Consumer Willingness to Pay for Vehicle Attributes: What Do We know?

David Greene, U. Tennessee
Anushah Hossain, Julia Hofmann, Robert Beach, RTI Int.
Gloria Helfand, USEPA

The content of this presentation does not necessarily reflect the views of the US EPA, the University of Tennessee or RTI International.

Research Objectives: Estimate values of vehicle attributes to improve public policy making. Describe the state of knowledge (developed econometrically).

- Value the **direct or** indirect trade-offs between fuel economy or greenhouse gas emissions and other vehicle attributes.

- Understand how consumers value fuel economy improvements to inform cost/benefit analysis of regulations.

- What can we learn from the recent econometric literature?
  - Central tendencies
  - Uncertainty
  - Heterogeneity

- Estimate WTP for as many vehicle attributes as possible.

- Try to avoid confirmation bias.

Our analysis closely followed Van Houtven's (2008) meta-analysis paradigm.

- Methods
  - Data Collection: Literature Search and evaluation.
  - Estimating WTP: Method, metrics
  - Checking for errors

- Overview of characteristics of studies & WTP Estimates

- Meta-analysis
  - ANOVA: What causes variation in estimates for an attribute?
  - Fuel cost & performance: Seeking consensus.

- Insights from studies comparing alternative models

- Concluding observations

Van Houten, G., "Methods for the Meta-Analysis of Willingness-to-Pay Data", *Pharmacoeconomics*, 2008: 26(110: 901-910.

Estimating Willingness to Pay (WTP) from Existing Studies

- Many researchers have used data on people's vehicle purchases and stated preferences to estimate relationships between vehicle attributes and vehicle choices or sales.
  - Stated Preference: designed choice experiments, simplified choice problems.
  - Revealed Preference: based on consumer behavior in markets
    - Discrete choice: the probability of purchasing a vehicle depends on its attributes and those of consumers. Survey or market sales.
    - Hedonic price: the price of a vehicle depends on its attributes.

- Authors infrequently calculate and publish WTP estimates, but it is usually possible to produce estimates from the coefficients of attributes and price.

Our literature search focused on recent U.S. studies.

Types of literature: 1) peer reviewed publications, 2) grey literature from academic/research institutions → Initial pool of 160 papers.

Search engines: Google Scholar, Econlit, Science Direct

Sample journals: Energy Economics, Econometrica, American Economic Review, Transportation Research (Parts A-E), Resource and Energy Economics, Review of Economics & Statistics, Transportation Research Board
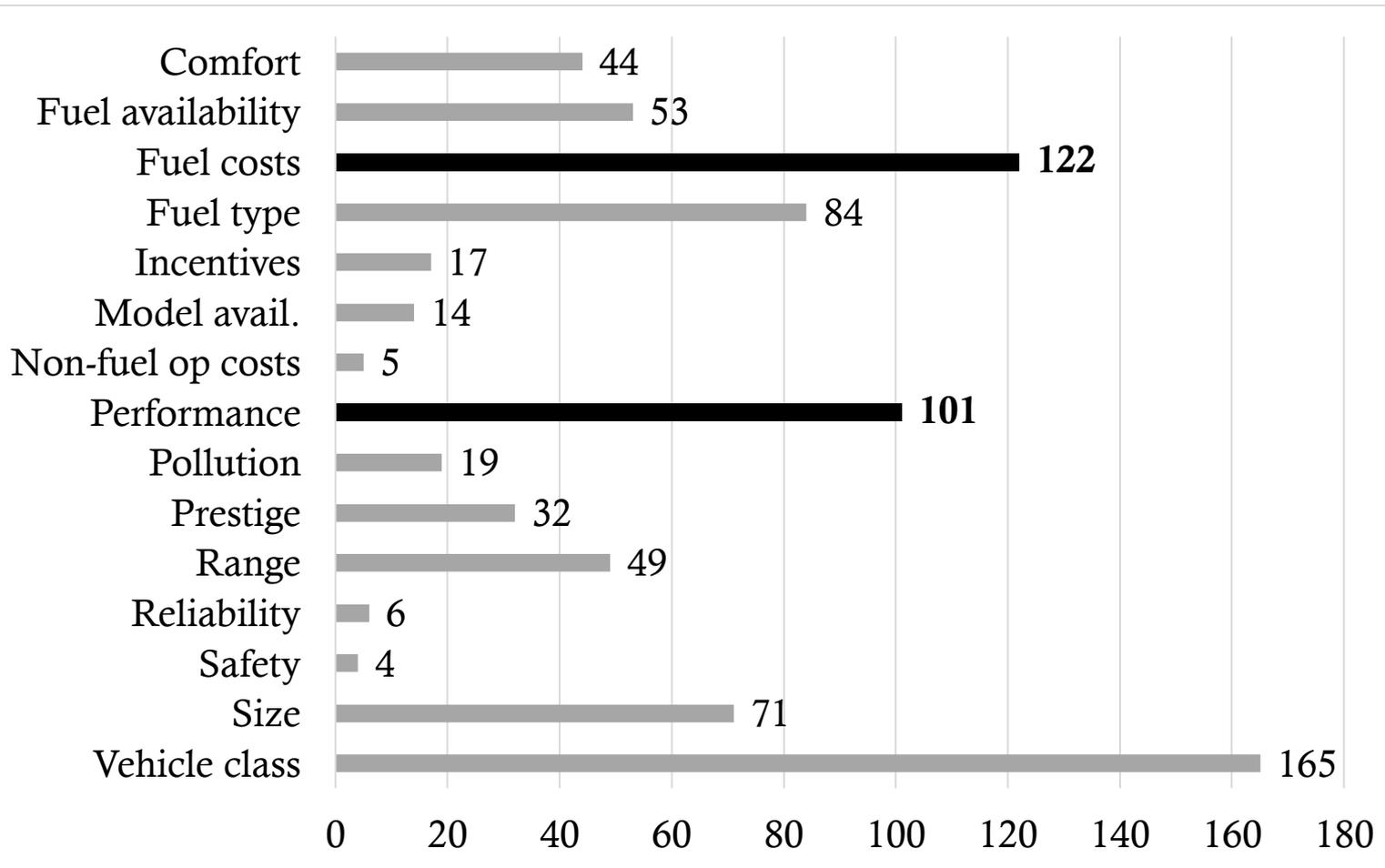
Publication Years: 1995-2015

Region: primarily US

Search terms: willingness to pay, WTP, demand, stated preference, revealed preference, vehicle characteristics, vehicle attributes, automobile, design, fuel, choice

The search yielded 52 papers published from 1995 to 2015.

- 86.5% peer-reviewed, 13.5% grey literature

- Sources of data:
    - 58.6% survey data
        - 19.3% revealed preference
        - 39.3% stated preference
    - 29% market sales
    - 12.4% other data.

- Types of Models:
    - 30.2% Mixed Logit
    - 29.4% MNL
    - 13.1% NMNL
    - 7.7% BLP
    - 9.6% Hedonic price
    - 11% other

We estimated 786 WTP values for 146 attributes in 15 classes.

Attribute	Value
Comfort	44
Fuel availability	53
Fuel costs	**122**
Fuel type	84
Incentives	17
Model avail.	14
Non-fuel op costs	5
Performance	**101**
Pollution	19
Prestige	32
Range	49
Reliability	6
Safety	4
Size	71
Vehicle class	165

In theory, estimating WTP is straightforward. In practice…not so much.

- Functional forms can be complex:
  - Price often divided by income
  - Attributes frequently interacted with other variables.
  - **Attributes measured in varying units**

- Descriptive statistics for attributes and interacted variables sometimes missing or incomplete

- Units sometimes uncertain

$$WTP = -\frac{\partial U / \partial x}{\partial U / \partial P}$$

- Coefficient estimates are random variables and so WTP is a ratio of random variables.

- We estimated WTP ***conditional*** on the mean or median value of the price coefficient.

We took steps to find and correct errors in our calculations.

- When uncertain of units or interpretations we queried authors.

- Each paper's calculations are contained in a separate spreadsheet to facilitate checking our work.

- All spreadsheets were sent to lead authors for comments or corrections (obviously voluntary).

- Outlier analysis
  - Histograms of WTP distributions
  - Outlier if >3s from trimmed sample

The variance of WTP estimates was very large for almost all attributes.

- Out of 35 attributes (table 4):
  - Mean of trimmed sample > 1s.d. for 22
  - Mean of trimmed sample > 2 s.d. for 9

WTP for a 1 Second Decrease 0-60 mph
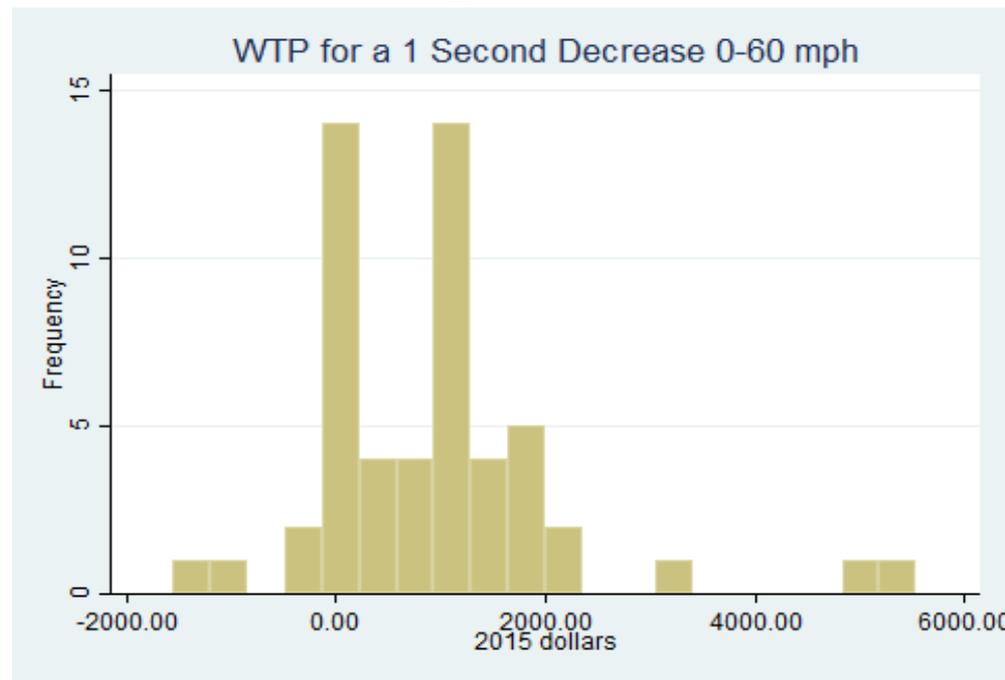
We used ANOVA of the Full Sample to analyze relationships between ALL study attributes and WTP estimates. (Units nested in Grouping)
(**Bold** = 0.01 level; *Italic* = 0.1 level)

1. **Data type**: market data, stated preference (SP) survey, revealed preference (RP) survey, SP & RP, literature review
2. **Statistical model**: the method of Berry et al. (1995) (BLP), mixed logit, multinomial logit (MNL), nested MNL, hedonic, other
3. **Interaction variable**: none, vehicle type, income, demographic
4. **Sample region**: U.S., CA, ME, MD+VA+TN, CO, WA, Canada, Austin TX
5. **Metric**: Units of measurement nested within attribute Group
6. *Assumed endogeneity of price*: yes, no
7. *Authors' preferred form*: yes, no
8. *Choice level*: fuel type, make-model, powertrain, vehicle class
9. *Journal Rank*: Top 25, 26-100, 100-300, >300, unranked or gray literature
10. Date: midpoint year of data set used in estimation minus 1970

The Full Sample ANOVA model was significant at the 0.0001 level but its adjusted R2 was only 0.20. Remaining variation may be due to:

1. Decisions we made in estimating WTP.

2. Researchers' decisions about which variables to include in the model and which to exclude.

3. Correlations among variables included in the estimated model and excluded or unobserved variables.

4. Choices of functional forms for variables, interactions and distributions of random coefficients.

5. Decisions about estimation methods, such as choices of instrumental variables in models assuming endogeneity.

Three studies that present results from multiple models using the same data illustrate how important modelers' choices can be.

- Haaf et al. (2014) selected models based on objective metrics:
  - Price coefficients varied from -0.19 to -1.56 (BLP).
  - Alternative metrics for size changed the sign on fuel cost.

- Klier and Linn (2012) show results for 14 models:
  - Tested choice of IVs, hp/wt vs. hp & wt, error structures
  - WTP for 0.01 hp/lb: $303, $264, $303, $283, $52, $51, $8

- Petrin (2002) compared 4 estimation methods, obtaining coefficients for Miles/$ of 0.18, 0.05, -0.54 & **-15.97**, the latter being the only statistically significant estimate.

Interactions with different household attributes can produce very different WTP estimates that probably do not reflect genuine preference heterogeneity.

Willingness to Pay for a $1 Present Value Decrease in Operating Cost
1- and 2-Vehicle Households (Brownstone et al., 1996)
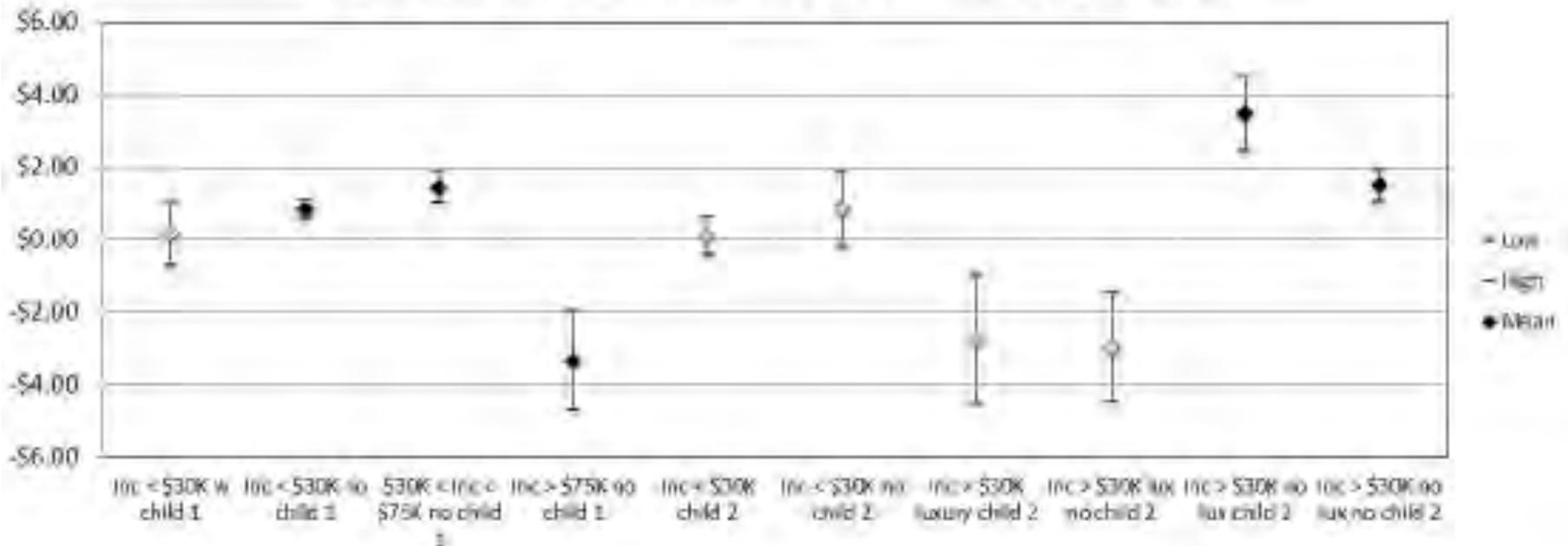
We used the Stata™ random effects method for the meta-analysis of WTP for fuel cost savings. All p-values strongly rejected homogeneity.

WTP for $0.01/mi Reduction in Fuel Cost: All Models

Price Endogenous?	Mean	C.I. Low	C.I. High	p-value	Count
Yes	$569	$369	$770	0.000	36
No	$1,368	$-14	$2,752	0.000	59
ALL	$1,057	$-12	$2,128	0.000	95

As a reference point, a light-duty vehicle that travels 115,000 discounted (6%/yr) lifetime miles would value a $0.01/mile reduction in fuel cost at $1,150.

N.B.: Because we could not estimate true standard errors, the C.I. are not true confidence intervals but only indicators of uncertainty.

WTP estimates also vary by data type and model type. In fixed coefficient models revealed preference data indicate about half as much WTP as stated preference experiments.

WTP for $0.01/mi Reduction in Fuel Cost: Fixed Coefficient Models

Data Type	Mean	C.I. Low	C.I. High	p-value	Count
Market Sales	$678	$330	$1024	0.000	37
Revealed Preference Survey	$549	$325	$773	0.000	11
Stated Preference Survey	$1,225	$942	$1,509	0.000	20
Market + Revealed Preference	$693	$444	$943	0.000	48
ALL	$853	$636	$1,071	0.000	68

WTP for $0.01/mi Reduction in Fuel Cost: Random Coefficient Models

Data Type	Mean	C.I. Low	C.I. High	p-value	Count
Market Sales	$-760	$-4,300	$2,742	0.000	12
Revealed Preference Survey	$4,140	$-186	$8,465	0.000	2
Stated Preference Survey	$2,866	$1,824	$3,908	0.000	13
ALL	$1,706	$-450	$3,862	0.000	27

N.B.: Because we could not estimate true standard errors, the C.I. are not true confidence intervals but only indicators of uncertainty.

Estimates of WTP for a one second reduction in 0-60 mph time vary much less across data and model types.

WTP for a 1 Second Reduction in 0-60 mph: Comparing Model Types

Coefficient Type	Mean	C.I. Low	C.I. High	p-value	Count
Random	$686	$403	$970	0.000	20
Fixed	$964	$830	$1,098	0.000	28
ALL	$845	$713	$977	0.000	48

WTP for a 1 Second Reduction in 0-60 mph: Comparing Data Types

Data Type	Mean	C.I. Low	C.I. High	p-value	Count
Market Sales	$685	$392	$979	0.000	23
Revealed Preference Survey	$847	$684	$1011	0.000	10
Stated Preference Survey	$949	$570	$1,328	0.000	15
Market + Revealed Preference	$796	$592	$1000	0.000	33
ALL	$845	$713	$977	0.000	48

What do we know about WTP for vehicle attributes?

- The literature has produced a very wide range of estimates for most attributes.

- For some attributes, there are large differences depending on data and estimation methods.

- Choices made by researchers strongly influence results.

- Central tendency estimates or estimates from any model must be used with appreciation of the uncertainty.

How can we make progress?

- We urge researchers to routinely report WTP estimates, along with relevant statistics and data necessary for their calculation (e.g. covariances).

- Choose theoretically valid functional forms for variables. (e.g., fuel cost/mile, 1/range).

- Identify and assess the validity of variables included to represent omitted or inadequately measured factors.

- Continue estimating random utility models but also explore alternative models of consumer choice.

Thank you.

Backup slide.

$$E\left[\frac{-\alpha}{\beta}\right] \approx \frac{E[-\alpha]}{E[\beta]} - \frac{Cov[-\alpha,\beta]}{E^2[\beta]} + \frac{Var[\beta]E[-\alpha]}{E^3[\beta]}$$

Power or acceleration was the third most frequently included attribute. We converted three such measures to WTP for a reduction of 1s 0-60 mph.

WTP for Attribute	N	Mean	S.D.	Minimum	Maximum	Median
Acceleration (s. 0-30 mph)	11	1045	1122	-1,547	3,288	1,141
Acceleration (s. 0-60 mph)	8	1,096	627	35	2,200	1,183
Horsepower/weight	29	880	1,449	-860	5,544	198
Converted to (s. 0-60 mph)	48	954	1,259	-1,547	5,543	1,005
Horsepower	11	54	109	0	355	9
Top speed	9	100	58	28	210	75

Fuel cost was the most common attribute after purchase price. For the meta-analysis we converted most to WTP for a reduction of $0.01/mile.

Standard Units	N	Mean	S.D.	Minimum	Maximum	Median
WTP for $/yr	15	-63,204	274,177	-1,052,470	64,499	719
WTP for 0.01 gpm	24	46	3,091	-7,472	4,701	715
WTP for 10mi/$	8	-14,918	20,601	-59,619	-676.505	-4,051
WTP for cpm	60	1,366	3,318	-7,425	19,415	1,147
WTP for mpg	7	991	1,404	-325	3,849	800
WTP other units converted to cpm	3	896	702	116	1,476	1,098
Converted $/cpm	117	-8,331	97,820	-1,052,470	64,499	738