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Author(s): Charles J. Cicchetti and Jeffrey A. Dubin
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A Microeconometric Analysis of Risk Aversion and the Decision to Self-Insure

Charles J. Cicchetti

Arthur Andersen Economic Consulting

Jeffrey A. Dubin

California Institute of Technology

This study estimates a von Neumann–Morgenstern utility function using market data and microeconometric methods. We investigate the decision whether to purchase insurance against the risk of telephone line trouble in the home. Using the choices of approximately 10,000 residential customers, we determine the shape of the utility function and the degree of risk aversion. We find that risk aversion varies systematically in the population and varies with the level of income and that the observed choice behavior is consistent with expected utility maximization.

I. Introduction

Whether expected utility theory is consistent with individual behavior is a question that has received considerable attention by economists, marketing scientists, and psychologists. The growing body of evidence, derived principally from laboratory experiments (Mosteller and Nogee 1951; Grether and Plott 1979), suggests that expected utility theory is frequently violated. Limitations of expected utility theory have led to the development of many alternative theories such

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as prospect theory (Kahneman and Tversky 1979) and many others (see, e.g., Camerer [1994] for a comprehensive survey). While tests of consistency of the various theories with observed behavior have begun (see, e.g., Camerer 1989; Camerer and Kunreuther 1989; Currim and Sarin 1989), the conclusion of much of this analysis is that "no theory can explain all of the data, but prospect theory and the hypothesis that indifference curves fan out can explain most of them" (Camerer 1989, p. 61).

There are at least two reasons why the demise of expected utility theory may be premature. First, it has been observed that individual experiments and market experiments often produce dissimilar results. While laboratory experiments have shown that individuals may poorly estimate probabilities and violate the basic axioms of probability theory, experimental results in market settings have been more encouraging (see, e.g., Brookshire et al. 1985). Second, the majority of existing studies avoid the direct estimation of the individual's utility or value function. However, by avoiding the direct estimation of the utility function, researchers have ignored the potential for individual response error and for randomness or heterogeneity in preferences.

The purpose of the present analysis is to address both of these concerns by estimating a von Neumann–Morgenstern utility function using market data and microeconometric methods. The empirical analysis we conduct is based on the decision whether to purchase insurance or to self-insure against the risk of telephone line trouble in the home. Using the choices of approximately 10,000 residential customers, we determine the shape of the utility function and the degree of risk preference. Our model for the choice of firm insurance versus self-insurance is based on expected utility theory and random utility maximization. We allow for both state-dependent and status quo effects in the estimation and test for local departures from expected utility theory by allowing the subjective probability of line trouble to differ from the actual probability.

Our empirical analysis is most similar to that of Viscusi and Evans (1990) and Evans and Viscusi (1991) but relies on market rather than contingent valuation data. First, we use first- and second-order Taylor series expansions of the difference in utility states to examine the local properties of the underlying utility function, that is, whether insurance is an inferior good and whether consumers, in fact, reveal risk aversion. We then use a full information maximum likelihood (FIML) procedure to estimate a fully parameterized structural model. Our results indicate that (1) risk aversion varies systematically in the population and varies with the level of income, (2) observed choice behavior is consistent with expected utility theory, and (3) overweighting of low-probability events is not present in this context.

In Section II we discuss the basic inside-wire maintenance (IWM) contract, which allows a consumer to insure against potential telephone line trouble. In Section III we examine several theories behind the purchase of IWM contracts including service, insurance, and priority service aspects. In Section IV we develop a theory of IWM choice based on expected utility theory and discrete choice econometrics. Section V describes the data we use in the estimation, and Section VI develops both the reduced-form and the structural-form estimates. We present conclusions in Section VII.

II. IWM Contracts

Inside-wire maintenance service contracts were created as a result of the deregulation of the telephone industry. Before 1982, when the telephone industry was forced to unbundle many of its traditional service arrangements such as the installation and repair of telephones and the inside wiring for telephones, all customers with basic telephone exchange service were charged a monthly fee that recovered installation and maintenance costs. The single monthly charge paid by customers did not separate charges paid for maintenance or for installation. After the 1982 Federal Communications Commission divestiture order, regional phone companies were required to terminate many services such as phone repair and make optional some other services such as maintenance of inside home wiring. Phone customers could contract with the phone company to acquire IWM, they could hire a third party to do the work when it became necessary, or they could do it themselves.

In some parts of the country, customers were "negatively enrolled" in IWM programs. Negative enrollment occurred when customers were notified (typically by a phone bill insert) that they would automatically be charged for basic IWM service unless they specifically notified the telephone company they did not want the maintenance contract.[1] But many customers were not negatively enrolled in the post-1982 period. Customers who initiated new phone service (perhaps by moving into or within the service region or by adding new service) had the opportunity to choose from a variety of service features including IWM. We use a sample of individuals whose choices regarding IWM were nonpassive to reveal the preferences of the population at large.

[1] The negative enrollment aspect of IWM has brought challenges legally on the basis that many customers did not select and would not have selected IWM contracts had they been nonpassively enrolled. See, e.g., Sollenberger et al. v. Mountain States Telephone and Telegraph Co., Civil Action no. 87-1485-SC, 121 F.R.D. 417; U.S. Dist. LEXIS 13538 (August 12, 1988), decided.

As we discuss below, our data come from the Mountain States Telephone and Telegraph Company (U.S. West) service area. During the 1980s, Mountain Bell customers faced a monthly probability of line trouble of less than 0.5 percent. The mean time to failure for line trouble was thus about 17 years. Typical charges for IWM were approximately $0.45 per month. When line trouble would occur, repair charges averaged about $55. Therefore, the expected cost of line trouble was about $0.262 per month. Mountain Bell customers therefore paid, on average, an amount greater than was actuarially fair. Yet the market penetration of IWM among actively enrolled customers was eventually well above 50 percent. In the next section we consider several theories (including risk aversion) that help explain the purchase behavior of IWM.

III. Theories of Purchase Behavior for IWM Contracts

The inside-wire maintenance contract between customers and the phone company has elements of several different commodities. We discuss three potentially important elements: (1) IWM as a service contract, (2) IWM as insurance, and (3) IWM as priority service.

A. *Service Contracts*

The literature on service contracts (see, e.g., Day and Fox 1985; Fox and Day 1988) indicates that service contracts are typically expensive compared with the protection they provide; the expected cost of repair varies between 25 and 50 percent of the cost of the contract. Renewals for service contracts are typically low because of the low frequency of contact between the consumer and the organization offering the contract. Also, individuals with relatively little experience with a product class are more likely to obtain service contracts. Some features of IWM—including high renewal frequency, low renewal cost, and substantial product awareness—may make it more successful in gaining and keeping customers. These features tend to make the firm-insured state more desirable than the self-insured state.[2]

B. *Insurance*

Inside-wire maintenance contracts are insurance policies that fully cover the cost of replacement or repair of the phone equipment if it

[2] For a full discussion of these issues and aspects of IWM contracts as warranties, see Cicchetti and Dubin (1992).

fails. Customers cannot adopt to partially insure against the hazard of line failure so that the amount of insurance purchased is not relevant. Instead consumers must make a discrete decision whether to firm-insure or to self-insure. Empirical evidence on insurance purchases is largely laboratory experimental. Hershey and Schoemaker (1980) found, for instance, that individuals overweight low-probability events. Shogren (1990), also using experimental data, found evidence to support Hershey and Schoemaker. He too found that individuals overestimate the impact of low probabilities, but that the degree of overestimation decreased with repeated market exposure.[3]

C. *Priority Service*

Inside-wire maintenance also shares some aspects of priority service. Individuals who require service reliability or guaranteed access to the phone system may be willing to pay more for IWM contracts. But priority service offers gradations of service reliability to customers whereas inside-wire contracts offer no gradations at all, merely a method of dealing with service outages once they occur. If there is a perception on the part of customers that having an IWM contract reduces outage costs, then there may be a preference for IWM contracts.

Our theory of IWM contract choice most closely follows the discrete insurance model. To the extent that other motivations are present (status quo effects, certainty effects, priority effects, etc.), we generalize the expected utility theory model by allowing state dependence in the utility function, unobserved random preference, and the possibility for subjective and actual probabilities to differ.[4] These issues are taken up below when we operationalize a structural model for IWM purchase.

IV. A Theory of IWM Choice

Customers who choose inside-wire maintenance replace the uncertain possibility of having to pay for inside-wire repair (both the direct

[3] The recent theoretical literature on the demand for insurance is concerned with whether insurance is a Giffen good; this literature asserts that insurance purchases are inferior (Borch 1986; Briys, Dionne, and Eeckhoudt 1989). But these studies do not cite evidence for this widely accepted view. The theoretical model of Szpiro (1985) is most applicable to IWM because in his model only full coverage is possible. Our situation is also similar to that of Drèze (1981), who shows that the degree of absolute risk aversion can be inferred from the amount of insurance purchased, the distribution of losses, the probability of loss, and the level of wealth.

[4] Hartman, Doane, and Woo (1991) identify a strong preference for the status quo. In many cases customers must be compensated for switching reliability regimes even when the alternative entails more reliable service than they already receive.

charges for repair and the indirect costs of finding a repair service) with a guaranty of not having to bear the cost of repair at the expense of a fixed monthly fee. Risk aversion and differing levels of income in the customer class lead some individuals to prefer firm insurance to the alternative of self-insurance. In this section we develop a theory of IWM choice and consider how properties of the utility function can be inferred from a population of nonidentical consumers who reveal their preferences by their choices.

We begin with a von Neumann–Morgenstern utility function $U(W)$ that is increasing in wealth, $U'(W) > 0$. Let C denote the cost of repair for the uninsured individual, R the monthly fee for IWM, and p the exogenous probability of line trouble. The utility with insurance is $U(W - R)$. The expected utility under self-insurance is $pU(W - C) + (1 - p)U(W)$. Individuals will insure provided that the utility with insurance exceeds the expected utility under self-insurance. In the population, individuals are heterogeneous, and not all components of utility are observable. We account for these differences empirically through three sources: (1) differing levels of risk aversion, (2) differing levels of income, and (3) alternative specific preferences. Specifically, we specify a utility function $U(W; s, i, \epsilon_i)$, where s represents characteristics of the decision maker, i the state in which utility occurs (insured or self-insured), and ϵ_i a random component of indirect utility.

To generate a specific probabilistic choice system for observed choices, we follow McFadden (1981) and assume random utility maximization with additively separable random errors.[5] We therefore write the indirect utility function as

$$U(W; s, i, \epsilon_i) = \tilde{U}(W; s, i) + \epsilon_i. \quad (1)$$

Under the hypothesis of random utility maximization, the individual chooses to insure provided that

$$U(W - R; s, i, \epsilon_1) \geq pU(W - C; s, 2, \epsilon_2) + (1 - p)U(W; s, 2, \epsilon_2) \quad (2)$$

or

$$\tilde{U}(W - R; s, 1) + \epsilon_1 \geq [p\tilde{U}(W - C; s, 2) + (1 - p)\tilde{U}(W; s, 2)] + \epsilon_2. \quad (3)$$

If we further assume that the ϵ_i are independent extreme-value distributed (McFadden 1974), then the probability associated with the

[5] Our development of a random utility model for choice of IWM contract shares elements in common with both Eliashberg and Hauser (1985) and Laskey and Fischer (1987). Since our model assumes random utility maximization, it shares the error structure of Laskey and Fischer. But we interpret the randomness as Eliashberg and Hauser do—as unobserved effects known to the individual but unknown to the econometrician—rather than as response errors.

event in equation (3) is given by

$$q = \text{probability that individual buys insurance} \\ = \frac{1}{1 + e^{-\Delta V}}, \tag{4}$$

where

$$\Delta V = \tilde{U}(W - R; s, 1) - [p\tilde{U}(W - C; s, 2) + (1 - p)\tilde{U}(W; s, 2)]. \tag{5}$$

The probability of purchasing IWM depends on the indirect utility difference ΔV, which is a function of the individual's wealth level W, the costs R and C, the probability of having line trouble p, and the degree of risk aversion as embodied in the function $\tilde{U}$. Intuitively, we can determine the degree of risk aversion from the level of market preference for insurance. However, risk aversion need not be the only explanation for why individuals in aggregate prefer insurance to self-insurance. If, for example, the degree of absolute risk aversion declines in income, then the amount, R^*, an individual would be willing to pay to avoid a fixed-size gamble declines as income increases; that is, if $R_a'(W) \leq 0$, then $dR^*/dW \leq 0$. A proof of this result is provided by Mossin (1968), or one can easily verify that convexity of the function $f(p) = U'(W - R^*(p)) - [pU'(W - C) + (1 - p)U'(W)]$ in the interval $p \in [0, 1]$ is sufficient for $dR^*/dW \leq 0$.

Knowing whether R^* declines as income increases is not sufficient to determine whether ΔV will decrease; although $\Delta V = U(W - R) - U(W - R^*)$, the income level W is increasing at the same time as R^* is declining. Is there a set of conditions under which discrete insurance purchases are inferior? To answer this question, we examine $\partial \Delta V / \partial W$. From equation (5),

$$\frac{\partial \Delta V}{\partial W} = U'(W - R) - [pU'(W - C) + (1 - p)U'(W)] \\ = [U'(W - R) - U'(W - R^*)] + U'(W - R^*)\frac{dR^*}{dW}. \tag{6}$$

When the individual's maximum willingness to pay R^* is greater than the market cost of discrete insurance R, $U'(W - R^*) > U'(W - R)$ as long as utility is strictly concave. Since the first term in equation (6) is negative, a sufficient condition for $\partial \Delta V / \partial W \leq 0$ is that $dR^*/dW \leq 0$. But this is only a sufficient condition, and it is possible for $\partial \Delta V / \partial W \leq 0$ when dR^*/dW is close to zero. When the individual's maximum willingness to pay R^* is less than the market cost R, the first term in equation (6) is positive and it is necessary that dR^*/dW be negative (and sufficiently so) in order that $\partial \Delta V / \partial W < 0$.

The analysis above demonstrates that an empirical observation of discrete insurance purchases as inferior does not limit a priori the class of admissible utility functions. This observation notwithstanding, a family of utility functions that allows nonconstant absolute risk aversion may be a good candidate for structural estimation when it is reasonably assured that the individual's willingness to pay exceeds the market price.

V. Description of the Data

Our analysis is based on a random sample of 25,099 observations of residential customers in the Mountain Bell Colorado service area. The sample was taken from customer records in July 1990. Mountain Bell maintains records of its customers for the purposes of billing and telemarketing. Billing records contain information on the presence of or lack of various service options and the size of the monthly bill. We use the billing records to define two variables. First, any household that subscribes to an IWM program and pays a monthly service charge for this option is assigned a value of one using the indicator variable (IWM). All other households are assigned a value of zero. Second, we define a typical monthly bill (BILL), which is equal to the average amount paid by the household for service and tolls (including the amounts paid for special service features such as IWM, call waiting, and the like).

Mountain Bell maintains 24 variables for each customer matched either from company records or from census data. In the case of monthly income, a categorical variable matched at the block group/enumeration district level is the basis for our continuous variable (MINC). We also use information from company records to determine when a customer initiated telephone service. Customers with phone service prior to March 1982 were passively enrolled in basic IWM service, whereas subscribers who started phone service after March 1982 were actively enrolled. To include only households that actively decided about the IWM option, we restrict the sample to those households that began service after March 1982. This eliminates a total of 9,663 households from the analysis.[6] We have also defined a dummy variable (POST86) to indicate whether a household initiated phone service after or prior to 1986. This variable is used to capture differences in the types of IWM service options available during the period 1982–90. Prior to 1986, Mountain Bell offered

[6] We have further eliminated from the sample any individuals who are employees of the phone company and receive service at no charge (148 households), and have also eliminated households for which data are missing (4,644 households). After these deletions, our analysis sample consists of 10,644 households.

TABLE 1

SAMPLE STATISTICS AND VARIABLE DEFINITIONS (N = 10,644)

Name	Description	Mean	Min	Max	Standard Deviation
IWM	Inside-wire maintenance	.571	.0	1.0	.495
MINC	Monthly income ($ thousands)	1.6994	.3125	6.2500	.6138
BILL	Monthly bill ($)	25.30	5.0	100.0	10.42
TPROB	Trouble probability	.00477	.00318	.00742	.00093
POST86	Service acquired after 1986	.687	.0	1.0	.463

only a basic inside-wire service contract. In 1986, Mountain Bell marketed two new IWM programs. To allow for the shift in demand that may have resulted from the introduction of these new forms of IWM, we use the treatment variable POST86.[7]

In addition to billing and telemarketing records, we have used company records to determine the frequency of line trouble for differing service zones in the metropolitan Boulder/Denver area. Mountain Bell maintains "trouble tickets," which are records of individual trouble calls serviced by the company. The trouble tickets contain the nature of the trouble and the phone number for the lines that were serviced. We used some 350,000 trouble tickets for Colorado residential and business customers to estimate the probability of inside-wire trouble in various regions of Colorado. Trouble probabilities (TPROB) were assigned to individual customer records on the basis of the prefix of the individual's phone number.[8]

In table 1 we present variable definitions and sample statistics. As can be seen from the table, 57 percent of households subscribe to IWM. Nearly 70 percent of households acquired service after 1986, which reflects the high degree of turnover in the residential population. Households averaged about $20,000 in annual income and had typical monthly phone bills of about $25. Monthly trouble probabilities ranged from .00318 to .00742. The differences in zonal trouble probabilities reflect differences in the vintage of the underlying housing stock and differences in the vintage of phone equipment.

[7] For further discussion, see Cicchetti and Dubin (1992).

[8] We determined TPROB by finding the average number of monthly trouble occurrences by zone (in eight zones and a residual zone) for the years 1982–86 and then dividing by the average number of customers in the corresponding region who were covered under the company's IWM program.

VI. Estimation

We now examine the consistency of the observed choices of inside-wire maintenance with expected utility theory. We also compare the reduced-form and structural-form methods for estimating the individual's utility function.

A. *Reduced-Form Estimation*

Estimation of the probabilistic choice model given by equation (4) requires either a direct specification of the function ΔV or an approximation of this function. This section takes the latter approach. Since

$$\Delta V = f(W, p) = [U(W - R) - U(W)] - p[U(W - C) - U(W)],$$

a second-order Taylor series expansion of ΔV in wealth and the probability of trouble is given by

$$f(W, p) \doteq f(W_o, p_o) + f_W(W - W_o) + f_p(p - p_o) + \tfrac{1}{2} f_{WW}(W - W_o)^2 + f_{Wp}(W - W_o)(p - p_o) + \tfrac{1}{2} f_{pp}(p - p_o)^2.$$

The reduced-form estimation method uses the linear and quadratic terms in W and p as explanatory variables in a binary logit model for choice of IWM service. A negative value for f_W indicates that insurance is inferior and has implications for the properties of the underlying utility function as discussed above. A positive estimate of f_p shows that the utility is increasing in wealth. A negative value of f_{Wp} reveals concavity in the utility function. Similarly, the signs and magnitudes of the coefficients on the second-order terms provide additional information about the shape of the utility function.

In table 2 we present the reduced-form logit models. In each model we include an alternative specific construct and a dummy variable for those households that acquired telephone service after 1986. These two terms are entered to allow for state dependence in the utility structure; that is, they represent shifts in tastes and preferences that may be attributable to the insured versus uninsured states. In all cases the POST86 variable has a positive and significant coefficient, which affirms the hypothesis that consumers found the IWM insurance plans collectively more valuable after 1986.

Models 1 and 2 are estimated as baseline cases and do not include the income and probability covariates. In model 3 we include income, the trouble probability, and the size of the monthly telephone bill. Our hypothesis is that consumers with higher average bills require more reliable service and are willing to pay a premium to insure reliability. The coefficient of BILL is significant and positive in the

TABLE 2

REDUCED-FORM LOGIT MODELS (N = 10,644)

Dependent Variable: IWM

Independent Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	.286	−.402	−.939	−1.003	−.996
	(14.64)	(−11.37)	(−5.83)	(−15.56)	(−14.67)
POST86		1.015	.984	.984	.983
		(23.58)	(22.55)	(22.55)	(22.50)
BILL			.0249	.0249	.0248
			(11.61)	(11.61)	(11.51)
MINC			−.288		
			(−8.03)		
TPROB			89.36		
			(3.72)		
$\mathrm{MINC} - \overline{\mathrm{MINC}}$				−.288	−.318
				(−8.03)	(−7.87)
$\mathrm{TPROB} - \overline{\mathrm{TPROB}}$				89.36	146.1
				(3.72)	(3.23)
$(\mathrm{MINC} - \overline{\mathrm{MINC}})^2$					.0718
					(2.84)
$(\mathrm{TPROB} - \overline{\mathrm{TPROB}})^2$					−34,671
					(−1.57)
$(\mathrm{MINC} - \overline{\mathrm{MINC}}) \times (\mathrm{TPROB} - \overline{\mathrm{TPROB}})$					−3.39
					(−.07)
Log likelihood	−7,269.8	−6,984.1	−6,852.8	−6,852.8	−6,847.1

NOTE.—1 = purchase insurance (57.1 percent); 0 = self-insure (42.9 percent). t-statistics are in parentheses.

various models. This is consistent with our hypothesis that BILL provides a measure of the importance of service reliability to consumers.[9]

The coefficient of income in model 3 shows that discrete insurance purchases are inferior. As income rises, the probability that an individual will self-insure increases. The sign of the trouble probability variable in model 3 is also consistent with the theory. An increase in the trouble probability increases the demand for IWM and reduces the probability of self-insurance. Model 4 is a simple reprise of model 3 using only the first-order terms from the Taylor series expansion. Note that centering the income and probability terms around their mean values shifts the estimated intercept coefficient. Finally, model 5 adds the second-order terms to model 4. Here again the coefficients on the linear income and probability terms are consistent with the theory. The coefficient on the squared probability term is not significant from zero at conventional levels (also consistent with the predictions of expected utility theory).[10] The cross-partial term has the correct sign for a population of risk-averse individuals, but the estimated coefficient is not significant at conventional levels. Finally, the squared income term is positive and significant, which indicates that the propensity to self-insure is increasing at a decreasing rate.[11]

The estimated coefficients from the reduced-form estimation can also be used to estimate the parameters from a specified parametric utility function (Cicchetti and Dubin 1992). But given the lack of precision attached to some of the estimates in table 2, the mapping of reduced-form to structural-form estimates should not be preferred to direct structural estimation.

B. *Structural-Form Estimation*

We now consider the structural estimation of a utility function consistent with the revealed preferences of individuals who made choices

[9] The referee has suggested two alternative hypotheses to explain the effects of BILL on the consumer's IWM decision. First, consumers with larger values of BILL will find the monthly charge for IWM relatively less expensive and might therefore be more likely to purchase the insurance. The high degree of correlation between BILL and its reciprocal does not make it possible to distinguish these two hypotheses. Second, insofar as customers with higher values of BILL are likely to incur greater costs from the loss of service or the time spent searching for a repair service, they face "worse" self-insurance gambles. Machina's (1982) "fanning-out" hypothesis predicts that these customers should act as though they were more risk preferring. Since the reduced-form estimates show that consumers with larger values of BILL prefer the insurance, it is possible to interpret our results as a rejection of the fanning-out theory.

[10] The referee has noted that the marginal significance of the squared term for TPROB reveals some nonlinear weighting of the probabilities. This result, if credited, provides empirical support for both prospect and rank-dependent preference theories.

[11] Viscusi and Evans (1990) found all their second-order Taylor series terms to be insignificant.

regarding IWM service. The class of utility functions we adopt allows risk aversion to vary among individuals with the same level of income and to vary with the level of income for otherwise identical individuals. We specify utility to be a member of the hyperbolic absolute risk aversion (HARA) class with[12]

$$U(W) = a1 \cdot (W + a2)^L. \tag{7}$$

This utility class contains several well-known utility functions as special cases including linear, quadratic, negative exponential, power, and log. The degree of absolute risk aversion for the utility function in equation (7) is

$$R_a(W) = \frac{1 - L}{W + a2},$$

which is declining in both W and L. Monotonicity and concavity require that $0 < L < 1$.

The arguments to the binary logit function for the choice probability are ΔV and the state-dependent variables: the constant and POST86. To allow the level of risk aversion to vary across individuals, we take the parameter L to be a linear function in the monthly bill:[13]

$$L = b1 + b2 \cdot \text{BILL}. \tag{8}$$

This choice is consonant with our reduced-form analysis, where we found that customers with larger bills were more likely to purchase IWM contracts. We therefore expect the coefficient $b2$ to be negative, which implies that as BILL increases the degree of risk aversion increases. Since the willingness to pay will increase with the level of absolute risk aversion, $\Delta V = U(W - R) - U(W - R^*)$ will increase, making it more likely that insurance will be purchased.

Since overweighting effects may be present, we embed the observed probability within a transformation that allows individuals to consistently under- or overestimate the true trouble probability. We specify the log-odds ratio for the subjective probability of line trouble to be a linear function of the log-odds ratio of the true line trouble probability:

$$\log\left(\frac{p}{1 - p}\right) = c1 + c2 \cdot \log\left(\frac{\text{TPROB}}{1 - \text{TPROB}}\right). \tag{9}$$

This is equivalent to specifying a logit probability for p as a function of a constant term and the log-odds of TPROB. The specification in

[12] See, e.g., Merton (1971) for a discussion of the HARA class.

[13] Viscusi and Evans explore heterogeneity in their estimation by taking key parameters to be linear functions of individual characteristics. The characteristic data were not significant (at the 5 percent level) in their estimation.

TABLE 3

STRUCTURAL LOGIT MODELS (N = 10,644)

Dependent Variable: IWM

Coefficient	Model 1	Model 2	Model 3
$a1$	1,935.1	1,935.1	1,949.4
	(18.23)	(18.24)	(18.22)
$a2$	.6849	.6456	.6475
	(3.632)	(4.283)	(4.253)
$b1$	3.491	3.498	3.497
	(21.33)	(20.98)	(14.75)
$b2$	−.121	−.123	−.124
	(−12.62)	(−13.63)	(−12.89)
$c1$	.0	.0	−.0021
	constrained	constrained	(−.0012)
$c2$	1.0	1.0093	1.0096
	constrained	(72.41)	(2.71)
$d1$	−.054	−.050	−.054
	(−1.17)	(−1.06)	(−1.12)
$d2$	.992	.992	.988
	(22.66)	(22.65)	(22.57)
Log likelihood	−6,791.1	−6,790.9	−6,790.9

NOTE.—1 = purchase insurance (57.1 percent); 0 = self-insure (42.9 percent). t-statistics are in parentheses.

equation (9) allows the subjective probability to be constant ($c2 = 0$), equal to the actual probability ($c1 = 0$, $c2 = 1$), or consistently biased, with measurement of the bias reflected in the coefficient values for $c1$ and $c2$. The model we estimate by FIML is then

$$Q_i = \text{individual } i \text{ purchases IWM} = \frac{1}{1 + e^{-(d1 + d2 \cdot \text{POST86} + \Delta V_i)}}. \tag{10}$$

In all, eight parameters are estimated: $a1$ and $a2$, which characterize the utility function in equation (7); $b1$ and $b2$, which characterize risk aversion in equation (8); $c1$ and $c2$, which characterize subjective probability in equation (9); and $d1$ and $d2$, which characterize state-dependent effects in equation (10).

The results of the estimation are presented in table 3. The models we present vary depending on whether the subjective probability is constrained or not constrained in its relationship to the actual probability. The results are similar across the specifications. In model 3, for example, the parameters of the utility function $a1$ and $a2$ are both significant. The sign of $a1$ shows that the probability of purchasing insurance increases with ΔV as expected.[14] The significance of the

[14] The parameter $a1$ is not determined independently of the scale of the logit model.

term $a2$ rejects the power utility function in favor of the more general HARA class.

The estimated values for the parameters $c1$ and $c2$ reveal that consumers use a subjective probability that is nearly identical to the actual probability: $c1$ is not statistically different from zero and $c2$ is significant but not significantly different from one. Thus there is slight evidence that consumers overestimate the small trouble probability event, but not to any significant degree.[15] The estimates of the coefficients $d1$ and $d2$ are similar to those we obtained in the reduced-form estimation for the alternate specific constant and the POST86 dummy variable. The only difference is that the intercept is not significant from zero in the structural estimates.

The coefficients $b1$ and $b2$ for the risk parameter $L(b1, b2)$ are each significant, and $b2$ has the hypothesized negative sign. Predicting the risk aversion parameter L for each sample observation, we find that L is positive in about 78 percent of all households (consistent with expected utility theory) but negative in the remaining 22 percent (inconsistent with expected utility theory). The parameter L has an average value of 0.37 with a minimum of -8.86, a maximum of 2.87, and a standard deviation of 1.28. In about 41 percent of the cases, L lies in the unit interval. In these cases individuals experience declining absolute risk aversion. With only 22 percent of the cases having point predictions that are nonpositive, the overall pattern of results is remarkably consistent with expected utility theory.

The average individual (with monthly income of $1,699.40 and an L value of 0.37) has a relatively small degree of absolute risk aversion and would be willing to pay only $0.264 per month to avoid the inside-wire trouble. That 57 percent of households in the sample subscribe to the IWM program can be explained in part by the change in demand that resulted from the marketing efforts of Mountain Bell after 1986 and the general preference for the status quo and for priority service present in the 1980s.

VII. Conclusions

Day and Fox (1985, p. 83) hypothesized that "relatively affluent persons, especially those who also are well educated, are less likely to perceive real value in appliance service contracts, because these persons generally tend to be less risk-averse, i.e., more likely to self-

[15] A model that imposes a form of non–expected utility theory wherein $c2$ is constrained to be zero produced a smaller log likelihood ($-6,792.4$). The estimated subjective probability in this case was .00678 (t-statistic = 44.4). This suggests that consumers overestimate the mean probability to a degree that is small in absolute terms but large in percentage terms.

insure, than consumers on restricted budgets." Our estimation has confirmed the presence of risk aversion and has also revealed that IWM purchases are for the most part inferior.

The results we have obtained are also very encouraging for expected utility theory. The coefficients determined in the structural estimation were significant and in accord with our expectations. For most consumers, increases in income led to increases in the likelihood that self-insurance was selected. On the other hand, consumers who had higher phone usage were less likely to self-insure.

The structural models provided significant improvement in overall fit as compared with the reduced-form models, as evidenced by the significant improvement in the log likelihoods at convergence (note that model 5 of table 2 and model 3 of table 3 have the same degrees of freedom). Moreover, the structural logit model correctly predicts the choices of about 65 percent of the cases, which is significant since the frequency of observed selection was only 57 percent choosing IWM versus 43 percent not doing so.

The HARA utility class was found to perform better than other common choices such as log and negative exponential in the sense that imposing these functional forms led to either problems with nonconvergence or models that converged to implausible values (such as everywhere nonmonotonic utility). This may explain some of the difficulty encountered by Viscusi and Evans (1990). Using log utility, they were able to solve for the exact risk premium in closed form. Their estimation was accomplished using nonlinear least squares. For other forms of the utility function, Viscusi and Evans were not able to solve directly for the risk premium and were therefore unable to estimate their model by nonlinear least squares. Their attempts at FIML methods were nonconvergent.

Finally, our estimation sample does not reflect the greater participation levels for IWM that prevailed in the 1980s. In order to gauge the willingness to pay of individuals to avoid telephone line trouble, we have made an adjustment to the alternative specific constant in the structural logit model to reflect a 70 percent market penetration. In the 1980s, the median individual was willing to pay about $0.55 per month to avoid inside-wire trouble.

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