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RATES OF TIME PREFERENCE AND CONSUMER VALUATIONS OF AUTOMOBILE SAFETY AND FUEL EFFICIENCY*

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ABSTRACT

This article estimates hedonic price models for automobiles using a data set on almost 3,000 households from the U.S. Department of Energy Residential Transportation Energy Consumption Survey. The standard hedonic models are generalized to recognize the role of discounting of fuel efficiency and safety, yielding an estimated rate of time preference ranging from 11 to 17 percent. This range includes the prevailing rate of interest for car loans in 1988 and is consequently consistent with market rates. Purchasers exhibit an implicit value of life ranging from $2.6 to $3.7 million, which is within the range found in the labor market as well as other market contexts. The model also estimates a significant price effect for auto injury risks and fuel efficiency.

I. INTRODUCTION

AUTOMOBILES are among the most regulated consumer products. Two of the chief forms of regulation affecting cars are safety and fuel economy regulations. In the case of safety, the regulatory structure consists of government-mandated design standards for various safety features ranging from seat belts to air bags. Government interventions affecting fuel economy are more diverse, as they include fuel economy standards for corporate fleets (CAFE standards), a gas guzzler tax for low-mileage cars, and gasoline taxes intended to promote energy conservation.

If market forces were fully effective, these interventions would not be necessary to correct for inadequacies in consumer decisions. There would, of course, be a need to address broader societal externalities. Advocates of government intervention note the presence of externalities and also frequently assume that automobile owners may not appropriately value the safety features and fuel economy of their cars. The nature

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of individual choices in the market affects not only the rationale for government intervention but also the degree to which market-based interventions, such as various tax mechanisms, can be used to promote safety and fuel economy. For example, do gasoline excise taxes simply lower the welfare of automobile purchasers, or do they also promote the purchase of more fuel-efficient cars and reduce the total number of miles traveled?

In the case of business vehicles, such as company-owned cars, the effect of regulations such as the CAFE standards should reflect sound economic decisions. Companies presumably do not face the same degree of capital constraints that might influence consumer behavior. Moreover, businesses should be relatively sophisticated vehicle purchasers and will weight the long-term fuel efficiency and safety characteristics of vehicles appropriately.

This article examines the valuations of safety and fuel economy by a possibly less sophisticated purchasing group, private automobile owners. First, what is the implicit value of life and the injury-price trade-off that consumers exhibit in the market? Do these values indicate a trade-off rate similar to that found in other market contexts? The marginal trade-offs may differ, in part because of government-mandated safety equipment, which consumers may not value as highly as safety attributes purchased voluntarily. In addition, trade-offs will vary depending on the preferences of the affected group. Automobile purchasers and workers need not have the same risk-money trade-off.

Second, to what extent do individuals value the differences in fuel economy across cars? Do they internalize the incentives created by higher financial costs, such as gasoline taxes and the gas guzzler tax, or must the government utilize command-and-control regulations, such as CAFE standards?

Third, what is the implicit interest rate that individuals exhibit when valuing the long-run safety and fuel economy attributes of their automobiles? Do they weight these long-run effects in a manner that is consistent with their discounting behavior in financial contexts, or do they exhibit temporal myopia? The nature of this temporal weighting is of consequence, not only in diagnosing the extent to which there is market failure, but also in indicating whether policy interventions that affect the initial vehicle price, such as a gas guzzler tax, will have a greater effect on automobile choice than higher gasoline taxes that create a financial operating cost over time.

Thus, in each of these areas of inquiry, our concern will be twofold. First, what is the nature of the market trade-offs and is there any clear-cut evidence of market failure? Second, to what extent can we rely on market-based policy interventions to promote government objectives with respect to automobile use?

This research utilizes the general econometric approach developed in the hedonic price literature. For over a half century, there has been concern with obtaining quality-adjusted prices of automobiles, as exhibited in the work of A. T. Court,[1] Jack E. Triplett,[2] Zvi Griliches,[3] Makoto Ohta and Griliches,[4] and Keith Cowling and John S. Cubbin.[5] The most recent literature in this vein has exhibited a concern for fuel economy, as in the studies by Allen C. Goodman,[6] Thomas F. Hogarty,[7] Scott E. Atkinson and Robert Halvorsen,[8] and Ohta and Griliches,[9] although the estimated fuel economy signs are opposite of the predicted direction in many instances. In addition, one study, that of Atkinson and Halvorsen,[10] examined the price-vehicle safety trade-off but not the fuel economy–price relationship.

Although the implicit price literature for automobiles is well established, this article offers several advances over previous studies. This will be the first study to provide estimates of the implicit rates of interest used by individuals in assessing the long-run effects of automobiles, both with respect to safety and fuel economy. Automobiles are a consumption good that is durable in nature. Although used cars can be sold or possibly even rented, in each case the long-term attributes of the car, such as its

[1] A. T. Court, Hedonic Price Indexes with Automotive Examples, in The Dynamics of Automobile Demand (1939).

[2] Jack E. Triplett, Automobiles and Hedonic Quality Measurement, 77 J. Pol. Econ. 408 (1969); and Jack E. Triplett, The Economic Interpretation of Hedonic Methods, 66 Surv. Current Bus. 36 (1986).

[3] 3. Zvi Griliches, Hedonic Price Indexes for Automobiles: An Econometric Analysis of Quality Change, in Technology, Education and Productivity (1988); Price Indexes and Quality Change (Zvi Griliches ed. 1971).

[4] Makoto Ohta & Zvi Griliches, Automobile Prices Revisited: Extensions of the Hedonic Hypothesis, in Household Production and Consumption (Nestor E. Terleckyj ed. 1976).

[5] Keith Cowling & John S. Cubbin, Hedonic Price Indexes for United Kingdom Cars, 82 Econ. J. 963 (1972).

[6] Allen C. Goodman, Willingness to Pay for Car Efficiency: A Hedonic Price Approach, 17 J. Transport. Econ. & Pol'y 247 (1983).

[7] Thomas F. Hogarty, Price-Quality Relations for Automobiles: A New Approach, 7 Applied Econ. 41 (1975).

[8] Scott E. Atkinson & Robert Halvorsen, A New Hedonic Technique for Estimating Attribute Demand: An Application to the Demand for Automobile Fuel Efficiency, 66 Rev. Econ. & Stat. 417 (1984).

[9] Makoto Ohta & Zvi Griliches, Automobile Prices and Quality: Did the Gasoline Price Increases Change Consumer Tastes in the U.S.? 4 J. Bus. & Econ. Stat. 187 (1986).

[10] Scott E. Atkinson & Robert Halvorsen, The Valuation of Risks to Life: Evidence from the Market for Automobiles, 72 Rev. Econ. & Stat. 133 (1990).

expected longevity, will influence its value. Since an automobile is a capital asset, an important question to ask is, what is the extent to which the implicit rates of time preference for key attributes of the product are consistent with prevailing market rates of interest?

The second innovation of this article is that, instead of relying on average published prices for lines of cars, as in previous studies, we utilize individual household automobile holdings data. With this information, it will be possible to match cars with the household characteristics of those who own them. We have further refined our econometric analysis by including estimates of the fuel economy–price trade-off as well as the value of the life-price trade-off. Moreover, the value-of-life estimates will be generated by a price equation that also includes a variable categorizing the nonfatal injury risks associated with automobiles, so that the value-of-life estimates will not be capturing the omitted influence of nonfatal risk attributes of cars.

Section II of the article introduces the hedonic model, which extends the existing frameworks in the literature by incorporating the various discounting considerations. After discussing the sample characteristics and the variables in Section III, Section IV reports on the price equation estimates, including the role of discounting. The estimated real rate of interest is between 11 and 17 percent. As indicated in the conclusion in Section V, these estimates are consistent with prevailing interest rates for automobile purchases. The value-of-life estimates are on the order of \$2.6–\$3.7 million in 1988 prices.

II. The Hedonic Model

A. *The Hedonic Framework*

The basic elements of the econometric approach are based on Sherwin Rosen's paper on hedonic pricing,[11] which we will extend to consider intertemporal dimensions of automobile holdings. Automobiles embody a bundle of characteristics, designated below by A_k, where

$$\text{auto} = (A_1, A_2, A_3, \ldots, A_n). \quad (1)$$

In a competitive equilibrium, the price of the good is a function of the implicit prices of the bundle of its attributes:

$$P_{\text{auto}} = P(A_1, A_2, A_3, \ldots, A_n). \quad (2)$$

[11] Sherwin Rosen, Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition, 82 J. Pol. Econ. 34 (1974).

This relationship, P(auto), defines the hedonic price function, the equilibrium locus of vehicle prices resulting from the market interactions of producers and consumers for different bundles of vehicle characteristics.

Each implicit marginal price, $p(A_k)$, is the partial derivative of the equilibrium hedonic price locus with respect to the attribute of interest, A_k, or

$$p(A_k) = \frac{\partial P_{(\text{auto})}}{\partial A_k} = P_{A_k}(A_1, A_2, A_3, \ldots, A_n). \qquad (3)$$

This value simultaneously reflects consumers' marginal willingness to pay for an additional unit of that attribute and the firm's marginal cost of providing another unit of the attribute.

We use data drawn from household vehicle holdings to estimate vehicle price as a function of a set of individual automobile i's attributes, A_{ik}, and owner characteristics, X_{iz}, that is linked to automobile accident rates (for the zth characteristic of the owner of vehicle i). The reduced-form estimation equation is

$$P_{(\text{auto})i} = \sum_k \beta_k A_{ik} + \sum_z \delta_z X_{iz} + e_i, \qquad (4)$$

where the price of auto i is a function of vehicle and owner attributes and other unmeasured attributes represented by a random error term e_i.

B. Discounting and Hedonic Prices

Because of the durable nature of automobiles, the specification of the price equation ideally should be extended to account for the long-run nature of this consumer product. In particular, consumer discount rates enter as an important variable of concern in valuing the long-run cost and safety of the product.

The recent literature has included a variety of attempts to ascertain the implicit rates of time preference associated with consumer decisions, although none of the product market studies has used a hedonic price approach. In his examination of household purchases of home room air conditioners, using a simultaneous model of air conditioner purchase and utilization rate for 46 households, Jerry A. Hausman found that future energy expenditures were discounted at a mean rate of 26.4 percent, with a range of 5.1–89 percent, depending on the household's income level.[12]

[12] Jerry A. Hausman, Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables, 10 Bell J. Econ. 33 (1979).

Dermot Gately employed a similar model to analyze consumer choices of household refrigerators, for which he found that discount rates could be as high as 300 percent, with the lowest calculated discount rate equaling 45 percent.[13] Jeffrey A. Dubin examined explicit rates of discount affecting the type of heating for households, where he found discount rates at a similar range, such as 44 percent for fuel expenditures associated with water heaters.[14] Finally, Douglas A. Houston examined hypothetical energy choices in a contingent-valuation study, for which he ascertained a discount rate of 22.5 percent, although once again there was a considerable range of values.[15]

The approach adopted here will be somewhat different in that we will derive the implicit rates of discount from a hedonic price equation. In that respect, this analysis most closely parallels the labor market hedonic wage studies by Michael J. Moore and W. Kip Viscusi[16] and Viscusi and Moore.[17] In particular, they examined how the discounted expected life years lost due to job risks affected wage rates. However, their approach dealt with a continuous job activity, not a capital good, so the structure of the models differs. Our approach will analyze how consumers' discount rates for operating costs and remaining life years of the vehicle owner affect the automobile price. Thus, the task is to structure the fuel-efficiency and the risk components of equation (4) to incorporate these intertemporal aspects of the automobile purchase decision.

Using data on the age distribution of the vehicle fleet, we determined each vehicle's expected remaining useful life, T_i. The present discounted value of operating costs (PDVOC) is the discounted sum of operating

[13] Dermot Gately, Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables: Comment, 11 Bell J. Econ. 373 (1980).

[14] Jeffrey A. Dubin, Will Mandatory Conservation Promote Energy Efficiency in the Selection of Household Appliance Stocks? 7 Energy J. 99 (1986). Some authors have not estimated discount rates explicitly but instead have determined the payback period for appliance types and the discount rates implicit in the estimated payback period. Henry Ruderman, Mark D. Levine, & James E. McMahon, The Behavior of the Market for Energy Efficiency in Residential Appliances Including Heating and Cooling Equipment, 8 Energy J. 101 (1987), found discount rates ranging from 20 percent for room and central air conditioners to as high as 800 percent for electric water heaters.

[15] Douglas A. Houston, Implicit Discount Rates and the Purchase of Untried, Energy-Saving Durable Goods, 10 J. Consumer Res. 236 (1983).

[16] Michael J. Moore & W. Kip Viscusi, The Quantity-Adjusted Value of Life, 26 Econ. Inquiry 369 (1988); Michael J. Moore & W. Kip Viscusi, Discounting Environmental Health Risks: New Evidence and Policy Implications, 18 J. Envtl. Econ. S51 (1990); Michael J. Moore & W. Kip Viscusi, Models for Estimating Discount Rates for Long-Term Health Risks Using Labor Market Data, 3 J. Risk & Uncertainty 381 (1990).

[17] W. Kip Viscusi & Michael J. Moore, Rates of Time Preference and Valuations of the Duration of Life, 38 J. Pub. Econ. 297 (1989).

costs in each year of the vehicle's remaining life,

$$\text{PDVOC}_i = (1 + e^{-r} + e^{-2r} + \ldots + e^{-(T_i-1)r})\text{OPERATING COST}_i, \quad (5)$$

which can be solved to yield

$$\text{PDVOC}_i = \frac{1 - e^{-rT_i}}{r}\ \text{OPERATING COST}_i, \quad (6)$$

where r is the implicit discount rate. The implicit discount rate of any individual will reflect the individual's rate of time preference and any premia for liquidity, risk, and uncertainty. The econometric analysis will estimate the average value of r for the sample, not for each individual.

A variable pertaining to the discounted operating cost per unit weight will also be included to capture the importance of operating cost characteristics in relation to the size of the vehicle. The relationship between fuel economy and weight is a result of the fundamental principle that additional mechanical energy is required to overcome additional inertia or weight. Holding all other design and performance factors equal, a heavier car will be less fuel efficient. But if weight could be held constant, other design factors would explain variations in fuel economy. To capture this connection, operating costs are included in the model as a stand-alone variable to reflect variability in fuel economy related to vehicle weight and other factors. Operating costs also enter through operating cost per unit weight, which should reflect the influence of variability in fuel economy across cars, adjusting for variations in weight.

Similarly, individual j's discounted remaining life years are calculated as

$$\text{discounted remaining life years}_j = \frac{1 - e^{-L_j r}}{r}, \quad (7)$$

where L_j is the expected remaining life of the jth individual and r is the discount rate over additional life years. Although the discount rate on operating costs and the discount rate over remaining life years theoretically may differ, these values could not be distinguished empirically. The discounted expected life years lost from accidents involving one's specific automobile holdings is calculated based on the discounted expected life years lost from fatality risks in each year the car is owned, multiplied by the discounted number of years the car is owned,[18] or

[18] This formulation is an approximation, as it abstracts from the change in the value of life expectancy over the course of the vehicle life. This approach was more feasible to estimate than even more complex nonlinear functions.

$$\text{discounted expected life years lost}_{ij} =$$

$$\underset{\substack{\text{discounted life}\\ \text{of vehicle}}}{\left[\frac{1 - e^{-rT_i}}{r}\right]} \times \underset{\substack{\text{discounted life}\\ \text{of owner at risk}}}{\left[\frac{1 - e^{-rL_j}}{r}\right]} \times \underset{\substack{\text{annual mortality}\\ \text{risk}}}{\text{pr[mortality]}_i}. \quad (8)$$

This expression captures the expected discounted years of life that the individual will lose during the discounted expected life of the vehicle. The potential life of the vehicle, T_i, will be less than the individual's life, L_j, but it is assumed that the consumer uses the same rate of time preference r in each of the two component discounting terms. The discounted expected life years lost term in equation (8) extends the Moore and Viscusi measure of quantity-adjusted life years[19] to situations involving capital goods in which the exposure to the risk and the individual life have a temporal aspect that must be taken into account.

Injury rates for autos also affect their long-term attractiveness and enter the model in discounted form. As in the case of vehicle operating costs, the relevant time frame for discounting the injury rating is over the life of the vehicle, not the life of the individual. An injury is by definition nonfatal, and the probability of an injury changes as an individual changes the vehicle driven. The injury risk term and the operating cost terms are defined analogously, where the difference in the annual injury rating for vehicle i replaces the operating cost for vehicle i in equation (6). The discounted expected operating costs and injury rating over the remaining vehicle life and the expected life years lost are substituted into the hedonic formulation for the operating cost and safety attributes.

The dependent variable in the model will be the natural logarithm of the price, and to permit flexibility in the functional form for the independent variables, we use a Box-Cox transformation with a coefficient λ to be estimated.[20] Given the recognition of life-cycle concerns in the operating cost and safety variables, including the discounted expected life years lost term from equation (8), the equilibrium hedonic price locus can now be specified as

[19] Moore & Viscusi, The Quantity-Adjusted Value of Life, *supra* note 16.

[20] Preliminary empirical analysis varying the functional form of the dependent variable suggested that the logarithm of price was a more pertinent formulation than the linear form. The logarithmic formulation is also standard in most labor market hedonic wage studies as well.

$$
\begin{aligned}
\ln[P_{(\text{auto})i}] = \beta_0 &+ \beta_1\left[\frac{1-e^{-rL_j}}{r}\frac{1-e^{-rT_i}}{r}\text{MORTALITY RISK}_i\right]^{\lambda} \\
&+ \beta_2\left[\frac{1-e^{-rT_i}}{r}\text{INJURY}_i\right]^{\lambda} \\
&+ \beta_3\left[\frac{1-e^{-rT_i}}{r}\text{OPERATING COST}_i\right]^{\lambda} \\
&+ \beta_4\left[\frac{1-e^{-rT_i}}{r}\frac{\text{OPERATING COST}}{\text{WEIGHT}}_i\right]^{\lambda} \\
&+ \sum_k \beta_k A_{ki}^{\lambda} + \sum_z \delta_z X_{iz} + e_i,
\end{aligned} \tag{9}
$$

where λ is the Box-Cox transformation coefficient, which is interpreted as follows:

$$A_{ki}^{\lambda} = \frac{A_{ki}^{\lambda} - 1}{\lambda} \quad \text{for } \lambda \neq 0. \tag{10}$$

If the transformation coefficient equals one, the model is linear, but as λ approaches zero, the right-hand side takes a logarithmic form:

$$\lim_{\lambda \to 0} A_{ki}^{\lambda} = \ln A_{ki}.$$

III. Sample Characteristics and Variables

The data used to obtain the empirical estimates differ from those used in earlier studies in the literature in that these data reflect actual consumer automobile holdings. In particular, we utilize the 1988 Residential Transportation Energy Consumption Survey (RTECS) conducted by the U.S. Department of Energy (DOE).[21] In 1988, DOE collected transportation-related energy data from a cross section of 2,986 sampled households. The survey included questions on vehicle holdings, usage, selected vehicle characteristics, and socioeconomic characteristics of the respondents. Additional vehicle attribute data have been collected from industry

[21] For a description of the survey, see U.S. Department of Energy, Household Vehicles Energy Consumption 1988 (1990).

TABLE 1

MEANS, STANDARD DEVIATIONS, AND ANTICIPATED SIGNS OF SELECTED VARIABLES WITH RESPECT TO PRICE

Variable	Mean*	Standard Deviation	Anticipated Sign
PRICE	6,622.81	4,109.10	N.A.
MORTALITY RATE (× 1,000)	.1962	.0957	−
INJURY RATING	100.93	23.61	−
OPERATING COST	563.65	144.08	−
POWER	.04	.01	+
CARGO CAPACITY	15.18	5.57	+
WEIGHT	2,724.65	568.20	−
MAINTENANCE RATING	.91	.28	+
LUXURY-SPORT	.18	.39	+
AUTOMATIC TRANSMISSION	.76	.43	+
TWO-SEAT	.02	.14	?
WAGON	.03	.16	?
CONVERTIBLE	.01	.06	?
DIESEL	.01	.10	?
RESALE VALUE RETAINED†	57.59	16.77	+

NOTE.—N.A. = not applicable.
* Means weighted by Residential Transportation Energy Consumption Survey population sampling statistics.
† Excluding 1988 model year new cars.

sources to supplement the RTECS data. The variables used are summarized below, and Table 1 provides selected summary statistics.

PRICE = Vehicle price as of end-of-year 1988. New price for model year 1988 vehicles, used car market prices for older cars.

MORTALITY RATE = Number of fatalities occurring in that make/model/year vehicle divided by number of vehicles on the road.

INJURY RATING = Vehicle injury rating measured relative to the rating for the median vehicle. Median rating equals 100, and lower values are safer cars.

OPERATING COST = Vehicle operating costs measured in dollars of fuel expenditure per year. Calculated as gas price

		divided by miles per gallon times average miles traveled.
OPERATING COST: WEIGHT	=	Vehicle operating cost per unit of vehicle weight.
POWER	=	The horsepower-to-weight ratio as a measure of vehicle power/acceleration.
CARGO CAPACITY	=	Vehicle cargo space in cubic feet.
MAINTENANCE RATING	=	A discrete variable coded as one if the *Consumer Reports* maintenance rating is two or higher and coded as zero if the maintenance rating is below two.
LUXURY-SPORT	=	A discrete variable coded as one if the vehicle is classified as a luxury or sport vehicle.
AUTOMATIC TRANSMISSION	=	A discrete variable coded as one if the vehicle has an automatic transmission.
TWO-SEAT	=	A discrete variable coded as one if the vehicle is a two-seat model.
CONVERTIBLE	=	A discrete variable coded as one for convertibles.
WAGON	=	A discrete variable coded as one for station wagons.
DIESEL	=	A discrete variable coded as one for diesel models.
AMC, FORD, GM, CHRYSLER, GERMANY, JAPAN, OTHER ORIGIN	=	Discrete variables coded as one for the manufacturer of domestic vehicles and for foreign vehicles, coded as one for the nation of origin if that designation is pertinent and zero otherwise.
YEARXX	=	Discrete variables coded as one for the vehicle model year.
SIZEX	=	Discrete variables coded as one for the appropriate size category. Four size categories are included, from SIZE1, smallest, to SIZE4, largest.

RESALE VALUE RETAINED = The percentage of original sales value retained, as of end-of-year 1988.

Because the data set contains information on the actual holdings of households, each vehicle represents the actual trade-offs among attributes made by some consumer in the marketplace. A wide selection of alternative vehicle models is included in this data set because many models are available equipped with a variety of optional engine types; hence, a named model may appear repeatedly with different attributes. Most previous studies included only one observation for a standardized version of each vehicle model.

Another unique aspect of this study is that the data reflect actual automobile holdings at a specific point in time—a snapshot of consumer behavior. Each vehicle's market price reflects the opportunity cost of owning that specific vehicle. The implicit attribute values derived from a household's vehicle holdings will provide insight into the trade-offs in their vehicle stock.

Based on a review of the economics literature related to vehicle choice and the available marketing information, we selected safety, fuel economy, power, reliability, and durability as the most important attribute variables. Other important variables include physical characteristics, vehicle size, manufacturer/nation of origin, and vehicle age. In most prior studies, a measure of vehicle safety has been an important missing element. Only Atkinson and Halvorsen include a measure of vehicle safety,[22] but fuel economy is not included in their model, precluding an examination of the trade-offs between fuel economy and safety. Some studies incorporated vehicle weight as a proxy for safety, but this attribute affects other aspects of vehicle performance as well.

Several vehicle attributes are closely related, such as different vehicle size parameters. Economists have recognized the difficulties posed by the relationship of vehicle weight to other attributes of interest for over half a century.[23] Including all possible variables of interest will create multicollinearity problems, as several authors have reported coefficient instability. While there are inherent problems of collinearity among motor vehicle attributes such as fuel economy and size in all such data sets, we attempted to reduce these problems by carefully choosing our measures

[22] Atkinson & Halvorsen, *supra* note 10.

[23] In his 1939 study, *supra* note 1, at 113, Court recognized that "car weight per se is undesirable and in a complete analysis would have a negative net regression." This statement presumably means that the weight coefficient should be negative.

of vehicle characteristics. For example, as a measure of vehicle power/acceleration, we chose the horsepower-to-weight ratio (as have several other authors), in part because of the lower collinearity than was created by measures such as zero-to-sixty acceleration.

Vehicle weight is an important design characteristic because of its physical contribution to several different aspects of vehicle performance. Holding all else equal, heavier cars are typically safer and have higher operating costs per mile traveled.[24] Following the lessons of prior studies, weight is not included as a stand-alone attribute but is entered as an interaction term where appropriate.

Several other variables which embody elements of vehicle styling are included, such as dummy variables for luxury and sport vehicles and vehicle size categories.[25]

A. *Vehicle Transactions Prices*

Because the hedonic price locus represents equilibrium transactions prices of different attribute bundles, an empirical analysis should ideally incorporate actual automobile marketplace transactions prices. Our analysis focuses on existing vehicle holdings. Average market prices for most vehicles, based on actual transactions, are widely available. Hence, the estimated vehicle prices should mirror retail market transactions prices.[26] These prices average $6,623 for our sample of vehicles.

[24] Triplett, Automobiles, *supra* note 2, paid particular attention to vehicle weight because of the correlation between weight and other attributes and because weight served as a proxy for other variables in his model. In the truncated model, he speculated that weight could have represented a number of desirable vehicle characteristics, such as the size or capacity of the vehicle, its durability, or its insulation against sound or vibration.

Griliches, Hedonic Price Indexes, *supra* note 3, raised another difficulty associated with these models, especially those including weight as an explanatory variable. He noted that the correlation coefficients between several of his right-hand-side variables, including weight, length, and horsepower, fell in the range between 0.73 and 0.92. Such highly correlated explanatory variables led to coefficient instability across several different model specifications.

[25] George E. Hoffer & Robert J. Reilly, Automobile Styling as a Shift Variable: An Investigation by Firm and by Industry, 16 Applied Econ. 291 (1984), found that styling and styling changes were important factors underlying automobile demand. Another variable commonly included in similar models but not incorporated here is vehicle handling. The only available measure of handling, the turning radius, proved to be too highly correlated with other characteristics to merit inclusion. Other attributes that have been used in hedonic automobile studies include slalom time as a measure of vehicle handling, noise and vibration insulation, leg room, ease of entry and exit, interior space, number of passengers seated comfortably, braking distance, and a variety of measures of vehicle size.

[26] Price data are for year-end 1988 from the Automobile Red Book: Official Used Car Valuations.

B. *Vehicle Safety Measures*

Vehicle safety is incorporated into the model with two separate measures. The first is the vehicle mortality rate, measured by the ratio of the number of fatalities occurring in each make/model/year vehicle to the number of those vehicles on the road. Vehicle mortality rates were calculated based on information from the U.S. Department of Transportation's *Fatal Accident Reporting System* (FARS) for calendar year 1989.[27] For each make/model/year vehicle, the mortality rate was calculated as follows:

$$\text{MORTALITY RATE} = \frac{\text{TOTAL FATALITIES FOR 1989}}{\text{NUMBER MANUFACTURED} \times \text{ON-ROAD FACTOR}}, \tag{11}$$

where the on-road factor accounts for the difference in the total number of that make/model/year vehicle manufactured and the estimated number on the road in calendar year 1989.

The second safety measure is an index of the relative number of personal injury claims filed for each vehicle model normalized by the total insurance exposure written by insurance firms for that model.[28] Since nonfatal accidents are much more frequent than fatal ones, this variable equals a nonfatal risk measure, or the likelihood of injury resulting from a given accident in a specific vehicle. The sign on the coefficients of the two risk variables should be negative since less safe cars (higher value of the variables in each case) are expected to have a lower price when holding all other attributes constant.

Vehicle accident rates also depend upon how safely the vehicle is driven. Measures of mortality risk are consequently a composite of vehicle and driver characteristics.[29] An ideal risk measure would relate fatalities strictly to the structural characteristics of each vehicle, exclusive of driver characteristics. Of course, no such comprehensive measure exists. To account partially for the joint determination of mortality risk due to

[27] Atkinson & Halvorsen, *supra* note 10, similarly relied on the FARS data for their fatality measure.

[28] These data are published annually by the Highway Loss Data Institute, an affiliate of the Insurance Institute for Highway Safety.

[29] Vehicle and driver characteristics may not be independent because certain vehicles are more likely to be owned by those with particular demographic characteristics (for example, households with children may own safer vehicles) and because, as Peltzman recognized, driving behavior may respond to vehicle safety characteristics. See Sam Peltzman, The Effects of Automobile Safety Regulation, 83 J. Pol. Econ. 677 (1975).

both automobile and driver characteristics in the FARS data set, a number of variables are included in the model which account for non-vehicle-specific determinants of mortality risk. This approach is similar to that of Atkinson and Halvorsen, who also used mortality data derived from the FARS database.[30] These variables measure the proportion of fatalities in each make/model/year vehicle for which the specific characteristic applies.

The variables used to categorize driver behavior as it affects auto risks are listed below. They include the proportion of young drivers and that of older drivers, the proportion of accidents occurring late at night, the proportion of one-car accidents, the proportion of alcohol-related accidents, the proportion of drivers wearing seat belts, and the proportion of male drivers. These variables encompass many of the important risk factors for vehicle accidents and key measures of risk-related behavior, such as whether drivers wear seat belts.

YOUNG DRIVER =	Proportion of fatalities in this make/model/year vehicle in which the driver was younger than 25 years.
OLDER DRIVER =	Proportion of fatalities in this make/model/year vehicle in which the driver was 45 or older.
LATE NIGHT =	Proportion of fatalities in this make/model/year vehicle which occurred between the hours of midnight and six in the morning.
ONE-CAR ACCIDENT =	Proportion of fatalities in this make/model/year vehicle in which only one vehicle was involved.
SEAT BELT =	Proportion of fatalities in this make/model/year vehicle in which the driver was wearing a seat belt.
ALCOHOL INVOLVEMENT =	Proportion of fatalities in this make/model/year vehicle in which the on-scene police officer reported alcohol involvement.
MALE DRIVER =	Proportion of fatalities in this make/model/year vehicle in which the driver was male.

30 Atkinson & Halvorsen, *supra* note 10.

C. *Vehicle Operating Cost*

The fuel efficiency of each vehicle is measured by annual vehicle operating cost, which is determined by the gallon cost of gasoline divided by the miles per gallon of fuel times average annual vehicle miles,

$$\text{OPERATING COST} = \left(\frac{\$}{\text{gallon}}\right) \Big/ \left(\frac{\text{miles}}{\text{gallon}}\right) \times \text{average miles driven} = \frac{\$}{\text{year}}. \tag{12}$$

The price of gasoline is determined by the household's regional location and the fuel type reported for that vehicle. Vehicle miles per gallon is an estimate of actual in-use fuel efficiency.[31] Average vehicle miles are calculated from the subset of RTECS respondents with valid responses to the mileage survey.[32] In the empirical analysis, vehicle operating cost is reformulated as a discounted value over the vehicle life cycle.

If consumers behave rationally in their automobile holdings, the discounted operating cost coefficient should be negative. Indeed, if the market efficiently capitalizes life-cycle costs into vehicle prices, the increase in price should exactly compensate for the discounted value of the fuel savings over the anticipated vehicle life.

In several previous hedonic studies of automobiles, unanticipated signs on fuel economy resulted, as reported in Goodman,[33] Cowling and Cubbin,[34] and Hogarty.[35] These and subsequent authors[36] have speculated that the unexpected sign on fuel economy resulted from multicollinearity

[31] This estimate is based on a U.S. Department of Energy adjustment algorithm described in an appendix available from the authors.

[32] Valid mileage estimates were much more likely to be missing from the RTECS data than for other variables because valid beginning and end-of-year contacts are required to generate a number. Respondents also must check the odometer reading, which requires more effort than recalling, for example, the number of seats in the car. Fewer than 65 percent of RTECS respondents supplied valid mileage values. Mileage estimates for the remaining households were imputed for RTECS reporting using a multiple regression procedure. Comparing the reported mileage values with the imputed mileage values shows that the imputation consistently underestimated vehicle miles. No differences in demographic characteristics between the reporting households and the imputed households could be demonstrated by the authors to account for the differences. The valid mileage results were used to calculate the average mileage for new 1988 model year vehicles and for pre-1988 vehicles in the household stock.

[33] Goodman, *supra* note 6.

[34] Cowling & Cubbin, *supra* note 5.

[35] Hogarty, *supra* note 7.

[36] For example, Atkinson & Halvorsen, *supra* note 8.

among automobile attributes used as explanatory variables for vehicle price.[37]

D. *Vehicle Power/Acceleration*

The power of each vehicle is measured by the horsepower-to-weight ratio. The horsepower-to-weight ratio should most accurately reflect vehicle acceleration because raw horsepower is adjusted for the amount of weight which must be overcome.[38]

E. *Vehicle Maintenance/Reliability*

A vehicle reliability measure is drawn from *Consumer Reports*. The raw data collected for reliability provide an ordinal measure of reliability rather than a cardinal measure. Therefore, reliability is incorporated in the regressions as a dummy variable with a value of one for vehicles with a 5-year average reliability rating of two and above and a value of zero for a rating of less than two.

F. *Cargo Capacity*

Vehicle cargo capacity is included as a measure of vehicle size. Consumers may choose between specific vehicles based on the convenience provided by cargo space.

G. *Durability and Vehicle Life*

Vehicle durability will be incorporated by a proxy variable measuring the proportion of the original sale value of the vehicle retained as of the end of 1988. No true measure of vehicle durability that would vary from one vehicle make/model/year to another was available. Though resale value retained is also an imperfect proxy for durability, it is presumed that vehicles with high retained resale values will have a longer life than vehicles with a lower proportion of original value retained.

The key components that determine the various terms of the model

[37] The potentially most troublesome remaining source of multicollinearity in this data set is that between operating cost and safety as measured by personal injury claims, with a correlation coefficient of −0.5. The simple correlation between operating cost and weight equals 0.73, while that between the safety measure and weight is −0.71.

[38] Alternative measures of power that have been used in prior studies include zero-to-sixty acceleration, horsepower, and this ratio. A measure of vehicle acceleration would have been desirable as acceleration is most readily interpretable by consumers, but comprehensive acceleration data were not available. An added advantage associated with this measure is that the ratio is uncorrelated with other explanatory variables.

involving discounting pertain to the expected useful life of the vehicle and the lifetime of the driver. The expected remaining life of the vehicle is determined from historic data on the age distribution of the vehicle fleet. The expected vehicle life is based on the age at which 50 percent of the vehicles for a particular model year are expected to be scrapped. These values are computed from historical reports of the number of vehicles in use in each calendar year for each vehicle model year cohort.[39] Based on this trend data, 50 percent of 1987 model year vehicles will remain in use for 13 years. This measure is intended to represent a consumer's expectation of the vehicle's useful life at the time of purchase. Although data are not available to differentiate expected vehicle life by manufacturer or vehicle type, the durability measure based on the retained resale value of each vehicle is included to capture some of the variability in expected vehicle life within each model year.[40]

The average automobile owner expects to hold a particular vehicle about 5 years, but because the vehicle is in turn purchased by a new owner—at a price approximating the present value of the vehicle, given its expected operating costs—the expected life of the vehicle, not its expected length of ownership, is the appropriate discounting time frame.

Similarly, the life expectancy data were derived from life expectancy tables that recognize the dependence of life expectancy on age, gender, and race of vehicle owners. The expected remaining life of each vehicle owner is determined as of the end of 1988.[41]

IV. Estimation Results: Discounting Long-Term Risks and Operating Costs

The estimation of equation (9) utilized 1,775 observations for the model years 1981–87. Cars older than the 1981 model year are not included because of limited safety data availability, nor are trucks, vans, and minivans held in household vehicle stocks.

Nonlinear least squares estimates of the model appear in Table 2 for three separate models, each of which was convergent. Three equations are estimated. The first equation includes the quantity-adjusted life years, the discounted injury rating, the two discounted operating cost variables,

[39] Motor Vehicle Manufacturers Association, MVMA Motor Vehicles Facts & Figures (1992 and other years).

[40] This approach ignores any bequested value of the vehicle, which even in the preaccident condition should be several orders of magnitude smaller than the implicit value of life, a term that is being estimated.

[41] U.S. Department of Health and Human Services, Vital Statistics of the United States 1988, Vol. 2, Mortality, Pt. A (1991).

TABLE 2

NONLINEAR LEAST SQUARES RESULTS

Variable	Model (1)	Model (2)	Model (3)
CONSTANT	4.529	4.124	3.655
	(1.824)	(1.318)	(1.321)
QUANTITY-ADJUSTED LIFE YEARS	−1.092	−.479	−.499
	(.590)	(.213)	(.213)
DISCOUNTED INJURY RATING	−.015	. . .	. . .
	(.007)		
DISCOUNTED DURATION OF ANNUAL OPERATING COSTS	.017	.048	.069
	(.010)	(.029)	(.029)
DISCOUNTED DURATION OF ANNUAL OPERATING COSTS: VEHICLE WEIGHT	−.905	−.935	−.979
	(.101)	(.070)	(.070)
POWER	.305	.286	.273
	(.129)	(.100)	(.101)
CARGO CAPACITY	−.054	−.046	−.040
	(.011)	(.011)	(.010)
RESALE VALUE RETAINED	.070	.115	.121
	(.021)	(.035)	(.035)
MAINTENANCE RATING	.030	.029	.034
	(.013)	(.013)	(.013)
LUXURY-SPORT	.208	.207	.213
	(.012)	(.013)	(.013)
AUTOMATIC TRANSMISSION	.026	.027	.026
	(.010)	(.011)	(.011)
TWO-SEAT	−.207	−.111	−.072
	(.070)	(.074)	(.073)
STATION WAGON	.147	.084	.053
	(.036)	(.032)	(.032)
CONVERTIBLE	.330	.349	.348
	(.055)	(.057)	(.057)
DIESEL	−.003	.005	−.004
	(.034)	(.035)	(.035)
SIZE2	−.008	.005	.018
	(.013)	(.014)	(.014)
SIZE3	.036	.059	.072
	(.020)	(.021)	(.021)
SIZE4	.040	.083	.096
	(.031)	(.031)	(.032)
AMERICAN MOTORS	−.116	−.072	−.124
	(.084)	(.086)	(.087)
GENERAL MOTORS	.006	.018	.022
	(.010)	(.010)	(.010)
CHRYSLER	.039	.044	.055
	(.013)	(.014)	(.014)
GERMANY	.283	.370	.400
	(.028)	(.028)	(.028)
JAPAN	.184	.222	.241
	(.014)	(.014)	(.014)

TABLE 2 (*Continued*)

Variable	Model (1)	Model (2)	Model (3)
OTHER ORIGIN	.140	.173	.180
	(.028)	(.028)	(.028)
YEAR82	.231	.211	.221
	(.017)	(.016)	(.016)
YEAR83	.386	.347	.368
	(.021)	(.020)	(.020)
YEAR84	.555	.491	.528
	(.027)	(.025)	(.024)
YEAR85	.692	.620	.670
	(.034)	(.031)	(.029)
YEAR86	.838	.759	.818
	(.041)	(.036)	(.034)
YEAR87	.961	.865	.933
	(.047)	(.040)	(.038)
YOUNG DRIVER	−.063	−.089	. . .
	(.025)	(.026)	
OLDER DRIVER	−.048	−.017	. . .
	(.021)	(.022)	
LATE NIGHT	.019	.017	. . .
	(.024)	(.025)	
ONE-CAR ACCIDENT	.021	.009	. . .
	(.053)	(.031)	
SEAT BELT	.097	.144	. . .
	(.028)	(.029)	
ALCOHOL INVOLVEMENT	.049	.038	. . .
	(.023)	(.023)	
MALE DRIVER	.004	.027	. . .
	(.028)	(.028)	
DISCOUNT RATE	.174	.107	.125
	(.024)	(.025)	(.031)
λ	.500	.370	.330
	(.075)	(.076)	(.076)

NOTE.—Asymptotic standard errors are in parentheses.

vehicle characteristic variables, and driver characteristic variables. The second equation omits the discounted injury rating variable since this variable is correlated with fatality risks and may be capturing to some extent the influence of the fatality variable.[42] Finally, the third equation omits the set of driver characteristic variables since these measures of the attributes of drivers in fatal accidents for particular vehicle types may

[42] In a survey of the literature on compensating wage differentials for job risks, W. Kip Viscusi, Fatal Tradeoffs: Public and Private Responsibilities for Risk (1992), found that a minority of these studies included measures of fatal and nonfatal risks and only a few of these 25 studies reviewed successfully estimated significant injury and fatality coefficients.

capture to some extent omitted attributes of the car related to safety. Ideally, the driver characteristic variables included in equations (1) and (2) should pertain to the particular vehicle, but since these data are not available, averages across the vehicle type are included, thus introducing a possible source of measurement error.

The principal coefficients of interest are consistently significant (95 percent confidence level, one-tailed test). The quantity-adjusted life years variable is significant in all equations, and the injury variable is significant in the first equation, the only one in which it is included. Both of the operating cost variables are statistically significant in all three specifications.

A. *Discount Rate Estimates*

The estimates of the discount rate presented in the bottom row of Table 2 are 17 percent (eq. [1]), 11 percent (eq. [2]), and 13 percent (eq. [3]). The highest discount rate is for the equation including injury and mortality risks. The 95 percent confidence intervals for the discount rate are [.13, .22] for equation (1), [.06, .16] for equation (2), and [.06, .19] for equation (3). Even at the lower bound of the confidence limits, a discount rate of zero is excluded.

There are a number of interest rate reference points that could be used to assess the nominal appropriateness of the discount rate. The first benchmark that one might use is the riskless societal rate of interest. The prevailing real rate of return in the U.S. economy in the sample year 1988 is typically estimated in the 2–5 percent range.[43] These values are outside the estimated confidence limits for the discount rate.

Adding the actual 1988 inflation rate of 4.1 percent to the mean estimated real discount rate in Table 2 implies nominal discount rate estimates of 21 percent, 15 percent, and 17 percent. These rates of time preference are in line with rates found in many other studies of consumer discounting discussed above and in fact are below most of these estimated rates, which typically are real rates of time preference.

Moreover, these high nominal rates of interest may not reflect temporal myopia since the riskless rates of return may not reflect consumer access to capital markets. Several different financing options are available to car buyers including commercial banks, savings and loans, credit unions,

[43] The lower bound is measured as 90-day Treasury-bill rate minus annual change in gross national product implicit price deflator (both for 1988). The upper bound is measured as AAA bond rate minus price deflator. See Council of Economic Advisors, Economic Report of the President (1993).

finance companies, and manufacturer-provided financing.[44] Financing may be more difficult to arrange for used car purchases as the average nominal interest rate for new car financing in 1988 was 12.6 percent, but for the used cars considered in our survey it averaged 15.1 percent.[45] This value lies within the 95 percent confidence interval for all three estimates of the discount rate. The estimated discount rates are consequently quite consistent with prevailing rates of interest facing members of the sample.

B. *Value of Life Estimates*

Discounted remaining life years are calculated based on the characteristics of the household head as reported in the DOE RTECS survey data. If the household head is not the purchaser/holder of a vehicle reported for the household, then an error may be introduced. The statistical value of life estimated in the life-cycle context is given by

$$\frac{\partial \text{PRICE}}{\partial \text{MORTALITY RATE}} = \beta_1 \times \frac{\partial \text{ELYL}^{\lambda}}{\partial \text{MORTALITY RATE}} \times \text{PRICE}, \quad (13)$$

where ELYL stands for the discounted expected lost years of life, and the final multiplication by price is necessary because the model was estimated on the natural log of price.

The estimates of the implicit value of life are $2.6 million for equation (1), $3.1 million for equation (2), and $3.7 million for equation (3). In column 2 of Table 2, results are presented for the model excluding the injury variable. The mean statistical value of life in this case is $3.1 million, 19 percent higher, indicating that excluding a separate measurement for nonfatal injuries causes the fatality valuation to reflect the value of nonfatal injuries.[46] By way of comparison, the Atkinson and Halvorsen estimate of automobile purchasers value of life was $3.6 million (in 1988 dollars)[47]—an estimate very close to those obtained here.

Because we also estimate the implicit rate of discount for life years lost, we can also calculate the value per discounted marginal life year. This amount is $476,000 for equation (1), $367,000 for equation (2), and

[44] In 1990, 62 percent of new car purchases were financed. Of those financed, 32 percent were financed through manufacturers. See Motor Vehicle Manufacturers Association, *supra* note 39.

[45] *Id.* at 52.

[46] An analogous result was first demonstrated in the labor market by W. Kip Viscusi, Employment Hazards: An Investigation of Market Performance (1979).

[47] Atkinson & Halvorsen, *supra* note 10.

$496,000 for equation (3). These discounted values per life year estimates are over twice as high as the estimated discounted value per year of life lost of $170,000 (in 1986 prices) implied by workers' choice of hazardous jobs by Moore and Viscusi.[48]

C. *Other Parameter Estimates*

The first two regression results in Table 2 include controls for the driver characteristics in fatal accidents. The mortality risk measure used in the model does not represent a pure measure of automobile-specific risk because driver characteristics are not excised from the rates. Therefore, selected characteristics of drivers in fatal accidents are included in the model as control variables. These variables measure the proportion of fatal accidents occurring in each make/model/year vehicle that reflect the characteristic in question. The first column in Table 2 indicates that the proportion of drivers who are young, who are older, who are wearing seat belts, and who have alcohol involvement were all statistically significant at the 0.05 level.

Another key market performance test is the extent to which fuel efficiency cost differences are fully capitalized into the price. The dollar value of consumers' marginal willingness to pay for changes in the annual cost of driving can be calculated from the transformation coefficients of the annual operating cost variable and the variable interacting annual operating cost with vehicle weight. Because PDVOC is a present value, the effect of PDVOC on price, based on both of the PDVOC terms in equation (9), is the capitalization rate of operating expenses. The capitalization rate refers to the rate at which the marketplace incorporates life-cycle fuel costs into market prices of vehicles. If markets function perfectly, there is full capitalization, that is a one-to-one correspondence between changes in the discounted value of life-cycle operating costs and vehicle price, and the capitalization rate is one. If, however, there is no relationship between life-cycle fuel expenditures and vehicle price, the capitalization rate would be zero.

The capitalization rate for discounted life-cycle operating costs is estimated at −0.35, implying that a $1 increase in life-cycle operating costs lowers vehicle price by $0.35. Several factors could account for this re-

48 Moore & Viscusi, Quantity-Adjusted Value of Life, *supra* note 16. Our overall value of life estimates are, however, more reasonable than those obtained in their labor market discounting study.

sult. Consumers may, for example, not believe the time before the vehicle is scrapped is as great as we have assumed.[49]

V. Conclusion

If automobile markets functioned perfectly, consumers would fully value the safety and fuel efficiency of their vehicles, and the government could restrict regulatory intervention to broader societal externalities. Additional problems arise if consumers are myopic and neglect their future selves and the future ramifications of car purchases with respect to safety and fuel efficiency. This type of market failure also limits the efficacy of regulatory interventions that exploit consumers' responsiveness to prices. If, for example, consumers ignore the fuel efficiency attributes of their autos, then higher gasoline taxes that raise the operating costs of vehicles would not affect their vehicle purchase decisions.

Our findings suggest that these extreme consumer responses are not evident. The implicit value of life estimates for automobile owners were in the range of approximately $2.6–$3.7 million, where these estimates accounted for the injury risk of the autos and were obtained within the context of a nonlinear model that discounted the expected life years at risk. This estimated value-of-life range is the same range as previous estimates in the literature, including previous evidence on the value of life for automobile purchasers.[50] These findings provide no basis for concluding that consumers undervalue automobile safety. The safety of automobiles is highly regulated and mandated through government regula-

[49] Both the low capitalization rate and the high discount rate could be the result of the application of the estimation model. It is assumed in these estimates that a vehicle lasts 13 years and then has no scrap value. This assumption is based on the median time to scrap for all vehicles on the road. The median time that car buyers expect to keep their new cars is only 5.5 years. Motor Vehicle Manufacturers Association, *supra* note 39. After this period, well over 90 percent of vehicles are still on the road. Upwardly biased rates could occur if a consumer bases a vehicle ownership decision on a short time frame, but the discount rate is calculated for a longer time frame. The computed discount rate may appear higher than the rate underlying the ownership decision.

Two sources of measurement error may have been introduced by data on the expected lives of vehicles and vehicle owners. The 13-year expected vehicle life ignores variability among different makes and models. However, other variables, such as manufacturer and durability, may act as controls for variability across vehicles, minimizing any errors associated with measurement of expected vehicle life.

[50] Viscusi, *supra* note 42, reviews the literature on the estimates of the value of life and health. Although most of the estimates in the literature are clustered in the $3 million–$7 million range, estimates in the $2 million–$3 million range, such as that yelded in one of our specifications, are not unprecedented. For example, eight of the labor market studies he reviews and six of the value of life studies outside of the labor market have estimated values of life at or below this level.

tions. If these safety regulations provide more safety than is optimal from the standpoint of a fully informed consumer, one would expect to observe a lower estimated marginal value of life for automobiles than for other areas of choice in which the safety level provided is freely chosen.

The focal point of the analysis was on the role of discounting as it relates to consumers' valuation of the fuel economy attributes of cars and the life and health effects of automobiles. The estimated rates of time preference range from 11 to 17 percent. Although these rates of time preference exceed the riskless rates of return in the economy, they are quite consistent with the prevailing rates of interest for automobile purchases. Moreover, these estimated rates are at the low end of the estimated implicit rate of interest found in a variety of other contexts in the literature. Consumer discounting for automobiles appears to be consistent with prevailing market rates and in a much more reasonable range than many estimated discount rates for energy efficiency for home appliances and similar choices.

Although these results are not sufficiently precise to imply that there is pinpoint accuracy in the discounting behavior of consumers, the results do suggest that there is sufficient consumer orientation toward the present value of decisions that market interventions can be utilized that affect the stream of payoffs associated with choices. These interventions need not be restricted to those with an immediate effect. Consumers do have a long-term perspective with respect to safety and fuel efficiency, and government officials can potentially influence the choices consumers make by affecting the perceived time stream of payoffs along these dimensions. Whether there is a legitimate rationale for such intervention hinges on concerns outside the scope of this paper.

Safety and fuel efficiency are two of the most prominent concerns of transportation regulation policymakers. These attributes of automobiles are salient for consumers as well. The principal application of our findings is that policymakers contemplating intervention in this market context should be cognizant of the extent to which there are already market forces in operation. Moreover, if we do choose to intervene, we should attempt to design the interventions to work in concert with the powerful market forces that exist in this market rather than to be independent of them.

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