

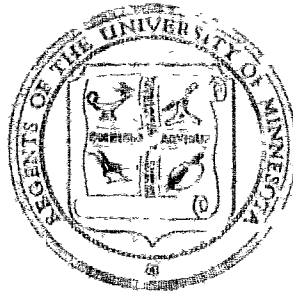
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## THE COST OF INACCURATE AUTOMOBILE MILEAGE INFORMATION

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## ABSTRACT

The model in this paper integrates the possibility of misinformation into consumer utility theory. If the utility realized from a good differs from the utility anticipated at time of purchase, shifts in demand would occur, and thus changes in consumer surplus. These changes provide a measure of the cost of misinformation or value of improved information. The empirical analysis yields estimates of the private and social cost of inaccuracies in automobile buyers' pre-purchase mileage estimates. If automobile purchases are based on imperfect gasoline mileage information, a discrepancy results between expected and actual fuel-efficiency. The data source is a survey of 1980 model car buyers conducted by the authors.

THE COST OF INACCURATE AUTOMOBILE  
MILEAGE INFORMATION

Traditional economic theory assumes consumers possess perfect information. In reality, this assumption is rarely fulfilled. In this paper a model is presented which relaxes this assumption and explicitly introduces the possibility of imperfect information into the theory of consumer behavior. Specifically, the focus is on a situation where, due to inaccurate information, the utility realized from a good can be different from the utility anticipated during the budget allocation process.

When a consumer's purchase decision is based on imperfect knowledge about a good, the utility actually realized from consumption of the product may differ from the utility previously anticipated or perceived. Consumer demand for a product can be envisioned as shifting when consumers discover the true nature of the goods they have purchased. These shifts in the demand function produce changes in consumer surplus which can be used to measure the economic losses generated by imperfect information. The demand shifts yield both a private transfer and a dead weight allocative loss to society.

This analysis is related to earlier work, particularly that of Peltzman (1973), who in evaluating drug regulations made an important conceptual contribution to analyzing the welfare effects of imperfect information. Kotowitz and Mathewson (1979) allowed for differences in perceived and realized characteristics of products. In addition, Auld (1972) and Colantoni, Davis and Swaminathan (1976) analyzed the effects of misinformation about product characteristics on consumer demand and subsequent welfare. However, this study is the first which integrates

the possibility of imperfect information directly into the utility maximization process.

With sharply increased gasoline prices, consumers are placing increasingly greater emphasis on fuel-efficiency as a characteristic in the automobiles they purchase. This heightened concern about fuel-economy places increased importance in the purchase decision on accurate information concerning gasoline mileage. Purchases based on imperfect gas mileage information will result in a discrepancy between the perceived or expected pre-purchase mileage and the actual or realized post-purchase mileage. If the realized mileage is less than the expected mileage, the cost of operating the vehicle will be greater than anticipated. If the realized mileage is greater than the expected level, the cost of operation will be reduced. The difference between the perceived and realized mileage figure can be translated into a present discounted value of additional expenditure or savings on gasoline.

The application of the model developed in this study provides a minimum monetary estimate of the private and social cost of inaccurate mileage estimates. The empirical analysis is based on a survey of new car buyers carried out by the authors in Hennepin County, Minnesota in September 1980. A final result of this research is an estimate for the United States of the value to consumers and to society of improved mileage information.

## THEORETICAL FRAMEWORK

### The Utility Functions

The utility perceived by the individual from consuming a vector of goods and services  $X = (x_1, \dots, x_n) \in \bar{X}$  in  $R_+^n$  is denoted as:

$$(1) \quad U_p = U(X; M_0).$$

Perceived preferences on the set  $\bar{X}$  are assumed complete, reflexive, transitive, continuous, strictly convex and strongly monotonic. The parameters of (1) are given by the vector  $M_0$ . This vector can be viewed as reflecting a consumer's preferences which depend upon his or her access to information about the goods and services in  $\bar{X}$  at the time of their acquisition. Hence,  $M_0$  can be viewed as embodying a consumer's state of knowledge of the utility obtainable from  $X \in \bar{X}$ . Let,

$$(2) \quad U = U(X; M)$$

denote the utility function of the same consumer who now possesses complete information concerning the utility obtainable from the goods in  $\bar{X}$ .

The consumer's preferences are now reflected by the parameter vector  $M$ . The fundamental properties of preferences stated above are assumed to remain unchanged. Thus, (1) and (2) differ only in that the elements of  $M$  can differ from the corresponding elements of  $M_0$ . If the consumer possessed perfect information then  $M = M_0$ .

The consumer with perfect information chooses vector  $X^*$  to maximize (2) subject to:

$$(3) \quad Y - P'X = 0$$

where  $P$  is a vector of known prices and  $Y$  is spendable income. Let,

$$(2') \quad U^* = U(X^*; M)$$

denote the result.

With incomplete or inaccurate information, the consumer chooses vector  $X^0$  to maximize (1) subject to (3) and obtains

$$(1') \quad U_p^0 = U(X^0; M_0).$$

However, upon consuming  $X^0$ , the consumer realizes utility based on the "true" function (2) with parameter vector  $M$ . Hence, realized utility is given by:

$$(4) \quad U^\theta = U(X^0; M).$$

Thus, (1) and (2) yield three states of utility, optimum ( $U^*$ ), perceived ( $U_p^0$ ) and realized ( $U^\theta$ ). If  $M \neq M_0$  for any element, say  $m_i$ , then

$x_i^0 > x_i^*$  or  $x_i^0 < x_i^*$ . The vector  $X^0$  is only a feasible solution to the constrained maximization of (2) since, by construction,  $X^*$  is an optimal solution.

Hence,

$$(5) \quad U^\theta = U(X^0; M) \leq U(X^*; M) = U^*$$

The inequality between realized  $U^\theta$  and the optimal state  $U^*$  suggests a measure for the value of information. The loss in welfare,  $U^* - U^\theta$ , can be viewed as the maximum value of information, in utility terms, yielding perfect knowledge of  $M$ .

Perceived utility ( $U_p^0$ ) may be greater or less than realized utility ( $U^\theta$ ) depending on the values of  $M_0$  relative to  $M$ , i.e.,

$$(6) \quad U_p^0 = U(X^0; M_0) \begin{matrix} > \\ < \end{matrix} U(X^0; M) = U^\theta.$$

However, since  $M$  and  $M_0$  reflect mutually exclusive states of knowledge which cannot exist simultaneously for the consumer, no a priori comparison between perceived utility ( $U_p^0$ ) and optimum utility ( $U^*$ ) can be made.

Measurement of the Cost of Inaccurate Information

The next task is to provide a measure of losses in consumer welfare which occur when the consumer chooses  $X^O$  and then discovers that  $X^*$  is preferred. The problems of using consumer surplus as an exact measure of consumer welfare are relatively well known. Chipman and Moore (1979) and others have shown that constant marginal utility of income is both a necessary and sufficient condition for compensating and equivalent variation and consumer surplus to be equivalent and precise measures of changes in consumer welfare.<sup>1/</sup> For purposes of this section, we assume constant marginal utility of income, which simplifies the following exposition of consumer surplus measures of welfare for the problem considered in this paper.<sup>2/</sup>

Let the indirect utility function corresponding to the constrained maximization of perceived utility (1'), be denoted as:

$$U_p^O = V(P, Y; M_o)$$

and let the indirect utility function corresponding to (2') be denoted as:

$$U^* = V(P, Y; M).$$

If (1) represents the consumer's beliefs, then the perceived Marshallian demand functions corresponding to (1') are:

$$(1'') \quad x_i^O = V_i(P, Y; M_o) = - \frac{\partial V(P, Y; M_o)}{\partial P_i} / \frac{\partial V(P, Y; M_o)}{\partial Y}, \text{ for all } i,$$

which can differ from the Marshallian demand functions corresponding to (2'):

$$(2'') \quad x_i^* = V_i(P, Y; M) = - \frac{\partial V(P, Y; M)}{\partial P_i} / \frac{\partial V(P, Y; M)}{\partial Y}, \text{ for all } i.$$



If  $X^0$  are data, then it is the perceived functions which are observable where  $M_0$  underlies the parameters we frequently attempt to empirically estimate. If information and experience cause consumer beliefs to change, then the perceived demand functions are not structural in an econometric sense.

Consumer surplus with perfect knowledge of  $M$  is:

$$CS_i^* = \int_0^{x_i^*} V_i^{-1}(X, Y; M) dx_i - p_i x_i^* \approx \int_{p_i^b}^{p_i} V_i(P, Y; M) dp_i$$

where  $V_i$  is the Marshallian demand function (2''),  $V_i^{-1}$  is its price inverse and  $p_i^b$  is some price of  $x_i$  for which  $x_i \approx 0$ . If  $M_0 \neq M$ , then it is possible for any good to be either underconsumed or overconsumed relative to the optimal choice. The case of underconsumption is illustrated in Figure 1.a. where  $x_j^0$  is given by (1'') for  $j=i$  at price  $p_j$ . Consumer surplus realized ( $CS_j^\theta$ ) from the choice  $x_j^0$  is:

$$CS_j^\theta = \int_0^{x_j^0} V_j^{-1}(X, Y; M) dx_j - p_j x_j^0 \approx \int_{\hat{p}_j}^{p_j^b} V_j(P, Y; M) dp_j + (\hat{p}_j - p_j) x_j^0.$$

This value is equal to the area  $p_j^b p_j b a$  in Figure 1.a. It follows from (5) that  $CS_j^* - CS_j^\theta \geq 0$ . Hence, the maximum welfare gain from exact knowledge of  $M$  with respect to a single good  $x_j$  is, in value terms,

$$W_j = CS_j^* - CS_j^\theta.$$

This value is equal to  $p_j^b p_j c - p_j^b p_j b a$ , which yields the triangle  $abc$  in Figure 1.a.

Consumer surplus realized when  $x_s^0 \geq x_s^*$  at price  $p_s$  is illustrated in Figure 1.b. In the case of overconsumption,

$$CS_s^\theta = \int_0^{x_s^0} V_s^{-1}(X, Y; M) dx_s - p_s x_s^0 \approx \int_{p_s}^{p_s^b} V_s(P, Y; M) dp_s - (p_s - \bar{p}_s) x_s^0$$

which is equivalent to the triangle  $p_s^b p_s^a$  (consumer surplus with perfect knowledge of M) less the right hand triangle  $adb$ . The welfare loss from the overconsumption of  $x_s$  is given by:

$$W_s = CS_s^* - CS_s^\theta$$

This value is equal to the triangle  $adb$  in Figure 1.b.<sup>3/</sup>

The implications of an allocative error in the consumer's choice of a single good are more far reaching, however. Due to the budget constraint, a nonoptimal expenditure on a single good induces nonoptimal expenditure on other goods and services. Hence, it follows that the total value of consumer welfare gain from exact knowledge of M is the summation of the gains  $\sum_1^n W_i$  over all goods and services in  $\bar{X}$ . The larger the budget share of the good for which the consumer's knowledge of M is incomplete, the greater can be the error induced in the choice of other goods. The estimation of a single  $W_i$  is, therefore, a lower bound to the total gain from exact knowledge of M.

In addition to the possible allocative welfare loss, either consumers or producers of specific goods may incur a private transfer loss under conditions of imperfect information. If the good's attributes are overevaluated due to imperfect information and overconsumption occurs, consumers may suffer a transfer loss to producers. If the good's attributes are underevaluated and underconsumption occurs, producers may suffer a transfer loss to consumers.

In the case of underconsumption in Figure 1.a. the transfer is from producers to consumers and is equivalent to the rectangular area,  $\hat{p}_j p_j ba$ . With  $M_o \neq M$ , the demand function  $V_j(P, Y; M_o)$  yielded purchases of  $x_j^o$  at the price  $p_j$ . However, with perfect information, the demand function  $V_j(P, Y; M)$

would be applicable. Consumers would then have been willing to purchase the quantity  $x_j^0$  at the higher price  $\hat{p}_j$ . Under conditions of perfect information  $M_0 = M$ , producers could have still sold  $x_j^0$  but received revenue equal to  $\hat{p}_j 0x_j^0 a$ , rather than  $p_j 0x_j^0 b$ . Therefore, the area  $\hat{p}_j p_j b a$  represents the sum of the potential undercharges on the quantities actually purchased.

In the case of overconsumption in Figure 1.b. the transfer is from consumers to producers and is equal to the area  $p_s \bar{p}_s d b$ . With  $M_0 \neq M$ , the demand function  $V_s(P, Y; M_0)$  yielded a quantity of  $x_s^0$  at the price  $p_s$ . Under perfect information with the demand function  $V_s(P, Y; M)$  purchases of  $x_s^0$  could only be achieved at the lower price  $\bar{p}_s$ . Producers could have only derived the total revenue  $\bar{p}_s 0x_s^0 d$  from the quantity  $x_s^0$ , not revenues of  $p_s 0x_s^0 b$ . Therefore, consumers have overpaid the amount  $p_s \bar{p}_s d b$ .

In the empirical analysis, geometry is used to determine the area of the allocative loss triangle and potential transfer rectangle. The area of triangle  $abc$  and  $adb$  in Figure 1.a. and b. may be derived as one-half of the change in quantity times the change in price ( $1/2\Delta x \Delta p$ ). The elasticity formula ( $\Delta x / \Delta p \cdot p / x$ ) can be solved for  $\Delta x$  and that value substituted into the triangle area formula. If the quantity ( $x$ ), the price change ( $\Delta p$ ) and an estimate of the price elasticity of demand ( $e_p$ ) are known, the area of the allocative loss triangle may be derived as:

$$abc \text{ or } adb = \frac{e_p x \Delta p^2}{2p}$$

The area of the potential transfer rectangle,  $\hat{p}_j p_j b a$  or  $p_s \bar{p}_s d b$ , is equivalent to the price change times the original sales quantity ( $\Delta p x$ ).

## EMPIRICAL APPLICATION

Survey Data

The authors obtained the names and mailing addresses of all registrations for model year 1980 automobiles in Hennepin County, Minnesota from the Minnesota State Department of Public Safety. This county contains the city of Minneapolis, its suburbs, and some outlying rural areas. The names of 800 new car buyers were selected in a random process from the registration listing. Buyers of both domestic and foreign automobiles were included, but corporate car owners were excluded. Of the questionnaires mailed to these 800 individuals, 440 were returned, of which 391 were usable in the context of the present analysis. The vehicle owners were asked the specific model of their vehicle, the miles per gallon (MPG) they expected to obtain when they purchased the car, and the MPG they actually experienced in normal driving. They were also asked to report the total miles the vehicle is driven annually, in addition to questions concerning the source of their information regarding expected gas mileage.

The difference between the individual's expected and realized mileage was calculated. The average absolute error was 2.9 MPG. Some 139 individuals, 36 percent, underestimated their realized mileage; 182, 46 percent, overestimated mileage, and in 70 cases, 18 percent, the expected and realized figures were equal. The average underestimate was 3.7 MPG. The average overestimate 3.6 MPG. Thirty-six percent of the car buyers erred in their estimate of the actual mileage by more than 3 MPG. In 13 percent of the cases the error was greater than 5 MPG. Some 14 percent of the buyers received more than 3 MPG better than expected, whereas 22 percent overestimated their actual mileage by more than 3 MPG.

Additional Data and Assumptions

The next step was to translate the mileage gap between the anticipated and the realized figure into a monetary value. Unexpected savings on gasoline purchases will be incurred if the pre-purchase estimate understated actual mileage and unexpected additional costs if the estimate overstated actual mileage, assuming miles driven remain constant. To translate the mileage difference into a monetary value required data on the length of operation of the vehicle, the miles driven per year, and the price of fuel. For a given discount rate, the present discounted value of the future stream of gasoline expenditures could then be derived. Since assumptions about the future must be made, including something so uncertain as the future price of gasoline, the approach of this study was to specify a set of alternative assumptions.

With regard to the time period over which the vehicle will be operated, two alternatives were utilized. In the first case, the average length of time a new car is operated before replacement was used. The best estimate available for this period is 3-1/2 years, based on a 1968 study.<sup>4/</sup> Data also exist on yearly travel of passenger cars by age of vehicle. The average new passenger car, as reported in a 1977 study, was driven 18,000 miles in the first year, 15,100 in the second, 13,400 in the third, and 12,200 in the fourth year (Dept. of Energy, 1977, p. 97). At these rates the average new car was driven 52,600 miles in the first 3-1/2 years. Both the short ownership period and high mileage in the initial years is in large part due to the sizable portion of new vehicles which are purchased for business use. In the second case, therefore, to better reflect the private purchaser's situation, the assumption was made that

the original owner keeps the car until 52,600 miles are reached at their individual annual mileage rates, or that the car is held for a maximum of eight years. The latter assumption was necessary for individuals with very low annual mileage in order to avoid unduly long ownership periods.

Two alternatives were also selected for discount rates. First, the average interest rate was used for a 36-month new car loan at a local bank in the survey area. The rate was averaged over the 12 months of the 1980 model year, October 1979 through September 1980, which yielded an interest rate of 13.29 percent. Second, the average interest rate paid by local banks on 2-1/2 year savings certificates was also used. That rate averaged 10.20 percent during the 1980 model year period.<sup>5/</sup>

Three alternative assumptions were made regarding gasoline price changes. Calculations were made assuming price increases of 10, 15, and 20 percent per year. The annual increase in the price of gasoline averaged 16 percent over the five-year period from December 1975 to December 1980 based on the Consumer Price Index.<sup>6/</sup>

An average price of \$1.19 per gallon for unleaded gasoline was used as the base price during the 1980 car model year. This price was the average price in the Minneapolis-St. Paul metropolitan area during the period from October 1, 1979 to September 30, 1980. A private newsletter for petroleum marketers, "Petroleum Market Data" reports gasoline prices weekly for the Minnesota area. The price of unleaded regular was used since most new cars require this fuel. A small number of the vehicles in the survey had diesel engines. The average price of diesel fuel during the model year in Minnesota was \$1.09 per gallon based on the same source.

Empirical Calculations of Cost

With these assumptions, alternative estimates of the present value of unexpected gasoline savings or additional expenditures due to the gap between expected and realized fuel-economy could be calculated. This unexpected savings or increase in the operating cost of the vehicle would shift the "true" demand function, based on perfect information, up or down, respectively, in relation to the demand function based on imperfect mileage perceptions.

For the case in which the consumer underestimates actual mileage, the distance ab in Figure 1.a. is equal to the present value of the unexpected reduction in gasoline expenditures. This dollar amount represents an unexpected private gain or savings to the individual. If the purchaser overestimates actual mileage, the distance bd in Figure 1.b. measures the present value of the unexpected increase in gasoline expenditure. This amount is the private cost of misinformation to the individual.

In Figure 1.a., if the consumer had perfect mileage information, instead of an underestimate, he or she would have been willing to pay the additional amount  $(\hat{p}_j p_j)$  for  $0x_j^0$  units. In Figure 1.b., with perfect information instead of an overestimate, he or she would have only been willing to pay  $\bar{p}_s$  for  $0x_s^0$  units. Consequently, the present discounted value of unanticipated savings on gasoline can be conceived of as a rebate reducing the purchase price of the vehicle by an equivalent amount. Unanticipated additional gas expenditures can be viewed as a surcharge increasing the purchase price. For instance, suppose the purchaser of a vehicle underestimated actual mileage by 3.5 MPG and, hence, receives an unexpected discounted gain of \$640 on the operating costs of his or her car. Therefore, if possible choices among other goods and services are

ignored, he or she would have been willing to pay a retail price \$640 higher for the auto. This study assumes that consumers possess perfect information about other vehicle characteristics, so that the effect of MPG, misinformation can be isolated.

In the case of this analysis the individual car buyer purchases a single vehicle or one unit of automobile in quantity terms. Therefore, the total private cost or gain for the individual is simply equal to the present value of the extra expenditure or savings on gasoline consumption, the distance ab or bd, because the multiplication is simply by the one original unit. The amount of automobile purchased can also be measured in value terms, and the purchase price used as a normalizing factor. With this approach, one can conceive of more or less than one unit of automobile. For example, suppose the price of a specific vehicle chosen as a base, with a given set of options, is \$6,500. If the addition of options raises the price to \$7,500, you have 1.15 of the original units. In Figure 1.a., therefore,  $x_j^0$  represents one unit of automobile; points to the right of  $x_j^0$  are more than one unit. Likewise in Figure 1.b., if  $x_s^0$  represents one unit, points to the left are less than one unit. This conceptual viewpoint is important to the notion of  $\Delta x$  embodied in the calculation of the allocative loss triangle.

To calculate the allocative loss, data on prices and the elasticity of demand are required. Prices for 120 automobile makes and models are reported in the April 1980 automotive issue of Consumer Reports. The prices utilized in this study were derived by averaging the dealer cost and list price with the options CU suggests buying for each car. This averaging was done to reflect the discounting from list price that typically occurs on new car sales.



For a price elasticity, the overall elasticity of demand for automobiles was used. Gregory Chow estimated elasticities of demand of  $-.601$ ,  $-1.11$ , and  $-.950$  depending on the specific regression used (Chow, 1960, pp. 158-159). He concluded that the price elasticity ranged between  $-0.6$  and  $-1.0$  (Chow, 1960, p. 160). Houthakker and Taylor (1966) obtained a short-run price elasticity estimate of  $-.9578$  with a dynamic model and a figure of  $-.92$  with a semi-log static equation evaluated at the mean. In the context of a dynamic demand system D. Weiserbs obtained an estimated long-run elasticity of  $-1.35$  (Phlips, 1974, p. 195). Sexauer (1977), using a partial adjustment model, obtained estimates of  $-1.04$  and  $-1.05$  for the long-run elasticity using annual and monthly data. Based on all these studies, the most reasonable estimate of a price elasticity for automobiles was deemed to be  $-1.00$ .

## RESULTS

### Estimates of the Costs of Inaccurate Information

Table 1 presents the allocative loss and private costs or gains for the average purchaser of a vehicle in our survey based on various assumptions. The authors suggest that Alternative 1 probably embodies the most reasonable set of assumptions. Alternative 1 contains the assumption of a 15 percent annual gasoline price increase, 13.29 percent discount rate, and a sufficient period of time to place 52,600 miles on the car or a maximum of eight years, whichever occurs first. With these assumptions, the average allocative loss per automobile purchased was \$86. For those who overestimated their MPG the private cost was \$752 and for those who underestimated their MPG the unexpected savings was \$749.

Although the private cost and gain are almost equal, they do not cancel each other out because they occur to different individuals.

The other alternatives in Table 1 are useful for estimating the sensitivity of these results to various assumptions. The only change in assumptions which has a marked impact on the results occurs in Alternative 5. In that alternative a period of ownership of 3.5 years was assumed, which significantly reduces the estimated impact.

The next step was to extrapolate these results to the national level.<sup>7/</sup> During the period October 1, 1979 to September 30, 1980, which approximates the 1980 model year, 9,174,556 automobiles were sold in the United States. This count includes both domestic and foreign vehicles. Automotive sales were depressed in 1980; in a normal sales year over 10 million vehicles are sold. Our survey covers individual purchasers who use their vehicle for either personal or business purposes or a combination. One might assume that large volume business purchases are based on better information than individual purchases. Both the experience level and the potential return to improved information are higher. On the other hand, the information base of small business purchasers is likely not much better than for individuals. Therefore, we excluded the 16 percent of national sales that are to large businesses, but included all others in our national estimate, which yields a sales level of 7.7 million cars (Flanagan).

Based on the results for Alternative 1 in Table 1, the estimated national allocative loss would be \$662 million on sales of 7.7 million automobiles. As previously reported, in our survey 46 percent of the respondents overestimated MPG and 36 percent underestimated actual MPG. These propor-

tions and the values in Alternative 1 can also be expanded to the national level at this sales rate. The aggregate private cost to auto buyers who overestimated mileage would be \$2.66 billion. The aggregate nationwide gain to car buyers who underestimated mileage would be \$2.08 billion. The former figure is in effect a transfer from consumers to producers. The latter represents a transfer from producers to consumers. The net transfer is approximately \$580 million from consumers to producers.

The net transfer concept is of limited usefulness, since the transfers to and from consumers do not really cancel each other out. They occur on different vehicles and to different consumers. The allocative error represents a significant social welfare loss due to misinformation, which is not recouped by any market segment. Improved mileage information could have a potential social value at least as great as that estimate.

#### Factors Affecting the Accuracy of Mileage Estimates

Survey respondents were also asked to indicate the sources of information about gasoline mileage used prior to purchasing their car. Each was asked which source of information was most important. Table 2 covers the nine response categories regarding the most important source of mileage information. Column (2) gives the percent in the sample in each category. Column (3) lists the absolute mean MPG error for each category. Column (4) gives the percent in each category who underestimated their actual mileage and Column (5) lists the average MPG error for the underestimators. Column (6) and (7) provide the same data for those who overestimated their mileage. The difference between 100 percent and the percent listed who underestimated and overestimated mileage in Columns (4) and (6) equals the proportion in each category who made no error in their mileage forecast. Their estimated and realized mileage were equal.

The results in Table 2 indicate that the most widely used sources of mileage information were automobile evaluation reports, friends and relatives, and auto magazines, in that order. The most accurate information was, not surprisingly, previous experience with a similar automobile. The least reliable information was provided by other owners and the Environmental Protection Agency (EPA) fuel-efficiency ratings, although the number in each group was small. For the entire sample, the average mileage error of those who underestimated and overestimated MPG was very close. However, when broken down by primary information source, the mean MPG error between the two groups differed substantially in several cases.

The results regarding the utilization and reliability of the EPA ratings as an information source are of particular interest from a policy perspective. The EPA ratings are widely published as official government figures. They are extensively referred to in the advertising of new automobiles. By law each new automobile must bear a label giving the EPA mileage information.

The EPA mileage estimates are typically presented with the cautionary note that they are best used for comparisons, that "actual mileage may vary due to driving speed, weather, and trip length," and that "actual highway mileage will probably be less." However, both the automotive manufacturers and the EPA use the estimates in a manner that would seem to indicate that they represent the mileage the average motorist should expect to obtain.

The survey indicates that the EPA ratings are not widely used, but for good reason, they are not very reliable. Only 7 percent of the individuals in our survey used the EPA estimates as their primary source of mileage information. However, since automobile advertisements are required to use the EPA fuel-economy figures, adding that group brings to 13 percent the number who used EPA based information. Another 13 percent relied on dealers,

an information source which is probably closely related to the EPA ratings. Of particular interest from the consumers' perspective is the balance between underestimates and overestimates with these sources. In each of the three cases, the proportion who overestimated mileage, and hence suffered unexpected additional operating costs, is more than twice as great as the percent who underestimated their MPG. For the entire sample, the portion who overestimated is only slightly greater than the proportion who underestimated mileage.

Table 3 recombines some of the information categories so that the mean MPG errors can be tested to see if the differences between categories are statistically significant. The test in Case 1 is between the means for those who used the EPA ratings vs. those who utilized other information sources. The numbers in parentheses indicate the significance level at which the two means may be considered statistically different. In testing the two means, the assumption that the samples have a common population variance was tested first. If the hypothesis of common variances was rejected, we used a revised t test suggested by Li for use when the two population variances are markedly different and sample sizes are also different (Li, pp. 142-143). Case 2 combined the EPA ratings and advertisements together for a comparison with other information sources.

In both cases in Table 3, the EPA based information led to larger mileage errors than other sources. This result is true for those who underestimated and overestimated fuel-economy and also in terms of the absolute MPG error for all consumers. For overestimates, the means are statistically different at a high level of significance in both Case 1 and 2. The absolute MPG errors can probably be assumed to be statistically

different, although the significance level is only moderate. For those who underestimated MPG, the null hypothesis of similar average errors cannot be rejected.

These results bring into serious question the utility of the EPA ratings to the individual automobile buyer. The reliability of EPA estimates should be of particular concern from the consumer perspective. Our data suggest that they lead to an overestimate of actual mileage in a high proportion of cases. In addition, the error for those who overestimate is higher for those who use EPA information than other sources, and the difference is significant. Recall that those who overestimate mileage face the unpleasant shock after buying their car of discovering that their gasoline expenditure will be higher than expected.

#### Some Qualifications

The preceding calculation of the private and social costs of MPG errors assumed that miles driven remain unchanged in response to unexpected savings or added expenditure on gasoline. Recent evidence tends to indicate that annual mileage is quite responsive to gasoline prices and expenditures. The average miles traveled per passenger car per year in the U.S. was 10,046 miles in 1978 (Dept. of Transportation, 1979). The figure fell to 9,390 miles in 1980 (Business Week, p. 16). The average driver could be expected to adjust miles driven in reaction to an unexpected savings or extra expenditure on gasoline, thus reducing the dollar loss or gain estimated in this analysis. However, shifting miles driven would affect the individual's utility level. By holding annual mileage unchanged, the utility loss or gain from inaccurate information could be translated into a monetary estimate.

On the other hand, there is a conceptual reason for arguing the values of the allocative loss and transfer are likely underestimated. The shifts in demand captured in this study are a result only of the monetary gain or loss due to the unanticipated gasoline savings or additional cost. The pleasant surprise of receiving better mileage than expected might have a direct positive impact on consumer utility. The disappointing shock of getting worse mileage could have a direct negative effect. Consumer utility might also be directly affected by the unexpected conserving or using of more energy for other reasons, such as contributing to national energy independence.

Finally, the loss is understated since the best that could be done empirically was to calculate the loss on each vehicle in isolation. However, a nonoptimal choice on one good produces misallocations on other goods and services through the budget constraint. To the extent that mileage misinformation causes consumers to purchase the wrong vehicle given their preferences, rather than to not purchase one at all, much of the ensuing additional misallocation is within the automotive group. In sum, ours is a partial rather than a general equilibrium analysis.

#### CONCLUSIONS

This study yields both general theoretical and specific empirical results. The latter have significant public policy implications. The theoretical developments have broad applicability as a conceptual structure. The bibliography on the economics of information has grown quite long. However, revision of the fundamental theory of consumer behavior to encompass the possibility of imperfect information has not previously

been carried out. This study attempts to partially fill that gap. As Green (1978) states in Consumer Theory:

We suggest, without having anything original to offer, that the theory could be improved if the information available to consumers and their interactions were taken into account (p. 29).

The assumption of perfect knowledge excessively restricts the ability of the traditional theory to explain consumer behavior.

This paper develops a conceptual framework for analyzing the losses due to imperfect information. The value of perfect information is equal to the losses incurred in its absence. Furthermore, it was shown that utility realized from the consumption of goods and services acquired with less than perfect knowledge can never be greater than the utility received from products selected with perfect knowledge. Among the important implications of this theory is that observed demand functions, if consumer information is imperfect, may not be structural and cannot be expected to hold across different states of knowledge.

In terms of public policy, this analysis has demonstrated the very sizable economic benefits that accurate automobile fuel-economy estimates could have. With the dramatic increase in the price of gasoline over the last several years, accurate fuel mileage information has become increasingly valuable. Contingent on a set of assumptions, the welfare loss due to allocative error was estimated at \$86 on the average 1980 automobile purchased. In the survey, 36 percent of the individuals underestimated their realized mileage and 46 percent overestimated their actual MPG. For the former group, the average discounted value of unexpected gasoline savings was \$749. For the latter group, the average discounted value of the unexpected extra expenditure on gasoline was \$752.



These figures translate into an allocative loss of \$662 million, a transfer to consumers of \$2.08 billion, and a transfer to producers of \$2.66 billion for 1980 car sales in the U.S.

The data on sources of information used by consumers showed the EPA fuel-economy ratings to be particularly unreliable. This conclusion reinforces statements made in a recent House Committee on Government Operation evaluation of the EPA mileage estimates. The chairman of the House Subcommittee producing the report concluded that "individual consumers are being misled by inflated fuel economy claims derived from their government's own test program" (House of Representatives, 1980). That study concluded by recommending specific reforms for the EPA's present methods. If the government is going to provide fuel-economy ratings, the obligation exists to make the mileage estimates as accurate as possible. The fuel-efficiency estimates publicized should reflect as closely as possible the actual on-the-road mileage the average motorist can anticipate. Only with accurate information can consumers make the right purchase decision.

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## FOOTNOTES

1/ Willig (1973) also shows that compensating and equivalent variations are the relevant surplus concepts for cost-benefit and welfare analysis and that either can be closely approximated by the consumer surplus areas of the Marshallian demand curve.

2/ This is a strong assumption. Three conditions under which it holds are outlined by Samuelson (1942). One of the three that would also be useful to assume is that all income elasticities are unitary, a result obtained by assuming homoethetic preferences. The practical implication of these assumptions is that the Marshallian and the Hicksian demand curves converge and measures of changes in consumer surplus are identical to measures of compensating variation.

3/ For simplicity, parallel shifts in the demand function are assumed. This is not theoretically necessary nor necessarily realistic. Changes from  $M_0$  to  $M$  could change the elasticity as well as the level of demand.

4/ Conversation with Mr. R. Grehher, Motor Vehicle Manufacturers Association, Detroit, Michigan, April 1980. Admittedly, there are many factors, such as the state of the economy, gasoline prices, and new car prices, that could possibly increase or decrease this period.

5/ Before January 1980, the 2-1/2 year certificate of deposit did not exist, but a 4-year certificate did and the rate on it was used.

6/ Currently, the oil market situation looks like the price increases for petroleum products may slack off over the next couple of

years. However, events can change very rapidly and dramatically in the world petroleum market. During the two-year period, December 1978 to December 1980, the price of gasoline increased at a 35 percent annual rate. Projecting price increases for gasoline which are greater than the relevant interest rates is not unreasonable. Commercial gasoline storage is costly and stocking significant quantities is unfeasible for the average individual.

<sup>7/</sup> Based on the types and quantities of automobiles purchased, the Hennepin County sample was assumed to be reasonably representative of national new car purchases. A check could not be made concerning the characteristics of the individuals purchasing vehicles.

FIGURE 1

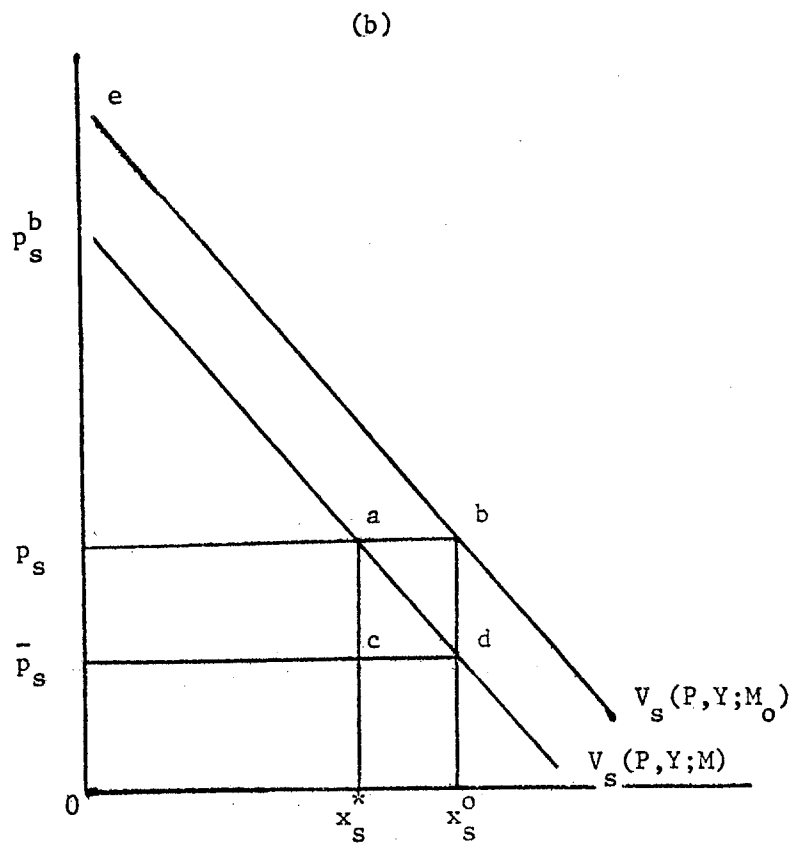
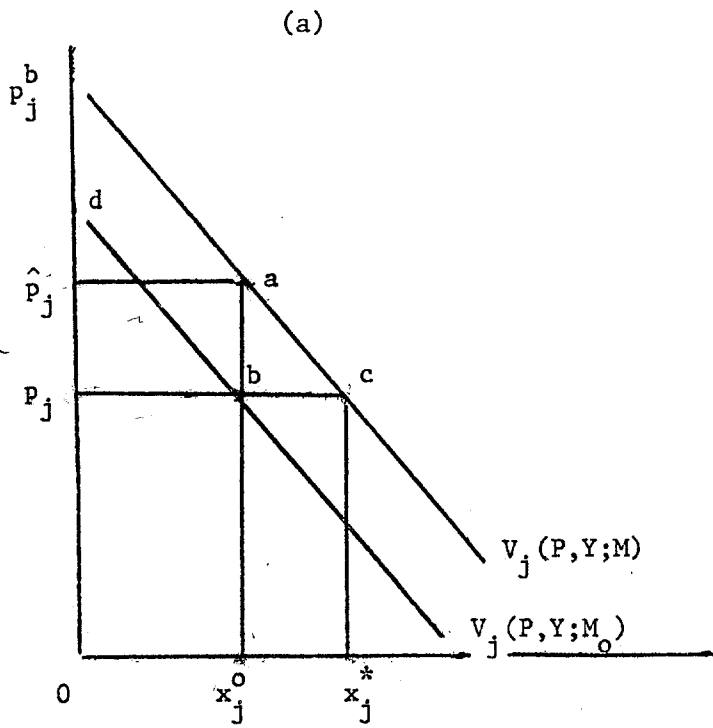


Table 1. Alternative Estimates of the Average Allocative Loss and Private Cost or Savings (in dollars)

Alternative Number	Gas Price Increase (%)	Discount Rate (%)	Period of Ownership	Allocative Loss	Private Cost	Private Savings
1.	15	13.29	miles	\$86	\$752	\$749
2.	10	13.29	miles	\$72	\$679	\$675
3.	20	13.29	miles	\$103	\$838	\$828
4.	15	10.20	miles	\$96	\$806	\$799
5.	15	13.29	years	\$23	\$377	\$422

TABLE 2. Mileage Errors by Information Source.

(1) Information Source	(2) Percent in Category	(3) Mean Absolute MPG Error	(4) Percent Underestimated	(5) Mean MPG Underestimate	(6) Percent Overestimated	(7) Mean MPG Overestimate
1. Auto dealers	13	2.8	25	3.7	55	3.3
2. Ads	6	3.1	23	2.3	68	3.9
3. Auto magazines	10	2.4	32	2.6	44	3.5
4. Evaluation reports	26	3.2	42	4.0	40	3.7
5. Friends & relatives	17	2.9	44	4.0	43	2.6
6. EPA ratings	7	3.8	24	5.4	55	4.6
7. Previous experience	4	1.9	57	2.2	21	3.2
8. Other owners	2	4.0	60	6.0	20	2.0
9. No answer	15	2.7	24	2.8	59	3.5
Total	100	3.0	36	3.7	47	3.5



TABLE 3. Mileage Errors Tested for Significance of Differences

Information Source	Mean Absolute MPG Error	Mean MPG Underestimate	Mean MPG Overestimate
Case 1.			
a) EPA ratings	3.83	5.36	4.60
b) All other sources	2.88	3.64	3.38
(Significance Level)	(.15) <sup>1/</sup>	(.30) <sup>1/</sup>	(.025) <sup>2/</sup>
Case 2.			
a) EPA ratings & ads	3.54	4.07	4.24
b) All other sources	2.87	3.69	3.34
(Significance Level)	(.10) <sup>1/</sup>	(.50) <sup>1/</sup>	(.025) <sup>2/</sup>

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<sup>1/</sup>Based on a revised t test.

<sup>2/</sup>Based on a normal t test.