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WARRANTY POLICY AND EXTENDED SERVICE CONTRACTS: THEORY AND AN APPLICATION TO AUTOMOBILES

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This paper characterizes the manufacturer warranty policy and its effect on consumer behavior under the following conditions: consumers are heterogeneous in risk-preferences, consumer actions affecting the probability of warranty redemption are unobservable to the manufacturer, and the product reliability is known. We obtain the "menu" of warranty contracts, and then make connections with its institutional counterpart: the extended service contract.

The model's implications for consumer behavior are examined using data obtained from a sample of recent buyers of new cars. The role of risk in consumer behavior with respect to choice of extended service contracts, and the allocation of effort for maintenance are found to be consistent with the model's predictions.

The empirical analysis permits quantifying the demand for extended service contracts as a function of the extent of manufacturer warranty. The estimates show that for our sample of buyers a manufacturer warranty of three years is optimal in the sense of overcoming the role of risk-aversion in the choice of extended service contracts.

(Warranty; Extended Service Contract; Consumer Heterogeneity; Risk Aversion; Moral Hazard)

1. Introduction

Chrysler, General Motors, Ford and the Japanese manufacturers are currently engaged in a warranty war. In the home appliance market, General Electric, Maytag and Lennox all promote their "Satisfaction Guaranteed" programs. These campaigns emphasize the manufacturer warranty which refers to the coverage provided by the manufacturer with the purchase of the product (hence the term base warranty). Consumers who desire added warranty protection can purchase additional coverage in the form of extended service contracts (henceforth referred to as ESC). These contracts, which are the optional component of the overall product warranty, have also become increasingly important to firms. The profit at Ford from sales of ESC exceeds $100 million (Menezes 1988). Sears reports sales in excess of $1 billion of ESC in 1991 (*San Francisco Chronicle*, January 20, 1992).

These examples evidence at a minimum the growing prominence of product warranty in the marketing mix for a product. The research literature in marketing is beginning to pay attention to this topic (e.g., Menezes and Currim 1992). This paper investigates the effect of consumer moral hazard and consumer variation in the demand for insurance. The analysis provides insights into the determination of both the base warranty for a

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product as well as ESC. We empirically validate some of the predictions of this theory with data from a survey of new car buyers. The empirical analysis also helps provide managers with some insight on the relationships between base warranty and service contracts and its implications.

An interesting aspect of product warranty is its relationship with product quality. The firm's ability to support a warranty clearly depends on the quality of the product. The literature in marketing (Hauser and Clausing 1988) and operations management (Garvin 1992) highlights the relationship between quality and reputation, quality commitment and employee motivation and the interfunctional connections between quality, design and manufacturing. These issues related to quality are important and need to be considered in setting the overall warranty policy.[1] We concentrate in this paper on the analysis of the impact of consumer moral hazard and heterogeneity on warranty policy. While the quality issue is important, we will take quality as given and not consider the quality-warranty tradeoff in the paper. This is because we believe that moral hazard and heterogeneity play a critical role in warranty policy, especially in the provision of ESC, and adding quality provision to the model would detract from our desire to focus on analysis of the impact of these variables on warranty policy. While moral hazard and heterogeneity form only part of the warranty puzzle, they are important given the potential for consumer underinvestment in effort and the need for the firm to guard against it.

2. Relationship to Prior Work

The extant literature has largely concerned itself with motivations for offering product warranties. Heal (1977) advanced the idea that warranties can be thought of as providing insurance to consumers against the risks associated with product failure. The marketing literature (e.g., Bearden and Shimp 1982, Menezes 1989) has also largely concerned itself with this role for warranties in mitigating consumer risk.

Another motivation for the firm to offer a product warranty is to provide consumers with assurance of product quality. Akerlof (1970) demonstrates how in a market in which consumers are not sure of product quality, bad products drive the good products out. Spence (1973) and Grossman (1981) demonstrate that this situation can be avoided by a product warranty serving as a "credible signal" of product quality. The signal is credible, i.e., consumers correctly expect products with higher warranty to be more reliable because the lower-quality firm cannot afford to match the higher warranty due to higher redemption costs. Chrysler's unilateral hike in base product warranties in the early eighties is an example of an attempt to convey the product's reliability. Courville and Hausman (1979) show that the market system provides the appropriate solution in terms of provision of warranty and reliability and no external intervention is required. Lutz (1989) discusses the finer details of whether and how warranties serve as signals of quality under conditions of consumer moral hazard.

Cooper and Ross (1985) demonstrate that warranty has a useful role to play if the seller and the buyer can each affect product reliability by actions unobservable to the other. For example, the firm can affect reliability through choice of quality, unknown to the consumer. The consumers can affect reliability through investment in product care and maintenance, unknown to the firm. They show that partial product warranties serve as "incentives" for the firm to make the product more reliable and for the consumer to care for it since losses are shared by both parties. Finally, there has been some work on the role of warranty as a sorting mechanism (e.g., Holmes 1984, Kubo 1986, Matthews and Moore 1987). However, these papers do not allow consumer actions to affect product reliability (i.e., there is no consumer moral hazard). The interested reader can refer to Emons (1989) for a detailed review.

[1] We thank John Hauser and Brian Ratchford for raising our sensitivity to these issues.

The literature on ESC is sparse in comparison. As Day and Fox (1985) point out ". . . *we could glean little insight from the existing literature* . . .". They report the results of a qualitative study conducted with a view to understanding consumer perceptions and decision making with regard to ESC. They suggest that factors such as risk-preference, product experience and usage habits are likely to influence demand. Bryant and Gerner (1982) investigate the nature of demand for ESC for home appliances. They conclude that demand for ESC is income and price inelastic and about unitary elastic with the number of appliances owned. They find that these contracts induce consumer moral hazard and report evidence in the form of repairs.

We are interested in the design of warranties when the market is heterogeneous. From a marketing point of view we know that consumers are not alike, and this is an important issue. We view warranty as primarily a form of insurance. Since individuals are likely to differ in their risk preferences, variation in individual risk preference is a natural way to incorporate consumer heterogeneity in a model of product warranty. Additionally, we incorporate consumer moral hazard in our model. We believe that including the consumer effort investment decision will not only will enrich the theory by bringing it closer to reality but also provide further insight into the moral hazard problem documented by Bryant and Gerner (1982).

The rest of the paper is organized as follows. In §3 we formulate the firm's problem in the framework of a principal agent model. We show that the optimal warranty policy consists of a menu of warranty coverage and associated prices. We briefly address the question of how the menu can be implemented in the institutional setting of marketing intermediaries. In §4, we analyze data gathered from new car buyers. In particular, we focus on their decision to buy an ESC and on the effort expended by them on product maintenance. Analysis of the data also yields estimates of the substitution between manufacturer warranty and sales of ESC. Section 5 ends with a brief summary.

3. Model and Analysis of the Warranty Decision

This section develops a model of a monopolist offering warranties to the consumers who differ in their risk-preferences.

3.1. *The Marketing Problem*

Consider a firm marketing a consumer durable to individuals who differ in their risk preferences. The product is such that the amount of effort expended by the consumer in product care and maintenance improves the reliability of the product. However, this effort input by the consumer cannot be observed or inferred by the firm. This is the consumer moral hazard problem. The firm would like to market product warranties because the presence of risk-averse individuals implies that insurance in the form of warranties is profitable. However, unobservability of consumer effort implies that (i) consumers will shirk on investing in effort since it is costly to them, and (ii) the firm cannot make warranties conditional on the amount of effort expended since the level of effort invested by the consumer cannot be verified. As a consequence, the firm faces the problem of higher servicing costs for the warranties due to higher failure rates caused by lack of consumer investment in effort.

3.2. *Assumptions*

We next outline and discuss the assumptions of our model.

ASSUMPTION 1. *The firm markets a product of known quality.*

Discussion. We assume that the quality of the product is known to both agents, i.e., the consumer and the firm. The assumption helps us focus on analysis of the impact of

consumer moral hazard and heterogeneity on warranty policy. Quality is therefore exogenous in our model. A consequence of this assumption is that the role of warranty as a signal of quality is not an issue here.

ASSUMPTION 2. *The product is subject to probabilistic failure. The probability that the product works, denoted by π, is assumed to depend on e_i, the effort expended by consumer i. We assume that*

$$\pi(e_i) = \alpha_0 + \alpha_1 e_i \qquad \textit{where} \qquad 0 < \alpha_0 < 1 \qquad \textit{and} \qquad \alpha_1 > 0. \tag{1}$$

Discussion. In general, π will be a concave function of e_i. We have assumed it to be linear in e_i. It is obvious that the problem is meaningful only for $e_i < (1 - \alpha_0)/\alpha$.

ASSUMPTION 3. *The utility of wealth x to consumer i, $U_i(x)$ is assumed to be given by the following function:*

$$U_i(x) = x^{\delta_i} \qquad \textit{where} \qquad 0 < \delta_i \leq 1. \tag{2}$$

Discussion. Since $0 < \delta_i \leq 1$, $U_i(x)$ is increasing in x and concave. Consumers are risk-averse if $\delta_i < 1$ and risk-neutral if $\delta_i = 1$.

ASSUMPTION 4. *The risk-preference of consumer i is known only to him. The distribution of consumers over δ_i denoted by F, is common knowledge.*

Discussion. Assumption 4 implies that while some consumers with relatively smaller δ would prefer more insurance than others with larger δ, the firm has no way of identifying these consumers.

ASSUMPTION 5. *The cost of effort to consumer i is given by $\varphi(e_i) = e_i^2/2$. Moreover, the utility of a consumer is separable in wealth and effort. The total utility from wealth x and effort e_i, can be written as*

$$U_i(x, e_i) = U_i(x) - \varphi(e_i). \tag{3}$$

Discussion. The effort input by the consumer is not without cost. We let φ denote the cost of effort. We assume that φ is a convex function of effort. A commonly used specification (e.g., Basu et al. 1985, Rao 1990) that satisfies this requirement is $\varphi(e) = e^2/2$. The separability assumption has been used widely in the economics and marketing literature (Holmstrom 1979, Rao 1990) and is made purely for purposes of analytical tractability. Pauly (1974) analyzes an insurance problem without this assumption. His analysis was restricted to homogeneous markets and we obtain identical qualitative results in our model for that case. A consequence of the separability assumption is that risk-preference now refers only to preference over lotteries of wealth and not lotteries over wealth and effort.

3.3. *Consumer's Problem*

For ease of exposition, we first consider the case when all consumers are alike, i.e., the market is homogeneous. Let $\delta \in (0, 1]$ index the risk-preference of the consumers. To focus on the incentive and insurance aspects of the problem, we will assume that all consumers have the same level of initial wealth which we will denote by y, where $y \geq 0$.

The consumers must decide whether to purchase (a single unit of) the product. Let p denote the price of the product. Assume that the product can either work or fail. If the product works, consumers enjoy a monetary benefit z, so the overall wealth is $y - p + z$. The consumers incur a loss of k due to the failure of the product. The loss $k = z$ if the loss due to failure is simply the loss in value of the working product or it could be

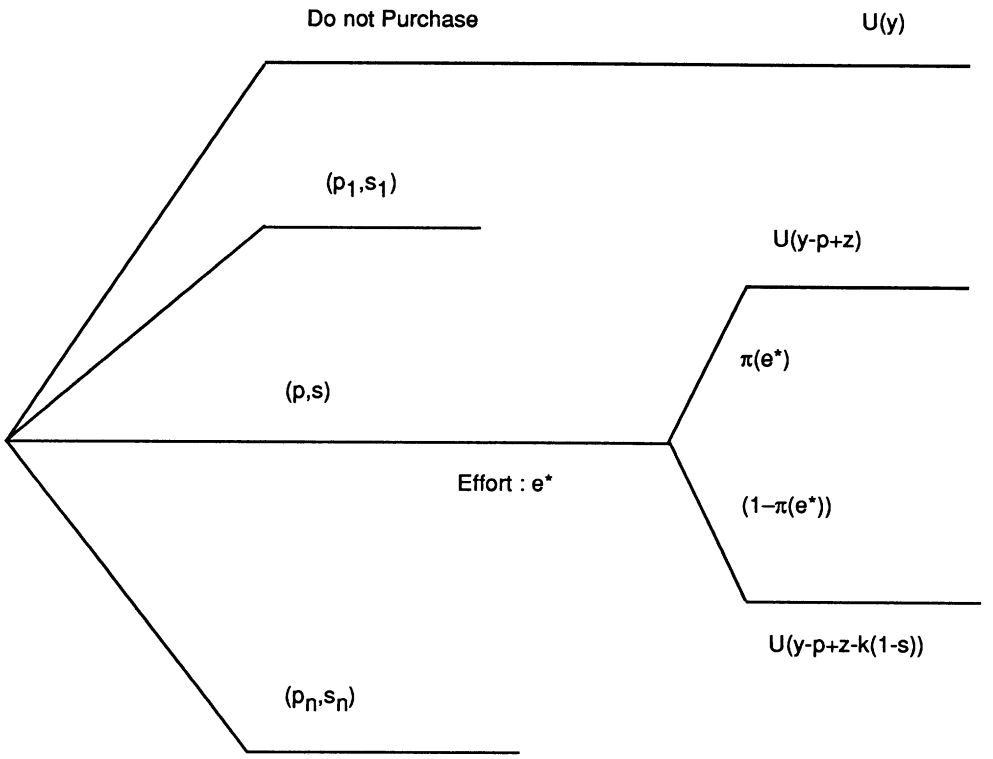

FIGURE 1. The Conceptual Model of Warranties.

greater than z if there are added costs to failure. The overall consumer wealth in case of product failure is $y - p + z - k$.

Now suppose that consumers can also make a decision on the degree of warranty protection to obtain. We model the consumer's decision as the selection of a degree of warranty protection or a level of coverage s, $0 \leq s \leq 1$. In case of product failure (which is publicly observable), the firm repatriates an amount sk, back to the consumer. Therefore with warranty protection, the net consumer wealth in case of product failure is $y - p + z - k(1 - s)$. Note that the consumer choice of a level of coverage translates into the choice of a deductible $k(1 - s)$ on the warranty. The level of coverage is a measure of the degree of warranty protection with $s = 1$ implying full coverage with zero deductible and $s = 0$ implying no coverage at all.[2] The consumer choices are as shown in Figure 1.

The expected utility from the purchase of the product is

$$\text{EU} = \pi(e)U(y - p + z) + (1 - \pi(e))U(y - p + z - k(1 - s)) - \varphi(e). \quad (4)$$

Consumers choose effort to maximize their expected utility. The first-order condition for the expected utility maximization problem implies

$$e^*(s; \delta) = \alpha_1[U(y - p + z) - U(y - p + z - k(1 - s))] \quad (5)$$

where $e^*(s; \delta)$ denotes the optimal effort choice by an individual with risk-preference δ for a product with warranty protection at level s. The concavity of expected utility in effort implies $e^*(s; \delta)$ is unique.

[2] The level of coverage s is a theoretical construct. In practice it is operationalized either by limiting parts of products that are covered or length of time for which they are covered. For instance, a coverage of $s = 1$ can be thought of as a lifetime warranty and $s = 0$ as no warranty coverage.

The voluntary participation of the consumer requires that expected utility from product purchase given the optimal effort input be at least as great as the utility derived from not purchasing the product. This is also called the Individual Rationality Constraint. Thus,

$$\pi(e^*(s;\delta))U(y-p+z)+(1-\pi(e^*(s;\delta)))U(y-p+z-k(1-s)) - \varphi(e^*(s;\delta)) \geq U(y). \quad (6)$$

The maximum price the consumer is willing to pay for a product with this warranty denoted by $p^*(s;\delta)$ is obtained when (5) holds with strict equality:

$$\pi(e^*(s;\delta))U(y-p^*(s;\delta)+z) + (1-\pi(e^*(s;\delta)))U(y-p^*(s;\delta)+z-k(1-s)) - \varphi(e^*(s;\delta)) = U(y). \quad (7)$$

This price $p^*(s;\delta)$ is the reservation price of the individual. The firm will charge this price since it is a monopolist. We next provide a technical result on the uniqueness of e^* and p^* for various levels of warranty protection.[3] In what follows from now on, we will dispense with the * notation.

PROPOSITION 1. *There exists a unique pair* $(p(s;\delta), e(s;\delta))$ *solving* (5) *and* (7) *for each* s *in* $(0, 1)$.

The uniqueness property is a useful simplifying device. Having obtained the effort $e(s;\delta)$ and the price $p(s;\delta)$, we can now predict how these are affected by changes in the parameters of the model: y, z, k and δ. These predictions of changes can in turn be tested empirically.

Consumer Effort Allocation. As coverage increases, effort allocated by the consumer decreases. As a result firms may not wish to offer full warranty. The consumer puts in the greatest effort when there is no warranty coverage (i.e., $s = 0$) and the least effort when the warranty provides full coverage (i.e., $s = 1$). As the potential loss from failure increases, effort increases. This makes intuitive sense since it is in the consumers' best interest to do the utmost to reduce the probability of occurrence of this adverse state of nature. The impact of income is in the expected direction: effort decreases as wealth increases. In fact, for large enough initial wealth (i.e., $y >> z$), effort allocated approaches zero for any level of coverage. Effort increases as risk-aversion decreases. Therefore, for the same warranty coverage, a risk-neutral person invests in more effort than a risk-averse person. As is shown later, this results in the risk-averse person having a higher reservation price for a warranty.

Willingness to Pay. As warranty coverage increases, the consumers' reservation price increases. In fact, when coverage is comprehensive (i.e., $s = 1$), all consumers pay the same price for the product (i.e., $p = z$). The price paid by the consumer decreases as the potential loss from failure increases. This is easy to understand if we consider the fact that as the potential loss increases, the effort allocated increases (i.e., higher self-insurance) and hence willingness to pay decreases.

3.4. *The Firm's Problem*

The firm's profit on a warranty with s level of protection depends on the price $p(s;\delta)$ and the expected cost $C(s;\delta)$. Note that $p(s;\delta)$ is the bundle price for the product and the warranty. The price $w(s;\delta)$ paid by the consumer for the warranty alone can be obtained as

$$w(s;\delta) = p(s;\delta) - p(0;\delta). \quad (8)$$

[3] Proofs of all the results are in a separate appendix that is available upon request from the first author.

The firm knowing $e(s; \delta)$ can calculate the expected cost for the warranty as

$$C(s; \delta) = (1 - \pi(e(s; \delta)))sk. \tag{9}$$

The firm's expected profit per unit of product on the warranty is the price less the expected cost. The profit maximization problem can now be formalized as

$$\max_s \mathbf{R}(s; \delta) = w(s; \delta) - C(s; \delta). \tag{10}$$

Maximization of $R(s; \delta)$ over s yields the following result.

THEOREM 1. *Faced with a risk-averse consumer, the optimal decision is to offer a warranty* s^*, $0 < s^* < 1$ *for all* δ, $0 < \delta < 1$.

This is the standard insurance result. In addition it obtains the *precise level of coverage* that maximizes the firm's profits. Note that this coverage is incomplete, i.e., it is not a full warranty. The warranty comes bundled with the product at a price $p(s; \delta)$. With moral hazard, the firm suffers a loss by offering *any* nonzero coverage to risk-neutral consumers. In the absence of moral hazard, the firm offers full coverage (i.e., $s = 1$) at a price $p = z$ irrespective of consumer risk-preference.

Heterogeneous Market of Consumers. We now consider the warranty problem for a firm faced with a population of heterogeneous consumers. We consider the case where the market is made up of two types of individuals, a risk-averse individual (type-1) with risk preference $\delta_1 < 1$ and a risk-neutral individual (type-2) with risk-preference $\delta_2 = 1$. For purposes of exposition we make type-2 risk-neutral. In fact, what we really need is $\delta_2 > \delta_1$, and the results to follow hold. We initially present a comparative static result of price with respect to risk-preference before obtaining the firm's optimal choice of level of coverage for the different individual types.

PROPOSITION 2. *The more risk-averse person pays more for the warranty.*

The less risk-averse person invests in more effort (higher self-insurance) and consequently is not willing to pay as much for the warranty as a more risk-averse individual.

THEOREM 2. *The optimal warranty coverage offered by the firm to the individual decreases monotonically as risk-aversion decreases.*

With less risk-averse individuals preferring higher self-insurance, it is optimal for the firm to offer them lower warranty levels. Let $s_1 = s^*(\delta_1)$ and $s_2 = s^*(\delta_2)$ denote the optimal coverage levels as obtained from Theorem 1 for the two types. The warranty policy implication of Theorem 2 would be to have the firm offer a product with s_1 level of warranty protection at $p(s_1; \delta_1)$ and another product with s_2 level of warranty protection at $p(s_2; \delta_2)$. In other words, the firm offers an assortment (also referred to as a menu) of base warranty plans. The idea is that after consideration of the items in the menu, consumers self-select into the level of coverage specifically designed for them. However, this menu fails to obtain self-selection. The intuition (sketched in Figure 2) is that the reservation price for the risk-averse person for all levels of warranty coverage is always less than or equal to that of a risk-neutral person. Consequently, the risk-neutral individual is *strictly* better off by choosing the warranty plan designed for type-1 consumers. This is the adverse selection problem. By choosing s_2, the type-2 consumer's expected utility is $U(y)$, whereas by choosing s_1 it is $U(y)$ plus the price differential. This price differential, denoted by $M(\delta_2; s_1)$, is typically referred to as rent (e.g., Rothschild and Stiglitz 1976). A modification of the price schedule such that the firm offers the product with s_1

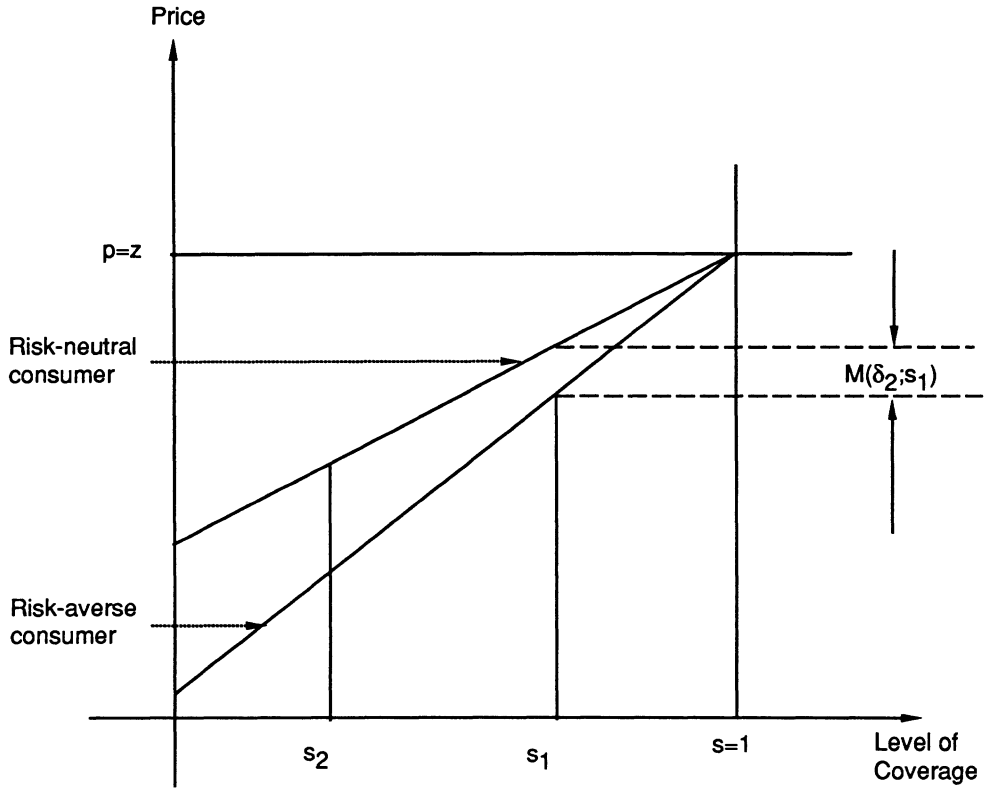

FIGURE 2. The Adverse Selection Problem.

warranty protection at $p(s_1; \delta_1)$ and the product with s_2 warranty protection at $p(s_2; \delta_2) - M(\delta_2; s_1)$ obtains self-selection. The idea being that if the rent has to be paid, the firm is better off by offering this rent at the coverage level that maximizes its profits from the type-2 consumers. But as the following theorem shows, the firm can do better than this.

THEOREM 3. *The optimal warranty policy requires the firm to offer the following menu*:

(i) *product with m degree of warranty protection at* $p(m; \delta_1)$,

(ii) *product with* s_2 *degree of warranty protection at* $p(s_2; \delta_2) - M(\delta_2; m)$.[4]

This solution requires the firm to *over insure* the type-1 consumers. The intuition (sketched in Figure 3) is that while the firm incurs a loss from over insuring the risk-averse consumers it is made up by the reduction in rents paid out to the less risk-averse consumers. The level of over insurance increases as the type-1 consumers get relatively more risk-averse than type-2 consumers. Given the risk-preferences of the two types, it is important to note that the equilibrium level of coverage offered to the type-1 consumers is a function of the proportion of type-2 consumers in the population (denoted by f_2 where $0 \leq f_2 \leq 1$). When there are no risk-neutral consumers, the level of coverage offered to the risk-averse consumers is s_1. As the proportion of risk-neutral consumers increases, the level of coverage offered to the risk-averse consumers increases till the

[4] Chrysler's recent move to a policy of offering consumers a choice of a three year bumper-to-bumper or a seven year power train warranty is one example of a manufacturer offering a menu of base warranties.

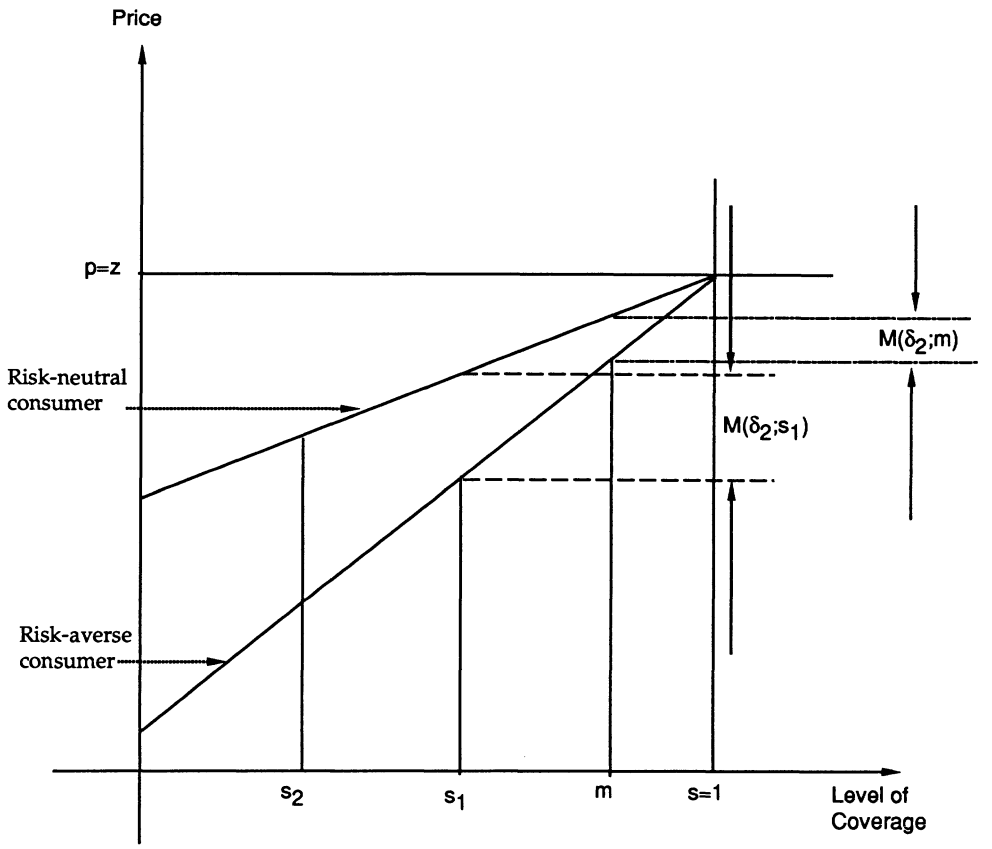

FIGURE 3. Optimal Coverage with Over Insurance.

proportion of risk-neutral individuals reaches a critical value f_2^*. If $f_2 > f_2^*$, the risk-averse consumers are excluded from the firm's marketing plan. The reason is that as the proportion of risk-neutral consumers increases, the losses from rents begin to outweigh the profits from insuring the risk-averse consumers. The variation in level of coverage offered to type-1 consumers as a function of the fraction of type-2 consumers in the population is shown in Figure 4. This result of exclusion of certain types can also be seen in the salesforce literature (e.g., Lal and Staelin 1986, Rao 1990).

3.5. *Implementation of the Menu of Product Warranties*

The warranty policy requires the firm to offer a menu of warranties to the consumers. The product warranty is essentially a legal contract that binds the firm to certain monetary transfers in case of product failure. In all cases, the physical product being sold to the different consumer types is identical. If the product is being sold to the consumers through channel intermediaries, then the menu of warranties has to be administered to the consumers by the retailer rather than the firm. The firm sells the base product to the retailer. The retailer's interest lies in selling as many units of the product as possible. The derived warranty policy requires the sale of a product that is bundled with the warranty. To the extent that bundling of the warranty to the product presents a real or imaginary barrier to product sales in the retailer's perspective, they will resist purchasing and reselling a bundled product.

It can be shown that the optimal policy as outlined in Theorem 3 can be modified slightly to cater to markets with this institutional mechanism. The fundamental difference

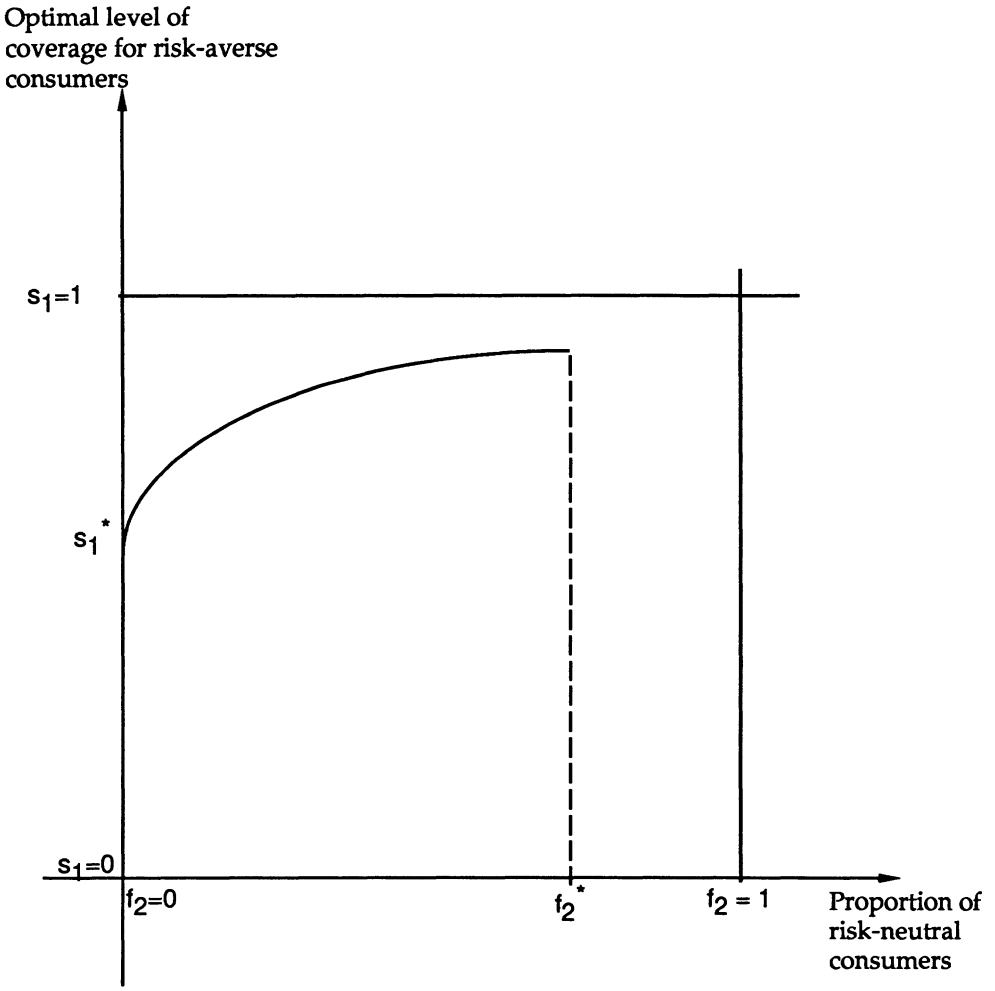

FIGURE 4. Variations in Over Insurance.

is that all consumers are offered the product with a common base warranty at the same price. The retailer then markets ESC offering additional levels of coverage as an optional add-on for a certain price.

THEOREM 4. *The optimal warranty policy for the firm when it markets the product through independent channel intermediaries requires that*

(a) *it market the product with a base warranty offering* s_2 *level of protection at a price* $p(s_2; \delta_2) - M(\delta_2; m)$; *and*

(b) *market an optional ESC that offers m level of protection at a price* $p(m; \delta_1) - p(s_2; \delta_2) + M(\delta_2; m)$.

The firm markets the product with a base warranty at the price that the least risk-averse segment is willing to pay for the product. Note that *the base manufacturer warranty for a product will be set at the optimal level for the least risk-averse segment of the population*. The price paid by the risk-averse segment for the base product is higher than the reservation price, but they are sold the ESC at a price which compensates for this. Overall, the consumers are at the same level of utility as they had obtained in the bundled solution of Theorem 3.

TABLE 1
Summary Details of the Sample

Total Number of Respondents	560
Respondents who purchased an extended service contract	199 (549)
Average price of a new car	$18256 (511)
Average length of base warranty	2.7 years (528)
Average price of an extended service contract	$590 (137)
Average length of an extended service contract	6.5 years (193)
Average age of respondent	45 years (521)
Percentage of single respondents	27% (549)
Percentage of male respondents	69% (549)
Percentage of risk-averse respondents	54% (546)

Note: The numbers in parentheses refer to the number of responses obtained for that variable.

4. Empirical Application

This section describes an empirical study we conducted on the purchase of service contracts by new car buyers. The model makes the following predictions about consumer actions when they are presented with a menu of service contracts.

(i) More risk-averse persons will buy ESC (§3.5, Theorem 4).

(ii) Effort allocation towards maintenance will be influenced by risk-aversion, income and choice of ESC (§3.3, Consumer Effort Allocation).

We examine the data to see if these predictions hold. In addition, a recent development in the automobile industry is the move by third-party companies to market ESC. As the base warranty and ESC are essentially insurance instruments, firms in this situation can retaliate by increasing the length of the base warranty. This is the notion of substitutability between alternative instruments of insurance discussed by Bryant and Gerner (1982). We provide a measure of this substitution effect.

4.1. *Data*

We conducted a mail survey to obtain data from new car buyers on the purchase of ESC. The acquisition of a new car is a significant purchase for most individuals and consequently, issues related to warranty should affect purchase behavior. Information was obtained from the individuals on the base (manufacturer) warranty, purchase (if any) of ESC, usage habits, and the expected length of ownership. We also obtained data on the consumer maintenance schedule for items such as oil changes, fluid-level checks, car washes, etc. We obtained a measure of the individual's risk preference from responses to lottery questions dealing with their choice of alternatives in uncertain situations. Finally, demographic information relating to respondent's age, sex, marital status, education, income and size of family were also obtained.

The questionnaire was extensively pretested on a convenience sample of new car buyers. The questionnaire was then mailed to 2,400 new car buyers in the Dallas-Fort Worth Metroplex area. There were a total of 612 replies for a response rate of 25.1%. The response rate is comparable to, or higher than most studies using a single mail-out.[5] Summary details of the sample are presented in Table 1. Approximately 36% of our sample purchased an ESC. This figure is consistent with industry estimates of the market penetration of service contracts (30–35%) as well as with independent data from one of

[5] Gordon Wayner of M/A/R/C confirms that based on their real-world studies, they would have expected a response rate of 15%.

the largest automobile dealerships in the area. This consistency mitigates to some extent possible concerns about nonresponse bias.

4.2. *Estimating Models and Variable Operationalization*

We test the validity of this prediction regarding choice behavior with the use of a binary logit model. The model used for specifying the utility derived from an ESC relative to buying without the ESC is

$$U_i = \lambda_0 + \lambda_1 \text{PRISK}_i + \lambda_2(\text{PRISK}_i^* \text{MYEAR}_i) + \lambda_3 \text{MYEAR}_i + \lambda_4 \text{INCOME}_i + \lambda_5 \text{CPRICE}_i + \lambda_6 \text{MSTATUS}_i + \lambda_7 \text{IMPORT}_i + \text{error}. \quad (11)$$

The dependent variable is BUY which is zero if a consumer does not buy an ESC and one otherwise. Consumer risk-aversion, operationalized by a binary variable PRISK (as defined in Table 2), is expected to be positively related to the BUY decision (i.e., $\lambda_1 > 0$). Consumer risk-preference is ascertained from their response to a lottery question. Respondents were presented with a lottery and asked to make a choice from among five price points on what they would be willing to pay for insurance in that situation. If the price chosen was less than the expected value of the lottery then PRISK_i was set at zero for that respondent, otherwise it was set at one. A χ^2-test of the consistency of consumer response to this question with another lottery question rejects independence of responses ($\chi^2 = 8.85$ with 1 d.f.). There is considerable literature on the development and use of risk-measures (see Peter and Tarpey 1975, Srinivasan and Ratchford 1991). They suggest using seven-point "improbable-probable" and "important-unimportant" judgment scales to obtain measures of financial, performance, physical and convenience risks associated with the purchase of the product. However, we are interested in mapping an individual's risk-preference to choice behavior and hence chose our procedure.

As coverage increases, utility for all consumers approaches z in the theoretical model. The substitution between base warranty and ESC (Bryant and Gerner 1982) derives from the fact that they both provide insurance. As remarked earlier, the real-world analog of level of coverage is the length of the warranty. Therefore, the substitution argument implies that an increase in the length of the base warranty decreases the degree of perceived risk (Bearden and Shimp 1982, Menezes 1989) and hence the influence of risk-aversion on the utility derived from an ESC. This is captured by the interaction of PRISK and MYEAR. We expect $\lambda_2 < 0$. Further, the utility for ESC is likely to be lower for an automobile with a larger base warranty. This is captured by the inclusion of MYEAR. We expect $\lambda_3 < 0$.

Additionally, we include four other variables that previous research and conventional wisdom suggest are likely to influence the utility for ESC. The work of Gerner and Bryant

TABLE 2

Choice of Extended Service Contract Dependent Variable: BUY

Variable	Coefficient	Chi-square	*P*
PRISK	0.93	4.63	0.03
PRISK*MYEAR	−0.29	2.64	0.10
MYEAR	−0.18	2.03	0.15
CPRICE	0.00004	6.07	0.01
MSTATUS	1.03	13.71	0.002
INCOME	0.00001	3.12	0.07
IMPORT	0.06	0.00	0.97

Model Chi-square = 46.08 (d.f. = 7), $P = 0.0001$.

(1980) and Bryant and Gerner (1982) suggest that the impact of income needs to be investigated. However, the impact of income (denoted by INCOME) might have opposite effects due to its impact on risk-preference and cost of effort. If we assume that the price of the car (CPRICE) reflects the value of the purchase, then insurance should become more valuable as the purchase price of the car increases (Day and Fox 1985). Product experience/inexperience is also likely to impact utility (Day and Fox 1985). As a new car is often the first major purchase for single individuals, we include marital status (MSTATUS) to investigate the impact of this affect. We expect $\lambda_6 > 0$. We include a nationality of manufacturer dummy (IMPORT) to check whether that has any effect on the utility of an ESC. Casual observation suggests that people typically associate imports with lower product failure and therefore insurance might be less important for them. If that is the case, we would expect $\lambda_7 < 0$.

Effort Allocation. Consumer's effort allocation follows their decision on purchase of an ESC. Effort allocation was measured by their maintenance schedule for two activities: oil changes and fluid level checks. Respondents provided the average interval (in weeks) between successive events. A longer interval represents lower effort investment.

The comparative static results predict that all other things being equal: (a) individuals who buy ESC will invest in less effort, (b) risk-averse individuals will invest in less effort and (c) higher income individuals will invest in less effort. Inclusion of PRISK and INCOME allows us to check (b) and (c). Assessing the validity of (a) is complicated by the fact that data on effort is generated by individuals who have already made choices of belonging to one group (buyers) or another (nonbuyers). This is referred to in the econometric literature as the self-selectivity problem.[6] The suggested approach to overcome this problem (see Maddala 1983, pp. 221–289) requires splitting the sample into two groups and running the regressions on them individually. The effort equations are estimated using the independent variables and the appropriate Mills Ratio for each subsample. We include one other individual related covariate in the list of independent variables and that is USAGE. The work of Day and Fox (1985) and Gerner and Bryant (1980) suggest that usage of the product influences consumer decisions. We expect higher intensity users (e.g. those who use the car for business rather than simply to and from work) to be more regular in maintenance since downtime of the vehicle is more expensive to them. We estimate the following equations for the buyers and nonbuyers, respectively:

$$\text{Effort} = \beta_0 + \beta_1\text{PRISK} + \beta_2\text{INCOME} + \beta_3\text{USAGE} - \beta_4(\text{Mills Ratio}), \quad (12)$$

$$\text{Effort} = \gamma_0 + \gamma_1\text{PRISK} + \gamma_2\text{INCOME} + \gamma_3\text{USAGE} + \gamma_4(\text{Mills Ratio}). \quad (13)$$

4.3. *Results*

Choice of Extended Service Contract. The results of the logistic regression are shown in Table 3. The coefficient λ_1 that measures the impact of risk-preference on choice behavior with respect to ESC is positive (0.93) and significant. The theory suggests that given heterogeneity in consumer risk-preferences, firms should market ESC. These contracts will be chosen by risk-averse consumers. The data is indeed consistent with this explanation and provides credence to the validity of the theory.

The coefficient λ_2 that measures the substitution effect of base warranty on risk-aversion and hence choice probability of a service contract is negative (−0.28) and significant. This is consistent with the earlier findings of Bearden and Shimp (1982) and Menezes (1989) that demonstrate that warranty length influences the degree of risk associated with a purchase. This result has implications for determination of base warranty length

[6] We are grateful to a reviewer for bringing this to our attention.

TABLE 3
Effort Allocation of Consumer Dependent Variable: FLUID

	Estimate	
Variable	Buyers	Nonbuyers
PRISK	2.43	1.15
	(1.736)	(1.11)
USAGE	−1.23	−0.65
	(−0.5)	(−0.35)
INCOME	0.00002	0.00003
	(0.7)	(1.43)
MILLS RATIO	5.03	0.55
	(2.01)	(0.22)

Note: T-values are in parentheses, $R^2 = 0.05$ (buyers), $R^2 = 0.02$ (nonbuyers).

and is discussed later. The coefficient λ_3 (−0.19) that seeks to capture the direct effect of base warranty length on choice probability is negative as expected but is not significant.

The impact of income is in the positive direction ($\lambda_4 = 0.000013$) and significant. As remarked earlier, we had no prediction on the direction of this effect. In the light of this finding, we can say that the data confirms Bryant and Gerner (1982) finding that higher income individuals find ESC more attractive because of their higher value of time. Parenthetically, we must note that we find no correlation between INCOME and PRISK in our sample, thus further strengthening this interpretation for λ_4. The results suggest that consumers derive greater utility from service contracts on higher priced cars ($\lambda_5 = 0.000049$). The data also indicates that singles ($\lambda_6 = 1.04$) are more likely to purchase an ESC than married individuals. It is interesting to note that the nationality of the manufacturer does not have a significant impact on the utility derived from ESC. This implies that the insurance result does in fact generalize across manufacturers, and while quality perceptions may influence other decisions relating to new car purchase, they do not appear to influence the risk-preferences of consumers and their demand for insurance.

Effort Allocation of Consumers. The OLS regression results for buyers and nonbuyers are in Table 4. We initially report the results for the FLUID regression.

The theory predicts that risk-averse consumer will invest in less effort. This implies longer intervals between successive fluid level checks for the risk-averse individual. The coefficient β_1 (2.43) that measures this impact of risk-preference on effort allocation is positive and significant. This is consistent with the prediction of the theory. The impact of usage and income are in the expected direction but are not significant. These effects are repeated for the sample of nonbuyers.

The coefficient for the Mills Ratio is the covariance between the errors in the utility specifying Equation (11) and the effort equation. The estimates imply that COV(U, FLUID) = $\beta_4 = -5.03$ for buyers and COV(U, FLUID) = $\gamma_4 = 0.55$ for nonbuyers. The estimates point out that buyers of ESC do in fact systematically under invest in effort compared to nonbuyers. This suggests that there is a degree of consumer moral hazard in this market and that the inclusion of consumer moral hazard in a model of product warranty is important. The direction of this effect is consistent with the comparative static predictions of the model. Note that the explained variance in the regression is small. This could be because of inaccuracies in the measures used for consumer effort. Better measures should help shed more insight on this issue.

TABLE 4
Effort Allocation of Consumer Dependent Variable: OIL

Variable	Estimate	
	Buyers	Nonbuyers
PRISK	0.44	0.41
	(1.58)	(1.49)
USAGE	−0.82	−0.30
	(−1.66)	(−0.63)
INCOME	0.00003	0.00001
	(0.53)	(1.70)
MILLS RATIO	0.56	0.49
	(1.13)	(0.74)

Note: T-values are in parentheses, $R^2 = 0.05$ (buyers), $R^2 = 0.04$ (nonbuyers).

While the results for the impact of risk-preference, income and usage for the OIL equation (see Table 4) are in the expected direction, the coefficient for the impact of purchase of ESC on effort is contrary to what we expect. The data suggests that buyers are more regular in terms of oil changes than nonbuyers. We believe that this result is driven by the fact that most ESC require proof of regular maintenance in the form of oil changes for honoring warranty claims.

4.4. *Implications*

The results of the logistic regression have implications for warranty policy and we discuss these now. The discussion in the theory development section dealt with the topic of determination of level of warranty coverage. This section discusses implications for policy with regard to the corresponding time domain definition of level of warranty coverage which is the length of warranty coverage.

In the warranty context, the firm faces potential competition in two different areas: the product market and the third-party insurance market.[7] Managers are often faced with a situation where a competitor has made a change in their product warranty. In such situations, managers need information on the likely effects of their modification of the product warranty. One such effect is the change in the firm's sales of ESC following a change in the base warranty. The estimates of the impact of the length of base warranty on choice probability can be used to obtain a measure of this effect. The elasticity of choice probability to length of base warranty can be derived from the logit model as

$$\eta = \alpha^i(\text{MYEAR})(1 - P) \tag{14}$$

where $\alpha^i = \alpha_2$ for risk-neutral consumers and $\alpha^i = (\alpha_2 + \alpha_3)$ for risk-averse consumers. Therefore, if for the product in question the firm offers a one year base warranty and we assume that the probability of choice is the percentage of new car buyers who purchase an extended service (i.e., $P = 0.35$), we then obtain an estimate of $\eta = -0.31$ for risk-averse consumers. With this estimate it is now possible to answer a series of "what if" questions that deal with the likely changes in sales of ESC due to changes in the length of the base warranty. For example, an increase in the length of base warranty by one

[7] Given our model in which the manufacturer exercises market power, there is no role for third-party ESC. However, we can think of at least two factors that negate this. First, it is possible for third-parties to make their ESC more attractive through differentiation (e.g., allow consumers to get warranty repairs at any garage as opposed to the manufacturer specific dealer network). Second, retailers themselves may also have market power. In fact, most retailers nowadays carry two types of ESC (manufacturer ESC and third-party ESC).

year will cause a 30% decrease in sales of ESC from risk-averse consumers. In other words, the average fraction of risk-averse new car buyers who purchase an ESC will drop from 35% to about 24%. A change in base warranty of two years implies that only about 13% of risk-averse new car buyers will purchase ESC. This is consistent with the data (10–12% of all buyers) at a major manufacturer that recently moved to a three year base warranty from a one year base warranty.

A recent trend in the durables market is the growth in the number of third-party providers of ESC.[8] Manufacturers who market optional ESC can possibly try to minimize competition through appropriate incentive policies for their retailers. But manufacturers such as HONDA, TOYOTA, etc., that for a variety of institutional reasons do not market optional ESC, can do something else in such a situation. These manufacturers by a suitable choice of base warranty can appropriate the insurance profits that otherwise would have accrued to the third-party providers of ESC. In doing so, these manufacturers successfully exploit the substitution effect between length of base warranty and ESC. Rearranging (11), we obtain

$$U_i = \lambda_0 + (\lambda_1 + \lambda_2 \mathrm{MYEAR}_i)\mathrm{PRISK}_i + \lambda_3 \mathrm{MYEAR}_i + \lambda_4 \mathrm{INCOME}_i + \lambda_5 \mathrm{CPRICE}_i + \lambda_6 \mathrm{MSTATUS}_i + \lambda_7 \mathrm{IMPORT}_i + \text{error}. \tag{15}$$

Given our estimates (from Table 2), a value of MYEAR equal to three serves to erase the role of risk-aversion in demand for ESC. In other words, with a three year base warranty, consumers do not feel the need for added insurance in the form of ESC. This observation on length of base warranty for insurance purposes is consistent with the view of industry observers who believe that over time automobile manufacturers will standardize their base warranties at about three years.

4.5. *Alternative Explanations for Extended Service Contracts*

Finally, we would like to address the issue of alternative explanations for the use of ESC as screening devices by firms. Note that while we posit an explanation for screening, based on insurance principles, there exist two other possible explanations. The first explanation is based on the idea that not all consumers plan on owning the car for the same period of time. Therefore, the firm, by offering ESC of various lengths, can effectively discriminate between them and thereby reap profits. A simple χ^2-test of independence ($\chi^2 = 3.71$, d.f. = 3) rejects this explanation. The second explanation for screening relies on screening based on differences in usage, the idea being that low intensity users will not need extended coverage, whereas high intensity users will, and the firm can discriminate between them on this dimension with the use of ESC. The data rejects this explanation also ($\chi^2 = 0.30$, d.f. = 1). A more formal test of both these possible explanations with the use of binary logit models that included LENGTH and USAGE as independent variables showed that they were insignificant in predicting choice behavior for ESC.

5. Conclusions and Directions for Future Research

We have characterized the optimal menu of warranty coverage and associated prices which a manufacturer should offer to a market of consumers heterogeneous in their risk-preferences under conditions of consumer moral hazard. We show that given the institutional feature that a manufacturer markets his product through an independent channel intermediary, the optimal policy consists of offering a base warranty desired by the least

[8] See Lutz and Padmanabhan (1992) for results related to the existence of a competitive insurance market and its implications for manufacturer warranty policy.

risk-averse consumer, and then providing a certain level of over insurance for more risk-averse consumers through ESC. Analysis of the data on choice behavior for ESC confirms this prediction.

When manufacturers do not market optional ESC, it may be better for the manufacturer to offer a higher base warranty coverage. Analysis of the data indicates that risk-averse consumers are more likely to buy ESC if the manufacturer base warranty is less than three years. This suggests that a three year manufacturer warranty for automobiles, at this time, is sufficient to address the insurance demands of the risk-averse segment of the market.

The data analysis also suggests that: ESC demand is higher for more expensive automobiles, for single buyers; and lower as base warranty coverage increases, particularly for risk-averse consumers. As predicted by our model, risk-averse consumers expend less maintenance effort, moderated by usage and income. Thus there appears to be some consumer moral hazard. Finally, we find no support for the proposition that ESC may serve as devices for screening consumers based on usage or expected length of ownership. Based on these we conclude that the main role of ESC is one of being a part of a menu of insurance contracts.

There are several issues that need to be addressed in future research. Our empirical work has focused on analysis of consumer data. It would be useful to examine firm level data, perhaps across product categories, to better understand the role of warranty menus through ESC and through quality-price pairs in a product line. Another important issue is the role of the interaction of marketing intermediaries in the implementation of warranty policy. Explicit treatment of the strategic role of distributors and retailers would be important for managerial purposes. We have treated product quality as exogenous and public information. This rules out the signaling role of warranties in our model. A model which allows for double moral hazard would help in addressing this issue.[9]

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Operationalization of Variables

i : indexes consumers

$$\mathrm{BUY}_i = \begin{cases} 1 & \text{if individual } i \text{ purchases a service contract,} \\ 0 & \text{else,} \end{cases}$$

$$\mathrm{PRISK}_i = \begin{cases} 1 & \text{if individual } i \text{ is risk-averse,} \\ 0 & \text{else,} \end{cases}$$

MYEAR_i = base manufacturer warranty (in years) for car bought by consumer i,

$$\mathrm{MSTATUS}_i = \begin{cases} 1 & \text{if individual is single,} \\ 0 & \text{else,} \end{cases}$$

CPRICE_i = price paid by the individual for the car,

$$\mathrm{IMPORT}_i = \begin{cases} 1 & \text{if nondomestic manufacturer,} \\ 0 & \text{else,} \end{cases}$$

$$\mathrm{USAGE}_i = \begin{cases} 1 & \text{if car used for business,} \\ 0 & \text{else,} \end{cases}$$

LENGTH_i = expected length of ownership (in years).

References

Akerlof, G. A. (1970), "The Market for Lemons: Qualitative Uncertainty and the Market Mechanism," *Quarterly Journal of Economics*, 84 (August), 488–500.

Basu, A. K., R. Lal, V. Srinivasan and R. S. Staelin (1985), "Salesforce Compensation Plans: An Agency Theoretic Perspective," *Marketing Science*, 4 (4), 267–291.

Bearden, W. and T. Shimp (1982), "The Use of Extrinsic Cues to Facilitate Product Adoption," *Journal of Marketing Research*, 29 (May), 229–239.

Bryant, K. and J. Gerner (1982), "The Demand for Service Contracts," *Journal of Business*, 55 (3), 345–366.

Cooper, R. and T. W. Ross (1985), "Product Warranties and Double Moral Hazard," *Rand Journal of Economics*, Spring, 103–113.

Courville, L. and W. H. Hausman (1979), "Warranty Scope and Reliability Under Imperfect Information and Alternative Market Structures," *Journal of Business*, 52 (3), 361–378.

Day, E. and R. J. Fox (1985), "Extended Warranties, Service Contracts and Maintenance Agreements—A Marketing Opportunity?" *Journal of Consumer Marketing*, 2 (Fall), 77–86.

Emons, W. (1989), "The Theory of Warranty Contracts," *Journal of Economic Surveys*, 3, 1, 43–57.

Garvin, D. A. (1992), *Operations Strategy: Text and Cases*, Englewood Cliffs, NJ: Prentice-Hall Inc.

Gerner, J. and K. Bryant (1980), "The Demand for Repair Service During Warranty," *Journal of Business*, 53 (4), 397–414.

Grossman, S. (1981), "The Informational Role of Warranties and Private Disclosure About Product Quality," *Journal of Law and Economics*, 24, 461–483.

Hauser, J. R. and D. Clausing (1988), "The House of Quality," *Harvard Business Review*, May–June.

Heal, G. (1977), "Guarantees and Risk Sharing," *Review of Economic Studies*, 44, 549–560.

Holmes, T. J. (1984), "Monopoly Provision of Warranty and Product Quality When Quality Is Unobservable," Working Paper, Northwestern University, Evanston, IL.

Holmstrom, B. (1979), "Moral Hazard and Unobservability," *Bell Journal of Economics*, 10, 74–91.

Kubo, Y. (1986), "Quality Uncertainty and Guarantee—A Case of Strategic Market Segmentation by a Monopolist," *European Economic Review*, 30, 1063–1079.

Lal, R. and R. S. Staelin (1986), "Salesforce Compensation Plans in Environments with Asymmetric Information," *Marketing Science*, 5 (3), 179–98.

Lutz, Nancy A. (1989), "Warranties as Signals Under Consumer Moral Hazard," *Rand Journal of Economics*, Summer, 239–255.

——— and V. Padmanabhan (1992), "Warranty and Service Contracts in Competitive Insurance Markets," Working Paper, Graduate School of Business, Stanford University, Stanford, CA.

Maddala, G. S. (1983), *Limited-Dependent and Qualitative Variables in Econometrics*, Cambridge, MA: Cambridge University Press.

Matthews, S. and J. Moore (1987), "Monopoly Provision of Quality and Warranties—An Exploration in the Theory of Multidimensional Screening," *Econometrica*, 55, 441–467.

Menezes, Melvyn A. J. (1988), "Ford Motor Company: The Product Warranty Program," (A), 9-589-001, Harvard Business School, Cambridge, MA.

——— (1989), "The Impact of Product Warranties on Consumer Preferences," Working Paper, Harvard Business School, Cambridge, MA.

——— and I. S. Currim (1992), "An Approach for Determination of Warranty Length," *International Journal of Research in Marketing*, 9, 177–195.

Pauly, M. V. (1974), "Overinsurance and Public Provision of Insurance," *Quarterly Journal of Economics*, 88, 44–54.

Peter, J. P. and L. X. Tarpey, (1975), "A Comparative Analysis of Three Consumer Decision Strategies," *Journal of Consumer Research*, 9 (March), 366–380.

Pratt, J. W. (1964), "Risk Aversion in the Small and the Large," *Econometrica*, 32, 122–136.

Priest, T. G. (1981), "A Theory of Consumer Product Warranties," *Yale Law Journal*, 90, 127–152.

Rao, R. C. (1990), "Compensating Heterogeneous Salesforces: Some Explicit Solutions," *Marketing Science*, 9 (4), 319–341.

Rothschild, M. and J. E. Stiglitz (1976), "Equilibrium in Competitive Insurance Markets: An Essay on the Economics of Imperfect Information," *Quarterly Journal of Economics*, 80, November, 629–649.

Spence, A. M. (1973), "Market Signaling: Information Transfer in Hiring and Related Processes," Cambridge, MA: Harvard University Press.

Srinivasan, N. and B. T. Ratchford (1991), "An Empirical Test of a Model of External Search," *Journal of Consumer Research*, 18 (September), 233–242.