in a separating equilibrium. If all firms offer the same warranty regardless of product quality, as in a pooling equilibrium, consumers cannot use warranties to infer relative product quality. The presence of costly warranties and asymmetric information does not ensure the existence of a separating equilibrium; if warranties are not sufficiently costly or if consumers do not sufficiently value product quality, a pooling equilibrium may still result.

There are varying lengths of warranty protection offered by manufacturers in the automobile industry. Not only do warranty terms differ across manufacturers, they also differ across product lines (or brands) offered by the same manufacturer. Lexus has a relatively longer warranty than a Toyota. Lincoln offers longer warranties than Ford. And Cadillac offers a longer warranty than most other GM brands. Under the assumption that a warranty is more costly for the firms producing "lower quality" products, variation in the length of car warranties is consistent with the existence of a separating equilibrium in the automobile industry. But the variation in warranties may not be intended as signals of unobservable product quality. It may simply be another form of product differentiation, no different from the variation in horsepower and fuel efficiency.

The literature raises four distinct motives for offering longer warranties.[5] First, manu-

[5]See Emons (1989)

facturers may use longer warranty as a signal of product quality, as discussed above. Second, a longer warranty may be offered as profitable insurance to risk averse consumers. Even if product information was symmetric between manufacturer and consumer, the manufacturer may still offer a warranty as the consumers may be more risk averse and/or the manufacturer better able to insure the risk. Third, differing warranty length across product offerings may be used by the manufacturer as a sorting device for second degree price discrimination. Fourth, a manufacturer may offer a warranty as a credible commitment against some moral hazard risk faced by the consumer. The warranty acts as a bond against possible *ex post* actions taken by the manufacturer that is harmful to the consumer. The nature of powertrain warranties allows us to focus exclusively on the first two motives.

Warranty length does not vary across models for the same brand. Combined with the fact that there are other, more prominent product differences across brands offered by the same manufacturer, it is unlikely that automobile manufacturers see warranties as a major sorting device.[6] Additionally, there is no obvious moral hazard problem that can be mitigated by a powertrain warranty. For new automobiles, product failure mainly depends on the *ex ante* actions of the manufacturer. However, the insurance motive remains viable as [1] it is reasonable to believe that a large corporation (automobile manufacturer) is less risk averse with respect to product failure than an individual household and [2] a manufacturer can, presumably, better offer insurance due to their ability to hedge the risk over all product sales. Thus, variation in warranty lengths may be due to firms targeting different segments of risk averse consumers (or differences in known failure risk across products), as well as attempts at signaling.

In an empirical study, directly controlling for consumer risk aversion may be imprac-

[6]This contrasts with warranties offered for other products, such as computer servers. See Chu & Chintaguna (2009)

tical due to the lack of suitable data. Suitable data would include expected utilities from both cases – when products fail and when products work well – and the associated risk premia. However, showing whether consumers reveal a strong risk aversion against product failure may be practical with the assumption that consumers are consistent in their response to similar types of risk. With such an assumption, consumer risk aversion can be inferred using consumer insurance expenditures on other matters, such as car liability, life, or property. Such insurance expenditure might proxy for consumer risk aversion. We infer a strong insurance motive for purchasing automobiles with long warranties if we observe that consumers who buy such automobiles also expend a greater amount on consumer insurance, in general.

A similar approach can be used to investigate the possible signaling motive underlying observed warranty differences. Signaling matters more to consumers for products for which consumers face more asymmetric information. The magnitude of asymmetric information will depend on the information available to the consumer prior to purchase. The source of this prior information may be separated into two general categories: private and public. Private sources are those that are idiosyncratic to the consumer – past purchase experiences and word of mouth from family and friends, for example. Public sources are those generally available to all consumers,such as published reviews in magazines and news reports and manufacturer advertisements.[7] The more prior information, both public and private, the consumer accumulates on the product, the less asymmetric information the consumer faces and the less attractive warranties are as signals of product quality.

In this empirical study, private sources of prior information are reflected by car brand fixed effects and "brand loyalty" variables indicating the consumer's past car purchase

[7] Among these, magazines and news reports are common in that third parties distribute the information. This is in contrast to advertisements, where producers directly convey the information.

history. The inclusion of the latter follows Train and Winston (2007) and is used to account for the influence of past purchases on the studied purchase. This influence may be due to prior information gained from past purchases, as well as other forms of brand loyalty.[8] We use three sets of "brand loyalty" variables: EXP1 is a dummy variable indicating whether consumers have previously purchased cars from the same manufacturer; EXP2 is a discrete variable indicating the number of vehicles from the same manufacturer in the consumer's car ownership history; and EXP3 is a dummy variable indicating whether consumers previously purchased cars from the same brand.[9] The brand fixed effects help account for the general word of mouth concerning automobiles from that brand. Car brands with substantial positive word of mouth should have larger brand dummies and brands with substantial negative word of mouth, smaller (perhaps negative) brand dummies.

Consumers may face different levels of asymmetric information based on their purchase history. When consumers have experience with a particular brand, they may have more information about the brand-specific component of unobserved product quality. Thus, the signaling value of a warranty will be higher, *ceteris paribus*, for automobiles offered by a brand from which the consumer has never purchased. For example, consumers who have bought Ford Taurus will place lower value on the warranty for Ford Focus (3 years and 36,000 mile) than the warranty for Chevrolet Malibu (3 years and 36,000 mile). The perceived value of warranties for automobiles offered by familiar vis-á-vis unfamiliar brands may help identify the signaling value of warranties.[10]

Car ratings from *Consumer Reports* are used to capture the information available to

[8]Train and Winston (2007) raises a possible identification issue. If unobserved consumer preference is correlated with the products they have chosen in the past and their current choice, the brand loyalty dummies may capture the unobserved consumers' preference along with the brand loyalty effect.

[9]Brands refer to product lines offered under one name and manufacturer the parent company that owns all of these brands. For example, 'Ford,' the manufacturer, has several brands: Ford, Mercury, and Lincoln.

[10]The intuition is analogous to Ackerberg (2001) which argues that the informative aspect of advertising should affect, more, consumers who have never tried the brand

consumers from public sources. *Consumer Reports* computes its ratings based on surveys of consumers who have purchased and used certain products, and therefore generally exclude new products. Since *Consumer Reports* ratings are based on surveys, they can be considered an indication of the general perception of product quality. The fact that *Consumer Reports* does not report on all car models may be exploited to identify models with particularly high levels of asymmetric information. For example, if consumers have plenty of information about the "tried and true" Toyota Camry but not enough about the newly introduced Toyota Matrix, then warranties, as product quality signals, may matter more for the Matrix than the Camry.

In general, variables that reflect available product information may help identify the extent of the signaling motive underlying available warranties. The extent to which longer warranties increase the estimated choice probability of a product with less prior information than one with more, *ceteris paribus*, indicates the extent to which the signaling motive drives observed warranty practices in the industry. We explore this insight using econometric specifications that interact the warranty length of an automobile with variables reflecting the available product information for that automobile.

3 Data and Empirical Specification

3.1 Data

Data on household purchases of new automobiles are obtained from the Consumer Expenditure Survey (CES) from 1998 to 2002. The CES is compiled from quarterly surveys which retain 75 percent of original respondents in the next wave, and replace 25 percent of the sample with new individuals. In each quarter of 1998, approximately 4500 households were surveyed, with the sample size of each quarter increasing to 7000 in 1999. After excluding households with data anomalies (e.g. significant missing data), the total number of ob-

served households is 52,361. Of this total, 1,173 households bought new cars. In addition to general household characteristics, data on insurance expenditures are also extracted from the CES.

Data on product characteristics are obtained from *Automotive News*. The main product characteristics include price, engine size and length of car. These characteristics are reported for automobiles at the trim level. For example, the Ford Focus has four different trim levels: 3-door, 4-door, 5-door, and wagon. The trim level data does not match perfectly with CES data since the CES data only reports model name and brand. A certain level of aggregation is, therefore, unavoidable. We aggregate product characteristics at the model level, so the characteristics of a Ford Focus will be the mean of those four trim level products. In *Automotive News*, cars are categorized into 7 classes based on vehicle size: budget, small, entry-medium, medium, large, sporty, and luxury. All 7 car classes will be considered in this study. Information regarding changes in warranties are obtained from Warranty Direct, an internet based company selling extended warranties. Data on car ratings are obtained from *Consumer Reports*.

Table (1) presents summary statistics for the data used in this study. The average consumer income is slightly higher than in other studies. This might be due to the fact that we focus only on consumers who bought a new car. For consumer characteristics, each quartile is not distributed evenly since cut-off points for the quartiles are derived from the entire CES sample, rather than the sub-sample used in estimation. Three income groups (low, middle, and high) are formed, and the cut-off points for these income groups are reported in table (2). The table also shows the percentage of consumers who belong to each income categories in the sub-sample used in estimation.

Table 1: Summary statistics

Variable	**Mean**	**Std. Dev.**
Vehicle Characteristics		
LENGTH	185.775	13.406
DISPLACEMENT	2.873	0.952
PRICE	27036.034	14015.904
WT	4.336	1.877
classD1	0.065	
classD2	0.14	
classD3	0.103	
classD4	0.168	
classD5	0.15	
classD6	0.093	
classD7	0.28	
Consumers' Characteristics		
INCOME	61287.537	52354.801
AUTO_INS_perC	0.019	0.058
1st Quartile Risk aversion	0.19	
2nd Quartile Risk aversion	0.28	
3rd Quartile Risk aversion	0.27	
4th Quartile Risk aversion	0.24	
Variables for Information of Vehicle		
rating	43.468	34.923
norate	0.364	0.481
EXP1	.22	.49
EXP2	.18	
EXP3	.04	

Table 2: Cut-off points for Income

Year	Cut-off(33%)	Cut-off(67%)
1998	20460	45545
1999	20275.25	47000
2000	20000	46000
2001	22429.5	51575
2002	25500	56004
% of consumers in each income categories		
Low Income	Middle	High
20.4 %	30.9 %	48.7 %

3.2 Vehicle choice model

We focus only on households observed purchasing a new automobile. This abstracts away two important margins: the margin between buying a car and not buying a car and between buying a new car and an used car. Moreover, we assume that each household considers buying, at most, one car in a given quarter.[11] We leave the relaxation of these assumptions to future research. We adopt an indirect utility specification similar to the one in Goldberg (1995), but extend it to include the impact of warranties. We differ from Goldberg (1995) in estimating the specification within the conditional and mixed logit frameworks, rather than the nested logit framework. We use the mixed logit to explore the relaxation of the "independence of irrelevant alternatives (IIA)" assumption. We also include car class and brand fixed effects. Although these two sets of fixed effects are used as nesting structures in Goldberg (1995), in our models the fixed effects capture the mean unobserved indirect utility from choosing a certain car class or brand.

Consumers maximize the following indirect utility associated with buying a new car

$$V_{ij} = \bar{V}_{ij} + \varepsilon_{ij} \tag{1}$$

where i is the index for household ($i = 1, 2, ..., I$) and j for product ($j = 1, ..., J$). V_{ij} indicates a consumer i's indirect utility from product j, and ε_{ij} indicates the component of the indirect utility unobservable to us (econometrician). The observable, deterministic component ($\bar{V}_{ij}$) is modeled as a known linear function of product and consumer characteristics including price (Z_{ij}), consumers' information about a certain product (X_{ij}), and warranty-related variables (W_{ij}).

$$\bar{V}_{ij} = \alpha' Z_{ij} + \beta' X_{ij} + \gamma' W_{ij} \tag{2}$$

[11] In the CES data, we observe no households who buy more than two new cars in the same year.

where α, β, and γ are the parameters of interest to be estimated.

The included product characteristics (Z_{ij}) are similar to those in previous vehicle choice studies.[12] We include displacement (DISP), length (LENGTH) and the difference between household income and retail price of the car ($Y_i - P_j$) as our main (non-warranty) vehicle characteristics. The ($Y_i - P_j$) specification for income and price imposes the strong assumption of constant marginal utility for after-purchase income. This implies that a dollar increase in after-purchase income will give the same utility at all income levels. We relax this assumption by separating income levels into three groups – low, medium, and high (Y_i^l Y_i^m Y_i^h) – and allowing the marginal utility to be constant within the group but different across the groups. We anticipate the marginal utility from an additional unit of after purchase income to be larger for low income than high income households.[13]

The variables reflecting the consumers' information (X_{ij}) include the "brand loyalty" variables (EXP1, EXP2, EXP3), the available rating of the automobile (RATE) from *Consumer Reports*, and a dummy (NORATE) indicating if no rating was available from *Consumer Reports*.[14] The warranty related variables (W_{ij}) are a set of interaction terms between the warranty length and relevant product and consumer characteristics. Specifically, warranty length is interacted with the car class dummies, with NORATE, with a dummy variable that indicate experienced brand (EXP3) and with our risk aversion proxies.

[12] See Goldberg(1995), Berry, Levison, and Pakes(1995), Brownstone and Train(1999), and Train and Winston(2007)

[13] The classification of income groups is explained in the appendix.

[14] The brand loyalty variables are based on the car ownership history questions in the *Consumer Expenditure Survey* Section 11 Part A.1

The indirect utility function, equation (2), can be fully expanded to

$$\begin{aligned} V_{ij} &= \alpha_1 LENGTH_j + \alpha_2 DISP_j + \alpha_3(Y_i^l - P_j) + \alpha_3(Y_i^m - P_j) + \alpha_3(Y_i^h - P_j) \\ &+ \beta_1 EXP1_{ij} + \beta_2 EXP2_{ij} + \beta_3 EXP3_{ij} + \beta_3 RATE_j + \beta_4 NORATE_j \\ &+ \sum_{class} \gamma_{class} WT_j * D_{class} + \gamma_1 NORATE_j * WT_j + \gamma_2 EXP3_j * WT_j \\ &+ \sum_{ra} \gamma_{ra} WT_j * D_{ra} + \sum_{class} \xi_{class} * D_{class} + \sum_{brand} \xi_{brand} * D_{brand} + \varepsilon_{ij} \end{aligned} \tag{3}$$

where α, β, γ and ξ indicate coefficients for product characteristics, information sets, warranty variables and fixed effects, respectively.

3.3 Measuring Risk Aversion

In order to distinguish between the risk aversion and signaling motives for warranty demand, we develop a proxy indicating the level of risk aversion for the sampled household based on observed (non-warranty) insurance expenditure. We use the total insurance expenditure on vehicles (liability, theft, property damage) reported for each household in the CES. The CES contains detailed questions on insurance expenditures by categories such as vehicle, house, and life. Vehicle insurance expenditure is used because the sampled households are much more likely to own this type of insurance than other types (life, home). This mitigates concerns associated with the discrete decision of whether to buy any insurance for that risk.

Using vehicle insurance expenditure as a direct proxy for consumer risk aversion has several problems. First, vehicle insurance expenditure varies with household income. Households with higher income are more likely to buy expensive cars, which are more costly to insure. Therefore, two households with the same level of risk aversion but with different income may spend a different absolute amount on insurance. Second, total insurance expenditure varies with the number of vehicles owned by the household. A larger (more cars) but less risk averse household may spend more on total vehicle insurance than a smaller

(fewer cars) but more risk averse household. In order to address these concerns, total vehicle insurance expenditure for the household is divided by household income and then by the number of cars owned. This variable indicates the per car average income share of vehicle insurance expenditure.

Similarly risk averse households living in different regions may still spend a different (per car) share of income on vehicle insurance if there are regional differences in the cost of insurance. In order to account for such regional differences, the distribution of the per car income share of vehicle insurance expenditure is examined for the four regions spanning the continental United States: Northeast, Midwest, South, and West. CES does inquire about the state of residence for each sampled household. However, this "state of residence" variable is reported missing for 20% of the sample. Furthermore, less populous states have only a few households represented in the sample – e.g. Delaware is represented by less than 80 households. As a result, we use regions rather than states. Lastly, we allow for the marginal cost of insurance to differ with the number of cars insured as, for example, the cost of ensuring a second car may be less than the cost of the first, leading to a lower average insurance cost. For each region, four different groups are created based on the number of cars owned (including current purchases): 1, 2, 3 and 4 or more. Distributions are calculated for each region and car ownership group.[15]

Instead of using the actual per car average income share, we use the quartile in which the share falls for the appropriate distribution for the household.[16] Using the quartiles allows us to consider each household's income share relative to other CES households residing in that region and having the same number of cars. For example, a household that owns a

[15]Four different CDF graphs (3) are reported in appendix in order to see the income share of auto expenditure based on the number of cars owned by consumers.

[16]This is the quartile with respect to all households in the CES sample, including those who did not purchase a new car.

single car, spends 2% of its income on auto insurance, and resides in the Northeast region belongs to the 3rd quartile. However, a household that spends the same 2%, resides in the same region, but owns a second car, belongs to the 4th quartile. In this way, we attempt to address regional differences in insurance costs and the marginal insurance cost difference based on the number of owned cars.[17]

3.4 Identification

Two key included product characteristics, warranty length and price, may depend on all product characteristics observable to the consumer, including those omitted from the indirect utility specification. This suggests that warranty length and price are both "endogenous" variables, correlated with the omitted but relevant product characteristics lumped with the additive error. Without properly addressing this endogeneity, some or all of the estimated warranty effect may actually be spurious correlation, unrelated to either the signaling or insurance motives. The empirical literature on consumer automobile demand suggests two possible identification strategies.[18]

One possible strategy, pioneered by Berry (1994) and Berry, Levinsohn, and Pakes (1995), uses instrumental variables (IV) within a framework that jointly models consumer demand and firm supply. Recently, Chu & Chintagunta (2009) uses this approach to mitigate price endogeneity (but not warranty endogeneity) in their study of warranties offered in the U.S. server market. Unfortunately, it is difficult to adapt this approach to address warranty endogeneity. Traditionally in the classic "BLP literature," the endogeneity of other included product characteristics is assumed away and/or argued to be minimal as

[17] The cut-off points for each quartile/region are reported in Table B. The actual CDFs are illustrated in Figure 2.

[18] Much of the empirical work on warranties relies on experimental data where price and warranty exogeneity is derived from experimental design – e.g. Dawar & Sarvary (1997), Srivastava & Mitra (1998), Purohit & Srivastava (2001), Chatterjee, Kang, & Mishra (2005). Few use observational data, the recent Chu & Chintagunta (2009) being the notable example

characteristics are fixed in the short-run (the included characteristics can only be changed with some lag).[19] However, such arguments are difficult to maintain for warranties. Operationally, changing a warranty is simple for a manufacturer and warranty length should vary with omitted product characteristics, for reasons similar to those of price. This necessitates a modeling of the firm's warranty length decision. Warranties are but one possible quality signal available to the manufacturer and there are no obvious observable "cost shifters" for the warranty supply decision.[20] Both complicate any explicit modeling of warranty supply.

An alternative strategy, adopted by Goldberg (1995) and Train & Winston (2007), uses cross-sectional variation available in household-level data. Product-specific fixed effects are incorporated into the indirect utility specification to help control for the mean effect of the omitted characteristics, mitigating price (and warranty) endogeneity due to correlation with omitted factors. The identification strategy relies on the standard maintained assumption that unobserved consumer taste heterogeneity is limited to the (*i.i.d.*) additive error (or assumed independent of the additive error, in the case of a model with random coefficients). In theory, the same product-specific fixed effects used to address price endogeneity can also be used to address warranty endogeneity. The main drawback to the approach is that it requires sufficiently rich data to allow for the estimation of product-specific fixed effects, in addition to the other included coefficients.

We adopt a version of the second identification strategy. Data limitations prevent us from estimating product (model) specific fixed effects with confidence.[21] Instead, brand and car class fixed effects are included in the indirect utility specification. The brand fixed effects should largely address warranty endogeneity as warranties vary across brands but not

[19] Note that warranties are an *omitted* characteristic in Berry, Levinsohn, and Pakes (1995). Thus, endogeneous warranties are not an explicit problem

[20] See Kirmani & Rao (2000) for a review of the signal mix literature

[21] For some models, we observe very few households purchasing the model

within, making warranties unlikely to be strongly correlated with model-specific omitted factors. Car class fixed effects allow the model to control for average omitted characteristics that vary across car classes. We believe that brand and car class fixed effects largely control for the variation in omitted automobile characteristics affecting pricing. But we acknowledge that the incomplete fixed effect specification raises the possibility that, in our estimation, some pricing effect may be confounded with the warranty effect – to the extent that the relevant omitted factors affecting pricing vary across models within brand or across models within car class. Lastly, we relax some (but not most) of the required restrictions on consumer taste heterogeneity by introducing random coefficients and interacting product characteristics with observed consumer characteristics.

3.5 Estimation

The empirical specification described in the previous section is estimated using two different discrete choice models, the conditional logit and the mixed logit. The benefit of the conditional logit is its computational simplicity, which comes at the cost of a restrictive substitution pattern stemming from the "IIA" assumption. The mixed logit allows for a more flexible substitution pattern by allowing some heterogeneity in consumer preferences for observed choice characteristics. However, estimating the mixed logit model incurs a much greater computational burden, one that increases with the degree of heterogeneity in consumer preference.

Let $\theta = \{ \alpha \, \beta \, \gamma \}$ denote the set of taste parameters to be estimated and $\theta_{mixed} \subset \theta$ the subset allowed to vary across consumers. While we do not observe the actual heterogeneity in consumer tastes, we assume that the distribution that characterizes this heterogeneity over the consumer population is multivariate normal: $\theta_{mixed} \sim N(\mu_{mixed} \, , \, \Sigma_{mixed})$.[22] Under

[22] We assume each random coefficient in θ_{mixed} is independent of each other, making Σ_{mixed} a diagonal matrix.

the assumption that these random taste coefficients are independent of the additive logit error ε_{ij}, the random coefficients can be "integrated out" of the standard logit likelihood to yield the mixed logit likelihood for consumer i choosing vehicle j

$$P_{ij} = \int \left(\frac{e^{V_{ij}(\theta)}}{\sum_j e^{V_{ij}(\theta)}} \right) \phi(\theta_{mixed}) \, d\theta_{mixed}$$

where $\phi(\theta_{mixed})$ is the multivariate normal density function mentioned above.[23]

We present estimates from the conditional logit model and a mixed logit model where consumer preferences are allowed to vary with respect to five choice characteristics: the difference between income and price $(Y_i - P_j)$, the interactions between warranty length and the risk aversion proxies, and the interaction terms between warranty length and information variables (NORATE, EXP3).[24] This particular mixed logit model allows consumers to vary in how income/price, risk aversion, and information asymmetry each affect their choice of vehicle. The mixed logit model is estimated using the public GAUSS code made available by K. Train, D. Revelt, and P. Ruud.[25]

4 Results

Estimates from the conditional logit and mixed logit models are reported in Tables 3 and 4, respectively. For the conditional logit table, the second column presents estimates from a simpler specification which excluded brand fixed effects (but kept car class fixed effects). The third column presents estimates from our full specification.

Comparing across columns in Table 3 provides some indication of how the inclusion of brand fixed effects alters the inference drawn on consumer preference for new automobiles. Many of the estimates are qualitatively similar between the two specifications. However,

[23] See Train (2003) for more details on the mixed logit model.
[24] i.e. $\theta_{mixed} = \{ \alpha_3 \ \alpha_4 \ \alpha_5 \ \gamma_{ra} \ \gamma_1 \ \gamma_2 \}$
[25] See http://elsa.berkeley.edu/Software/abstracts/train0296.html

Table 3: Estimation results : Conditional logit Result

Variable	**Coeff.**	**(S. E.)**	**Coeff.**	**(S. E.)**
length	0.004*	(0.002)	0.008**	(0.003)
Displacement	0.095	(0.060)	-0.005	(0.075)
Consumer Reports rating	-0.002	(0.003)	-0.010**	(0.004)
No rating on Consumer Reports	-1.182**	(0.270)	-1.694**	(0.300)
Number of previously owned car for a certain manufacturer	0.537*	(0.246)	0.578*	(0.241)
Consumer's previous experience of a certain manufacturer	6.323**	(0.425)	6.645**	(0.437)
Consumer's previous experience of a certain brand	1.087**	(0.273)	0.970**	(0.285)
Warranty * (budget)	0.130	(0.089)	-0.092	(0.104)
Warranty * (small)	0.291**	(0.073)	0.214*	(0.094)
Warranty * (entry-medium)	0.207**	(0.077)	0.096	(0.099)
Warranty * (medium)	0.203*	(0.083)	0.088	(0.103)
Warranty * (large)	0.135	(0.092)	-0.021	(0.115)
Warranty * (sporty)	0.216†	(0.116)	0.036	(0.134)
Warranty * (luxury)	0.192†	(0.116)	0.513**	(0.174)
class (small)	-0.445	(0.332)	-0.700†	(0.372)
class (entry-medium)	-0.241	(0.352)	-0.362	(0.405)
class (medium)	-0.226	(0.358)	-0.285	(0.412)
class (large)	-0.649	(0.423)	-0.226	(0.500)
class (sporty)	-1.220*	(0.510)	-1.045†	(0.554)
class (luxury)	-1.642**	(0.560)	-2.533**	(0.736)
Income -price Low	0.010	(0.011)	0.006	(0.012)
Income -price Mid	0.011	(0.009)	0.004	(0.010)
Income -price High	-0.020**	(0.007)	-0.022**	(0.008)
Warranty * Risk aversion (2nd quartile)	0.100	(0.083)	0.062	(0.085)
Warranty * Risk aversion (3rd quartile)	0.007	(0.089)	-0.010	(0.092)
Warranty * Risk aversion (4th quartile)	-0.045	(0.099)	-0.101	(0.102)
Warranty * NORATE	0.046	(0.038)	0.078†	(0.040)
Warranty * experienced brand	-0.135†	(0.070)	-0.181*	(0.071)
log likelihood		-3030.51		-2848.37
†: significant at 10 %	Class	dummies	Class	dummies
*: significant at 5 %			Brand	dummies
**: significant at 1 %				

Table 4: Estimation results : Mixed logit Result

Variable	**Coeff.**	**(S. E.)**	**Coeff.**	**(S. E.)**
length	0.004*	0.002	0.008**	0.003
Displacement	0.118†	0.063	0.004	0.076
Consumer Reports rating	-0.001	0.003	-0.010**	0.003
No rating on Consumer Reports	-1.159**	0.272	-1.698**	0.303
Number of previously owned car for a certain manufacturer	0.552*	0.247	0.626*	0.251
Consumer's previous experience of a certain manufacturer	6.362**	0.430	6.681**	0.448
Consumer's previous experience of a certain brand	1.106**	0.277	1.023**	0.348
Warranty * (budget)	0.142	0.090	-0.105	0.112
Warranty * (small)	0.303**	0.075	0.209*	0.100
Warranty * (entry-medium)	0.222**	0.079	0.093	0.105
Warranty * (medium)	0.221**	0.085	0.085	0.109
Warranty * (large)	0.156†	0.093	-0.021	0.120
Warranty * (sporty)	0.226†	0.117	0.031	0.139
Warranty * (luxury)	0.199†	0.119	0.519**	0.180
class (small)	-0.402	0.335	-0.711	0.379
class (entry-medium)	-0.173	0.356	-0.370	0.413
class (medium)	-0.104	0.368	-0.269	0.421
class (large)	-0.501	0.432	-0.217	0.508
class (sporty)	-1.049*	0.522	-1.014†	0.564
class (luxury)	-1.407*	0.588	-2.531**	0.754
Random Parameters				
Income -price (Low income)	0.019	0.012	0.009	0.013
Standard Deviation	0.003	0.035	0.003	0.037
Income -price (Mid income)	0.035*	0.015	0.016	0.014
Standard Deviation	0.048**	0.013	0.036*	0.016
Income -price (High income)	-0.008	0.011	-0.019*	0.0095
Standard Deviation	0.026†	0.013	0.011	0.026
Warranty * Risk aversion (2nd quartile)	0.094	0.085	0.083	0.094
Standard Deviation	0.006	0.104	0.001	0.101
Warranty * Risk aversion (3rd quartile)	-0.002	0.090	-0.003	0.101
Standard Deviation	0.003	0.190	0.007	0.164
Warranty * Risk aversion (4th quartile)	-0.057	0.101	-0.090	0.109
Standard Deviation	0.005	0.118	0.005	0.112
Warranty * NORATE	0.049	0.039	0.078†	0.041
Standard Deviation	0.008	0.057	0.020	0.065
Warranty * Experienced brand	-0.141*	0.072	-0.198*	0.092
Standard Deviation	0.016	0.107	0.217†	0.111
log likelihood		-3027.38		-2846.47
†: significant at 10 %	Class	dummies	Class	dummies
*: significant at 5 %			Brand	dummies
**: significant at 1 %				

the full specification (with brand effects) has more counterintuitive estimates for preferences in car characteristics: Consumers seem to prefer *less* displacement and *worse* rating from *Consumer Reports*. The estimated coefficients for after-purchase income is also puzzling. Consumers in low and middle income groups prefer to buy inexpensive cars, as we expected. However, the coefficient for the high income group is negative and statistically significant, suggesting that high income consumers have a *distaste* for greater after-purchase income. This counter-intuitive might be plausible if high income consumers highly prefer expensive (or luxurious) cars. This may be further plausible if manufacturers of luxury cars use price as a signal of product quality.

The conditional logit results from the simple model are mostly consistent with the results for the mixed logit model from the same specification, except for the coefficient of after-purchase income variable for low and middle income group. In the mixed logit model, those coefficients gain statistical significance and estimates of standard deviation for those variables also show statistical significance, suggesting that consumers indeed have a heterogeneous preference for after-purchase income. In the full model, the estimates from the conditional logit model are also consistent with the estimates from the mixed logit results except preference for displacement. Although the preference for cars with greater displacement is not statistically significant, the coefficient for this variable has a positive sign in the mixed logit, unlike the result in the conditional model. The difference between the conditional and mixed logit models might suggest that the counterintuitive preferences estimated for the conditional logit models may be an artifact of the restrictive IIA substitution pattern.

We focus on the estimates for the mixed logit model, as they seem to align best with conventional wisdom. We find some difference in the impact of warranties across

car classes. In the simple model (without brand fixed effects), warranties seem to matter differently based on car class, but the warranty effect on different car classes decreases after including brand fixed effects. This suggests the importance of controlling for warranty endogeneity, as otherwise the estimated warranty effect may be biased substantially upward due to correlation with omitted automobile characteristics.

In the full model, warranties seem to matter primarily for the "small" and "luxury" car classes and hardly at all for the larger, non-luxury classes. A possible reason, consistent with the signaling motive, is that these car classes are the ones targeted by consumers with the least brand experience – as suggested by a life cycle model of automobile purchases where consumers initially purchase small cars and transition to larger cars as they grow wealthier. A consumer considering a Ford Taurus (medium) may have experience with Ford from an earlier purchase of the smaller Ford Focus (small). But luxury cars are sold primarily by brands that only produce luxury cars. So, a first time consumer of a luxury car would be unfamiliar with most luxury brands.

Further supporting this view is our finding that consumer information matters greatly in warranty valuation. The estimated impact of the brand loyalty variables are positive, with all three experience variables having both a statistically significant and substantial impact on the consumer's indirect utility from automobiles of the same brand. But the interaction between warranty and brand experience is strongly and statistically negative, indicating that consumers value warranties much less for experienced brands. For small cars, warranties effectively have no mean impact ($0.209 - 0.198 = 0.002$) on the indirect utility of consumers with brand experience. This may also be true for luxury cars, despite the much larger luxury car warranty coefficient, as the estimate of the standard deviation of warranty / brand experience interaction coefficient is substantially large, as large as the

estimate of the mean. This suggests that consumers value warranties as substitutes for personal brand experience.

Additionally, we find that consumers heavily discount cars that have no *Consumer Reports* rating but *less* so for those that come with a longer warranty. Cars with no rating in the *Consumer Reports* are generally cars with relatively little history. This result of warranty lengths mattering much more for cars with no rating further supports the signaling motive, as NORATE cars are among those with the greatest asymmetric information between consumers and producers. The result that the value of warranty depends on other product information available to the consumers – whether first party brand experience or third party *Consumer Reports* information – follows those in the experimental literature on warranty, which show the moderating effect of consumer knowledge on warranty valuation.

The above results contrast those for the insurance motive. If risk aversion is a strong motive underlying warranty demand, we would expect the coefficients for the interaction between warranty and our risk aversion proxies to be positive. Moreover, they should be increasing with the quartiles: $0 < \gamma_{2Q} < \gamma_{3Q} < \gamma_{4Q}$. None of the four models exhibit statistical significance for any quartile of risk aversion and the signs of risk aversion coefficients are contrary to our expectation. Taken at face value, this implies that risk aversion might not be a strong motivation for preference of longer warranty cars.

However, there is a possibility that the proxy for risk averse consumers might not capture the true underlying risk averse behavior of consumers. We have tried using other specifications of consumer (non-warranty) insurance expenditures as our risk aversion proxy – yielding similar qualitative results. This suggests that, assuming consumer risk aversion toward automobile liability risk is similar to that of automobile product failure, the insur-

ance motive is not a major motive underlying powertrain warranty offerings.[26]

4.1 Marginal effect

Based on the estimates from the conditional logit and mixed logit models, we can calculate the marginal effects of the models. The marginal effects are calculated using the average of each studied individual's marginal effects rather than the marginal effects of a "representative" individual with the average value for each explanatory variable. For non-binary explanatory variables, the reported marginal effect is the average across each individual probability derivative, for the observed actual choice and explanatory variable of focus. For example, the marginal effect of car length is calculated as follows:

$$\frac{1}{N}\sum_{i=1}^{N}\frac{\partial \hat{P}_{ij}}{\partial \text{length}_{j(i)}} = \frac{1}{N}\sum_{i=1}^{N}\hat{\alpha}_1 \hat{P}_{ij(i)}(1-\hat{P}_{ij(i)}) \tag{4}$$

where $j(i)$ is the product observed chosen by i, $\hat{P}_{ij(i)} = \frac{e^{V_{ij(i)}}}{\sum_j e^{V_{ij(i)}}}$ the estimated probability that consumer i chooses product $j(i)$, and $\hat{\alpha}_1$ the estimated coefficient for the car length.[27] For binary explanatory variables, the reported marginal effect is the average of the *difference* between the *actual* estimated probability for the observed choice and the *counterfactual* estimated probability for the observed choice, assuming that the value of the binary explanatory variable of focus is zero.[28] The probability difference provides a more natural interpretation than the probability derivative for binary explanatory variables.

Table (5) shows the marginal effects calculated from the conditional and mixed logit estimates. The reported marginal effects reflect how the probability of a consumer's observed choice changes with shifts in the value of a single explanatory variable. For example,

[26] Alternatively, future research might improve upon this one by explicitly modeling risk aversion from a CRRA or CARA utility framework. Such approach requires more information than we have – e.g. some measure of the product failure risk itself

[27] For the mixed logit model, the probability derivative is calculated using the mean coefficient estimates

[28] For observed choices whose true value of the binary explanatory variable is zero, the contribution to the reported marginal effect is zero, as actual and counterfactual are the same.

Table 5: Marginal Effects

Variable	**Conditional logit**		**Mixed logit**	
	(1)	**(2)**	**(3)**	**(4)**
length	0.0004	0.0009	0.0004	0.0009
Displacement	0.0090	-0.0007	0.0113	0.0004
Consumer Reports rating	-0.0002	-0.0011	-0.0001	-0.0011
No rating on Consumer Reports	-0.0711	-0.1038	-0.0712	-0.1053
Number of previously owned car for a certain manufacturer	0.0531	0.0654	0.0531	0.0689
Consumer's previous experience of a certain manufacturer	0.0061	0.0061	0.0062	0.0061
Consumer's previous experience of a certain brand	0.0943	0.0936	0.1000	0.1028
Warranty * (budget)	0.0133	-0.0117	0.0136	-0.0115
Warranty * (small)	0.0285	0.0217	0.0291	0.0230
Warranty * (entry-medium)	0.0206	0.0088	0.0213	0.0102
Warranty * (medium)	0.0203	0.0080	0.0212	0.0093
Warranty * (large)	0.0138	-0.0041	0.0150	-0.0022
Warranty * (sporty)	0.0214	0.0019	0.0217	0.0034
Warranty * (luxury)	0.0194	0.0547	0.0191	0.0571
Income -price Low	0.0010	0.0006	0.0018	0.0010
Income -price Mid	0.0010	0.0004	0.0034	0.0018
Income -price High	-0.0019	-0.0025	-0.0007	-0.0021
Warranty * Risk aversion (2nd quartile)	0.0088	0.0122	0.0090	0.0090
Warranty * Risk aversion (3rd quartile)	-0.0009	-0.0022	-0.0001	-0.0003
Warranty * Risk aversion (4th quartile)	-0.0016	-0.0070	-0.0055	-0.0099
Warranty * NORATE	0.0044	0.0086	0.0047	0.0086
Warranty * Experienced brand	-0.0127	-0.0193	-0.0135	-0.0218
Column (2) and (4) indicate the results from models with brand fixed effects				

when the warranty of a small car increases by one year, the average consumer choice probability increases by 2.30 % (5.7 % for luxury car). The table also demonstrates the strong role of brand loyalty, a finding also found in Train & Winston (2007) – brand experience increases average consumer choice probability by 10 %.

In the appendix, we report the marginal effects for select brand dummies. The excluded brand was Suzuki. A positive value indicates preference over Suzuki and brands with larger values are those that, on average, are valued more than others, after controlling for the included explanatory factors. The calculations suggest that for equivalent makes sold for the same price, the Honda or Toyota branding increases the choice probability eight to ten percentage points. But a Chevrolet or Ford branding reduces the choice probability eight to nine percentage points. These marginal effects calculations suggest the presence of important, heterogeneous brand reputations.

4.2 Warranties and Branding

Warranties are but one signal of product quality available to automobile manufacturers. Another important potential signal is brand reputation. To examine possible trade-offs between warranty length and branding, we examine the degree to which longer warranties seem to offset differences in the estimated brand dummy, our best proxy for brand reputation. We compare Hyundai to Honda, and Lexus to BMW. Hyundai is the newer, lower reputation firm in the small/medium car categories and Honda the category leader. Similarly, Lexus is the newer, lower reputation firm in the luxury category and BMW the category leader.[29] In both comparisons, the newer firm (in 1998) offers a 2 year longer powertrain warranty; Hyundai offers 5 years compared to Honda's 3 years and Lexus 6 years compared to BMW's 4 years.

[29] Hyundai began U.S. sales in 1986, Lexus in 1989. Our study period begins in 1998

We consider three scenarios. In all scenarios, the consumer is assumed to be among the least risk averse (no warranty effect from risk aversion). In the first scenario, we assume both models – that of the newer firm and category leader – are unrated by *Consumer Reports* and the consumer has no past purchase experience with either brand; the difference in product quality information between the two models is strictly the difference in brand reputation, as captured by their brand dummies. In the second scenario, we allow the model by the category leader (Honda or BMW) to be rated by *Consumer Reports*; the consumer has additional third party information on the make by the category leader but not the newer firm. In the last scenario, we allow the model by the category leader to be rated by *Consumer Reports* and the consumer to have previously purchased a car from the category leader; the consumer has additional first *and* third party information on the category leader. We consider scenario two to be the most applicable, as consumers usually have some third party information about the category leader's make but perhaps not any based on personal experience. Table (6) summarizes the results across these three scenarios.

Table 6: Brand Dummy and Warranty Analysis

		Brand Dummy + Warranty Effect		
		Scenario 1	Scenario 2	Scenario 3
Firm	Brand Dummy	unrated, unexp	rated, exp	rated, exp
Honda (3 years)	2.9842	3.8452	3.6112	3.0172
Hyundai (6 years)	0.8731	2.3081		
Hyundai (8 years)	0.8731	3.1691		
Hyundai (10 years)	0.8731	3.7431		
Hyundai (11 years)	0.8731	4.0301		
BMW (4 years)	3.1223	5.5103	5.1983	4.4063
Lexus (6 years)	0.8562	4.4382		
Lexus (8 years)	0.8562	5.6322		

The difference in the estimated brand dummy between Honda and Hyundai is 2.984 - 0.873 = 2.111. Each additional year of powertrain warranty (small car, unrated, unexperi-

enced) adds 0.209 + 0.078 = 0.297 to the indirect utility of the consumer. For scenario one, this implies that Hyundai would need to offer an eight year longer warranty to offset its brand dummy disadvantage to Honda. For scenarios two and three, Hyundai offers not only a longer but also more valuable warranty, as there is more information for Honda (rated, experienced). This reduces Hyundai's needs to a seven and five year longer warranty, for scenarios two and three respectively. This suggests that Hyundai's two year longer warranty in 1998 was inadequate to compensate for Honda's greater reputation.[30] Hyundai's decision, in 1999, to expand its powertrain warranty from five to ten years, making its warranty seven years longer than Honda's, further corroborates our conclusion.[31]

The difference in the estimated brand dummy between Lexus and BMW is 3.1223 - 0.8562 = 2.2661. Each additional year of powertrain warranty (luxury car, unrated, unexperienced) adds 0.519 + 0.078 = 0.597 to the indirect utility of the consumer. For scenario one, this implies that Lexus would need to offer a 4 year longer warranty to offsets its brand dummy disadvantage to BMW. For scenarios two and three, Lexus offers a longer and more valuable warranty. For scenario two, Lexus still needs to offer a 4 year longer warranty but for scenario three, where BMW is both rated and experienced, the need falls to 2 years – precisely what Lexus offers. This suggests that Lexus' longer warranty is aimed primarily at experienced BMW consumers. The longer warranty does not sufficiently address perceived quality difference for first-time luxury car consumers. A possible reason for Lexus not offering a longer warranty may be that the parent company, Toyota, expects Lexus' reputation to catch up quickly, as Toyota is a quality leader in other car segments.

The above analysis suggests (but does not conclude) that automobile manufactur-

[30]The two year longer warranty, however, seems sufficient to offset Hyundai's reputation deficit with its other main competitors in the small car category, Chevrolet (dummy = 1.103) and Ford (dummy = 1.409).

[31]Hyundai's U.S. market share increased from 1% in 1999 to 2.4% in 2000

ers engage in interesting trade-offs among its possible product quality signals. A more conclusive analysis requires explicit modeling of automobile supply with endogenous firm signaling.

5 Conclusion and further research

In this paper, we seek empirical evidence on the role of warranties as signals of unobservable product quality. We adapt the linear random utility model of consumer automobile demand to investigate the extent to which warranties affect consumer choice and the extent to which this estimated warranty effect is due to the risk aversion and signaling motives. We strive for the latter goal by incorporating interactions between warranty length and measures of risk aversion and consumer product information into the consumer indirect utility function. We do not find direct evidence supporting the risk aversion motive for warranties but we find strong evidence for the signaling motive, with warranties more valuable for automobiles associated with which the consumer has no previous purchase experience and for which there are no *Consumer Reports* ratings.

Our finding of a stronger role of signaling than risk aversion is not entirely unexpected. With the presence of third party warranties, consumers who are unhappy with the level of warranty protection offered by the manufacturer can choose to buy additional warranty on their own. The bundling of warranty and automobile by the manufacturer matters, risk aversion-wise, to the extent that manufacturers can offer warranties at a lower cost than third party providers. This contrasts with the availability of third party signals of product quality. While published reviews in magazines and news reports act as third party signals, they can be much less informed signals than those sent by a manufacturer, especially for new products.[32] All of this suggests that signaling should be a more important motive for

[32]For example, magazines like *Motor Trend* may be informative about the current performance of a new

warranties in the automobile industry than risk aversion.

In terms of future research, estimating richer specifications that provide more direct measures of risk aversion and signaling motives for warranties will lead to a more complete picture of consumer perception of warranties as signals of product quality. This paper only focuses on the behavior of consumers. In order to understand how warranties work as signals of product quality, the producer side also needs to be analyzed – including how producers choose their signal mix. Our finding that consumers seem to value warranty primarily for automobiles from unexperienced brands suggests imperfect substitution between warranty and brand reputation. Automobile manufacturers may view particularly long warranties only as a transitional strategy, until their brand reputation "catches up."

car but less about its untested durability.

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A Market share changes after warranty changes

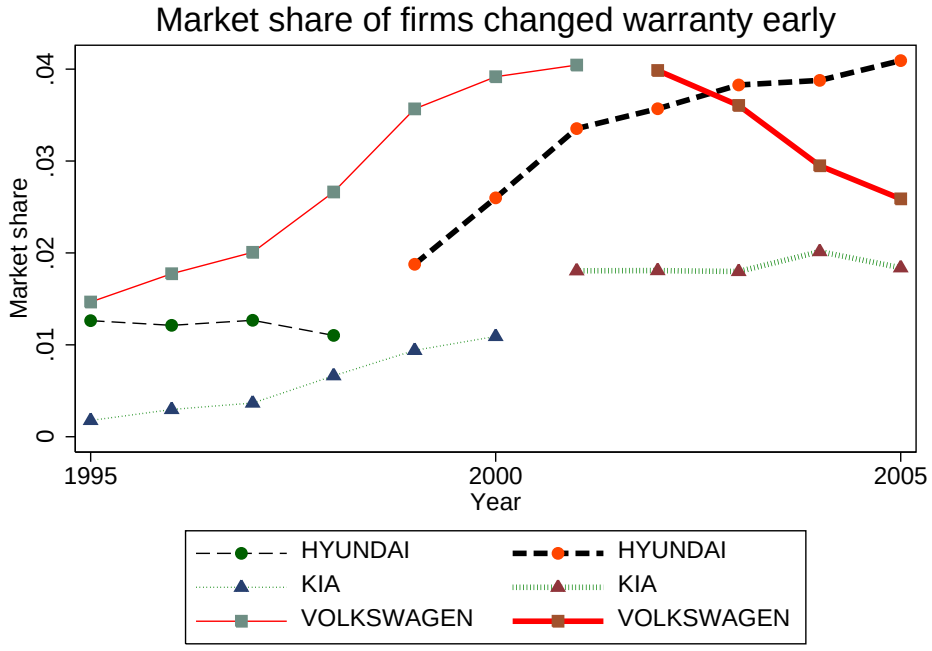

Figure 1: Market share changes over time

Maker	Warranty	Change	Before	After
Hyundai	5y/56km	10y/100km 1999	1.1	1.87
Kia	5y/56km	10y/100km 2001	1.09	1.80
VW	10y/100km	5y/60km 2002	4.0	3.9
* y: year and km: 1000mile				

In the figure 1, the disconnected line indicates when the warranty has been changed. In the table (A), Before and After indicates market share before and after warranty changes. Chrysler and Dodge are not included since both firms increased the length of warranty in 2001 and decreased warranty in 2002. Warranty of both firms were 3 year and 36km in 2000, 10 year and 100 km in 2001, and 7 year and 70km in 2002.

B Cut-off points for risk aversion

Figure (2) shows the overall distribution for each region. Figure (3) shows the distribution for each region and number of cars owned. The difference in the distributions across the car ownership graphs suggest changes in the marginal insurance cost. Table (B) shows cut-off points used to distinguish the different level of consumers' risk aversion. The cut-off difference are bigger for the number of cars owned by consumers than regional difference.

Table B: Percentile scores

REGION	Number of Cars	Cut-off(25%)	Cut-off(50%)	Cut-off(75%)
Midwest	1	0.0017	0.0123	0.0272
Midwest	2	0.0025	0.0067	0.0139
Midwest	3	0.0026	0.0053	0.0098
Midwest	4	0.0020	0.0044	0.0081
Northeast	1	0.0017	0.0140	0.0330
Northeast	2	0.0029	0.0075	0.0160
Northeast	3	0.0028	0.0058	0.0116
Northeast	4	0.0025	0.0056	0.0113
South	1	0.0004	0.0127	0.0315
South	2	0.0024	0.0070	0.0153
South	3	0.0022	0.0059	0.0118
South	4	0.0018	0.0048	0.0089
West	1	0.0022	0.0124	0.0284
West	2	0.0025	0.0067	0.0136
West	3	0.0025	0.0057	0.0114
West	4	0.0022	0.0048	0.0093

C CDF of income share of auto insurance expenditure

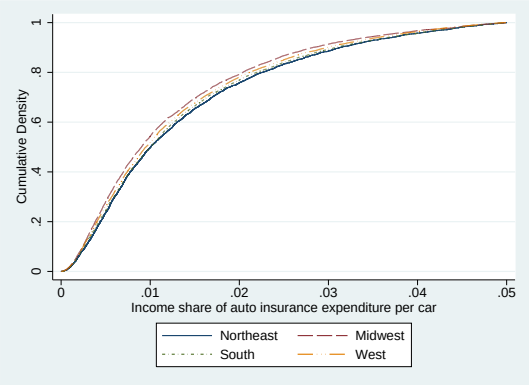

Figure 2: CDF of income share of Auto Insurance expenditure per car

The figure (2) shows that cumulative density function of income share of auto insurance expenditure by region, and the figure (3) shows the CDF by region and a number of owned cars. These figures indicates that consumers' auto insurance expenditure differs based on region and a number of cars that consumers owned.

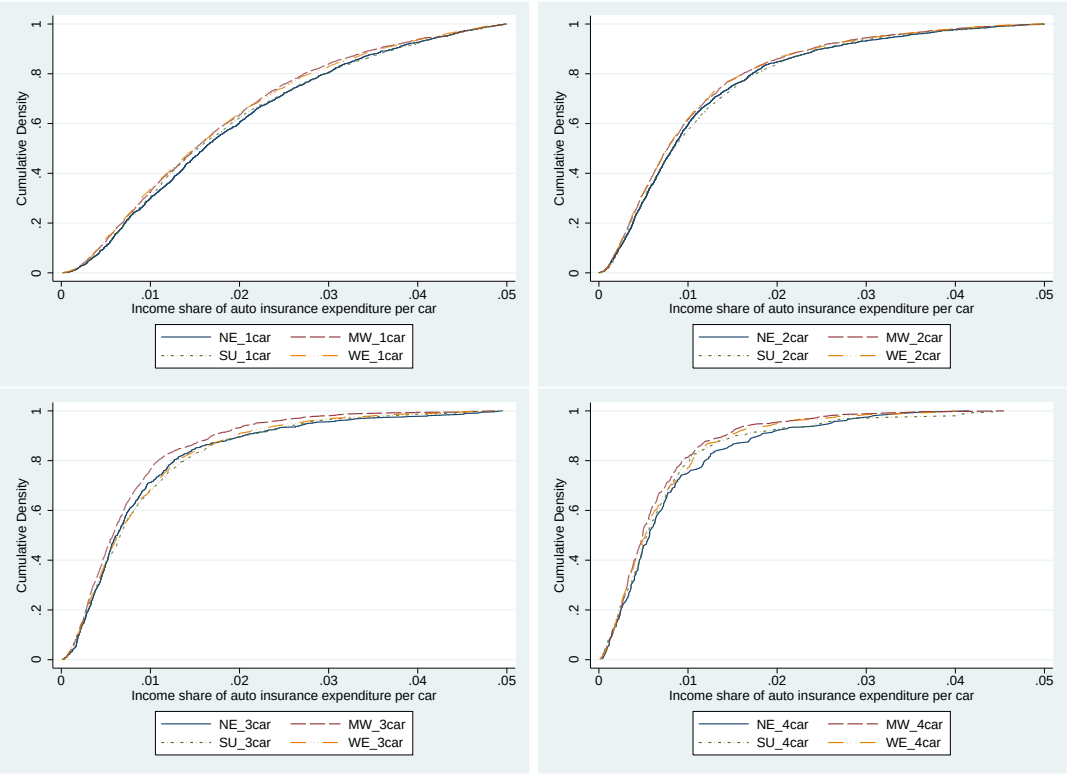

Figure 3: CDF of income share based on number of owned cars

D Marginal effects

Table 7: Marginal Effects on major brand dummy variables

Brand	**Conditional logit**		**Mixed logit**	
	Coefficient	**Marginal effect**	**Coefficient**	**Marginal effect**
CHEVROLET	1.362	-0.083	1.103	-0.085
FORD	1.650	-0.080	1.409	-0.081
HONDA	3.229	0.109	2.984	0.097
HYUNDAI	1.147	-0.105	0.873	- 0.108
MAZDA	0.590	-0.124	0.331	-0.125
SATURN	1.316	-0.098	1.039	-0.101
TOYOTA	3.068	0.076	2.918	0.086

Table (7) shows the marginal effects of major brand dummy variables. The marginal effect is calculated by the difference in the probability.