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Consumer willingness to pay for vehicle attributes: What do we Know?

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ABSTRACT

As standards for vehicle greenhouse gas emissions and fuel economy have become more stringent, concerns have arisen that the incorporation of fuel-saving technologies may entail tradeoffs with other vehicle attributes important to consumers such as acceleration performance. Assessing the effects of these tradeoffs on consumer welfare requires estimates of both the degree of the tradeoffs, and consumer willingness to pay (WTP) for the foregone benefits. This paper has two objectives. The first is to review recent literature that presents, or can be used to calculate, marginal WTP (MWTP) for vehicle attributes to describe the attributes that have been studied and the estimated MWTP values. We found 52 U.S.-focused papers with sufficient data to calculate WTP values for 142 different vehicle attributes, which we organized into 15 general groups of comfort, fuel availability, fuel costs, fuel type, incentives, model availability, non-fuel operating costs, performance, pollution, prestige, range, reliability, safety, size, and vehicle type. Measures of dispersion around central MWTP values typically show large variation in MWTP values for attributes. We explore factors that may contribute to this large variation via analysis of variance (ANOVA) and find that, although most have statistically significant effects, they account for only about one third of the observed variation. Case studies of papers that provide estimates from a variety of model formulations and estimation methods suggest that decisions made by researchers can strongly influence MWTP estimates. The paper's second objective is to seek consensus estimates for WTP for fuel cost reduction and increased acceleration performance. Meta-analysis of MWTP for reduced fuel cost indicates that estimates based on revealed vs. stated preference data differ, as do estimates from models that account for endogeneity and those that do not. We find greater consistency in estimates of MWTP for acceleration despite substantial uncertainty about the overall mean. We conclude with recommendations for improving the understanding of consumers' MWTP for vehicle attributes.

1. Introduction: problem formulation

Cars and light trucks are significant contributors to air pollution and to greenhouse gas (GHG) emissions in the U.S. and around the world. The incorporation of technologies to reduce emissions may not only increase vehicle costs but may also entail tradeoffs in

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other vehicle attributes important to consumers such as safety, comfort, or performance. Assessing the effects of these tradeoffs on consumer welfare requires estimates of both the degree of the tradeoffs, and consumer willingness to pay (WTP) for the foregone benefits.

Willingness to pay is defined as the maximum amount an individual is willing to give up to obtain a good or avoid a bad (Varian, 1992). Let $U(\boldsymbol{x},P)$ be the indirect utility function of a representative consumer, defined on a vector of vehicle attributes ($\boldsymbol{x} = x_1, x_2,\ldots x_k,\ldots x_n$) and a measure of present value dollars, p, such as the price of the vehicle. The total derivative of U with respect to x_k and p (assuming all other attributes are held constant) is $dU = (\partial U/\partial x_k)dx_k + (\partial U/\partial p)dp$.[1] By setting the total derivative equal to zero we can solve for the change in income (present value dollars) that exactly compensates for a marginal change in attribute k (Eq. (1)).

$$\frac{dp}{dx_k} = -\frac{\partial U/\partial x_k}{\partial U/\partial p} \tag{1}$$

This measure, known as the compensating variation, gives the quantity of present value dollars that is required to keep the consumer's utility unchanged, given a marginal change in product quality, represented in this case by a change in attribute k. Although functional forms vary greatly from one research paper to another, in all cases we use the marginal compensating variation to estimate the marginal willingness to pay (MWTP).

In this paper, we calculate MWTP values from published studies of vehicle demand. Our research objectives are two-fold: (1) to identify the vehicle attributes for which MWTP estimates can be obtained from economic studies and to describe the resulting estimates and (2) to attempt to develop consensus central tendency measures of MWTP via meta-analysis for fuel costs and acceleration performance. Dozens of papers have examined how consumer demand for light-duty vehicles is affected by vehicle attributes, such as fuel economy, performance, or size. It is possible from these papers to derive estimates of consumer MWTP for those attributes. Most often, the published papers do not report WTP values, nor do they compare the estimated values with those from other papers.

Our method follows the procedure for meta-analysis recommended by Van Houtven (2008):

- Problem formulation: specifying research objectives and defining the scope of the analysis (Sections 1 and 2),
- Data collection: via a formal literature search (Section 3),
- Data evaluation and abstraction: insuring that the WTP are appropriate and acquiring them along with descriptors (e.g., units) and study attributes (Section 4),
- Data preparation: standardization of WTP and potential explanatory variables in constant dollars and units to the extent possible (Section 5),
- Data analysis: choice of statistical package, weighting and estimation method (Section 6).
- Presentation of results: tables, graphs, descriptive statistics, hypothesis tests (Section 6).

We limit the scope of our analysis to U.S. studies published between 1995 and 2015, with the sole exception of Lave and Train (1979), the first use of a random utility model to vehicle choice. We focus on peer-reviewed studies but also include a smaller number of studies from the grey literature. By means of a structured literature search (described in Section 2), we identified 52 U.S.-focused papers with sufficient data to calculate MWTP values for various vehicle attributes. Only a few provided MWTP estimates calculated by the authors. For most we calculated MWTP values using the coefficients of models estimated in the studies. When questions arose about issues such as units of measure or functional forms, we queried lead authors. We included data from all models presented in the papers that were not rejected as implausible by the authors. We calculated MWTP estimates for all attributes for which it was feasible to do so. A detailed description of data and methods is provided in Greene et al. (2017).

The first phase of data analysis is descriptive (see Section 5). The key finding is that calculated MWTP values for most attributes vary widely. In the second phase, we investigate factors that might be causing the large variability of MWTP estimates. We do this through an analysis of variance (ANOVA) featuring measurable characteristics of the studies (see Section 6.1). The ANOVA model, while statistically significant, explains only a small portion of the variation in the estimates. We then present case studies of four papers, each of which provides an array of estimates for different models and estimation methods using the same data set; they provide important indications of how decisions made by modelers about included variables, metrics, functional forms, and estimation methods can profoundly influence coefficient estimates (see Section 6.2). In the third phase of analysis we attempt to derive consensus estimates of MWTP for fuel cost reduction and reduced 0–60 mph acceleration time via traditional meta-analysis (see Section 6.3). We conclude with suggestions for future research (see Section 7).

2. Literature review

A rich literature on consumers' vehicle choices has developed over the last 50 years from innovations in the theory and empirical estimation of consumer demand, going back to Lancaster's (1966) conception of consumer goods deriving their value from their attributes, rather than the good itself. Early applications of Lancaster's theory included efforts to predict transportation choice: Quandt and Baumol (1966) defined the value of a transportation mode by its speed, frequency of service, comfort, and cost. Hedonic price models arose from efforts to empirically test Lancaster's choice theory; they predict consumers' willingness to pay for goods as a

[1] The derivation is an adaptation of that presented in Gatta et al. (2015).