

EPA Research on Economic and Consumer Issues related to Light-Duty Vehicle Greenhouse Gas Standards

EPA Presentation to the NAS Light-duty Vehicle Fuel Economy Phase 3 Committee
June 16, 2020

Agenda

- EPA staff work related to consumer issues for gasoline vehicles
 - Past work (Gloria Helfand)
 - Willingness to pay for vehicle attributes
 - Consumer vehicle choice modeling
 - Energy paradox
 - Effects of the standards on consumer acceptance
 - New work
 - Consumer acceptance of advanced ICE technologies (Elizabeth Miller, Christian Noyce*)
 - Relationship between fuel economy and performance (Asa Watten*)
- EPA staff work related to consumer issues for electric vehicles (Dana Jackman)

*ORISE Participant at the U.S. Environmental Protection Agency, Office of Transportation & Air Quality

NAS recommendations, 2015

- **Recommendation 9.1** The Agencies should do more research on the existence and extent of the energy paradox in fuel economy, the reasons for consumers' undervaluation of fuel economy relative to its discounted expected present value, and differences in consumers' perceptions across the population.
- **Recommendation 9.2** The Agencies should conduct more research on the existence and extent of supply-side barriers to long-term investments in fuel economy technologies.
- **Recommendation 9.3** The Agencies should study the value of vehicle attributes to consumers, consumer willingness to trade off other attributes for fuel economy, and the likelihood of consumer adoption of new, unfamiliar technologies in the vehicle market. This will enable the Agencies to better understand consumer response to the CAFE rules and better assess the rules' costs and benefits.

National Research Council, Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, D.C.: National Academy of Sciences, 2015, pp. 9-36 - 9-37.

EPA's work related to consumer issues for gasoline vehicles

Past Work: Gloria Helfand

Consumer willingness to pay for vehicle attributes

- EPA commissioned RTI (who worked with David Greene, U. Tennessee) to examine estimates of consumer willingness to pay for vehicle attributes found in studies of consumer vehicle demand
- WTP values derived from 52 papers published from 1995 to 2015
 - 786 WTP values for 146 attributes in 15 classes
 - | | | |
|---------------|-------------------|--------------------------|
| • Comfort | Fuel availability | Fuel costs |
| • Fuel type | Incentives | Model availability |
| • Performance | Pollution | Non-fuel operating costs |
| • Prestige | Range | Reliability |
| • Safety | Size | Vehicle class |
- Variation in estimates was very large: out of 35 attributes,
 - Mean of trimmed sample > 1s.d. for 22
 - Mean of trimmed sample > 2 s.d. for 9
- Choices made by analysts, such as model type, influence results
- Existing literature doesn't provide us a clear message on WTP for attributes

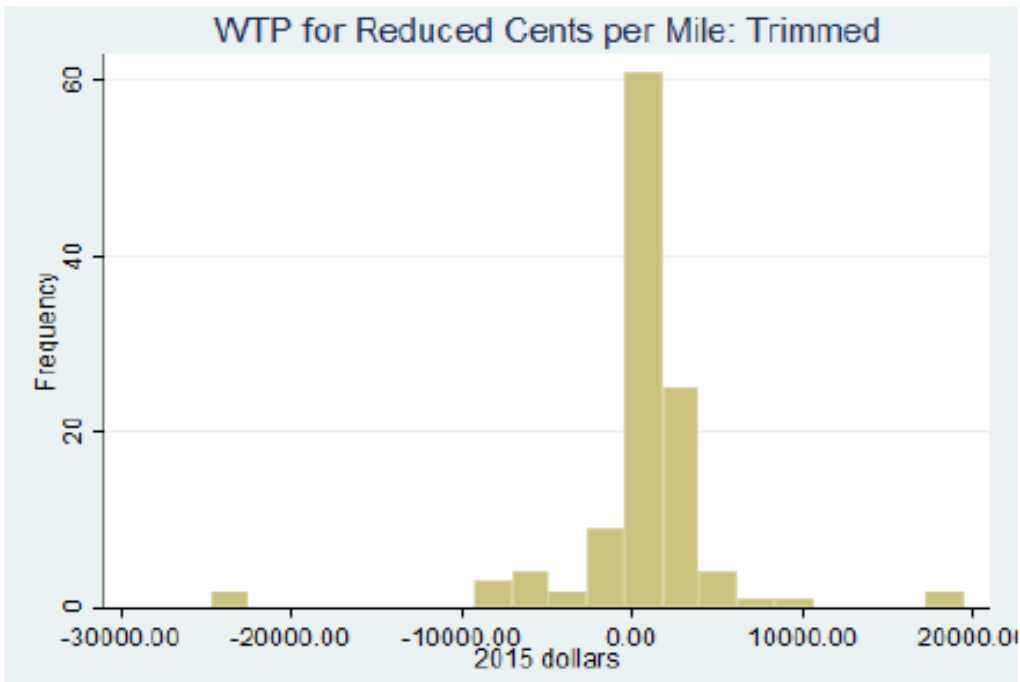
“Consumer Willingness to Pay for Vehicle Attributes: What is the Current State of Knowledge?” Report prepared for US EPA by RTI International. EPA-420-R-18-016, 2018.

Greene et al. (2018). “Consumer willingness to pay for vehicle attributes: What do we Know?” Transportation Research Part A 118 (2018) 258–279.

Fuel Economy

(\$/cent per mile, without outliers)

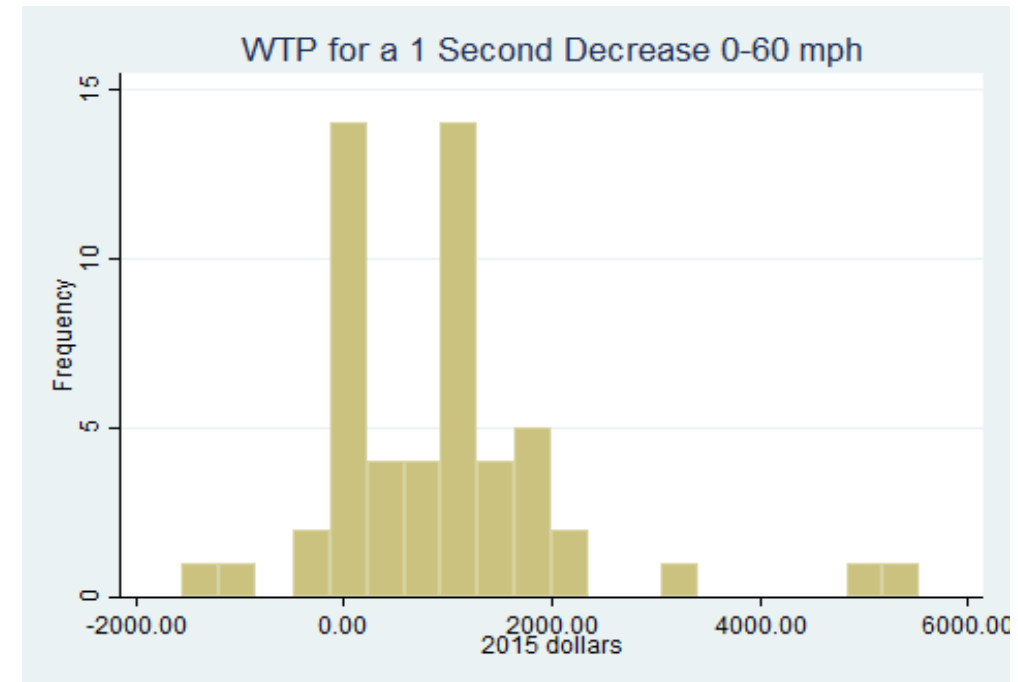
- Mean: \$1880
- Std. Deviation: \$6874
- Median: \$991



Performance

(\$/1-second reduction in 0-60)

- Mean: \$954
- Std. Deviation: \$1259
- Median: \$1005



Consumer impacts of GHG standards: Sales impacts

- Aggregate sales impacts depend on how vehicle buyers trade off increased up-front prices with improved fuel economy, but we don't seem to understand how consumers make that tradeoff
 - NAS 2015: "A large amount of literature in the economics and policy community attempts to understand and measure the extent and magnitude of consumer undervaluation of fuel economy, but the empirical evidence is still mixed."
 - [Greene et al. 2018 confirms a lack of consensus.](#)
- Models of vehicle class shifts, in the rare cases where they're tested, appear to develop worse estimates than holding market shares constant.
 - Haaf et al., 2014. Sensitivity of vehicle market share predictions to discrete choice model specification. J. Mech. Des. 136 121402-121402-9.
 - Haaf et al. 2016. Forecasting light-duty vehicle demand using alternative-specific constants for endogeneity correction versus calibration. Transport. Res. Part B 84, 182–210.
 - [Doremus et al. 2018. Simpler is better: Predicting consumer vehicle purchases in the short run. Energy Policy 129, 1404-1415.](#)
- The impacts of the standards on sales, either total or fleet mix, seem to be small compared to the effects of macroeconomic factors.
- The literature has not provided clear direction on the impacts of LD GHG/ fuel economy standards on sales.

Current EPA Research on Sales

- We have contracted with RTI (who is working with Prof. Mark Jacobsen, UC San Diego) to review the literature and develop estimates of:
 - The effect of changes in new vehicle prices or costs on new vehicle sales
 - The effect of changes in the new vehicle market on used vehicle prices or sales
 - The effect of changes in the new vehicle market, or used vehicle prices or sales, or new or used vehicle operating costs, on vehicle scrappage
 - The effects of the factors that influence total vehicle fleet size on fleet size
 - To understand better the role of standards relative to macroeconomic factors.
- We aim to have a peer-reviewed report in Summer 2021.

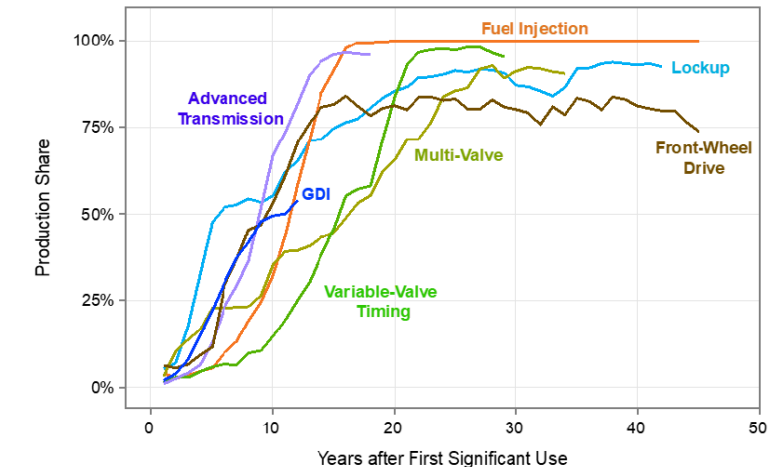
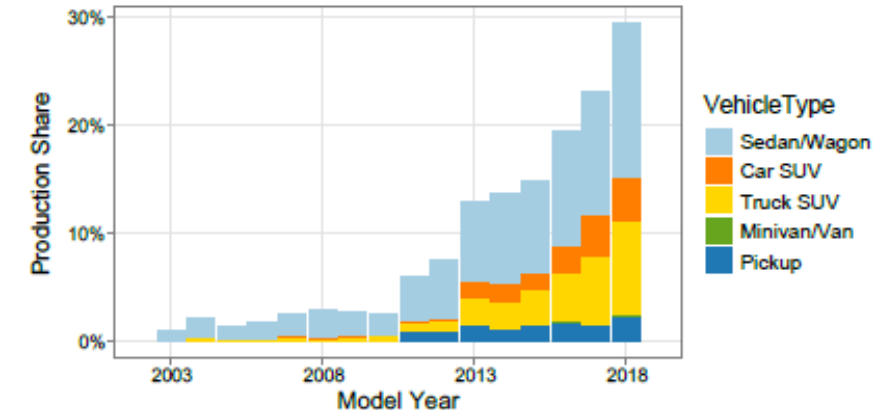
Understanding the energy paradox

- The Energy Paradox (aka Efficiency Gap) describes a scenario where private market adoption of energy-saving technologies appears lower than would be expected when comparing energy cost savings to the costs of the energy-saving technologies
- Two separate questions:
 - Does the gap exist? (Existence)
 - Why does the gap exist? (Explanation)
- For the energy paradox to exist in LD vehicles, there must be:
 - Technologies available that would cost less than the present value of fuel savings that buyers would get
 - Those technologies not spreading quickly to new vehicles in the absence of standards
 - Limited or no adverse effects of those technologies on other vehicle attributes

Existence of the Energy Efficiency Gap

Figure 4.7. Gasoline Turbo Engine Production Share by Vehicle Type

- Cost and effectiveness estimates made in 2010, 2012 for technology packages appear to have been reasonable, with payback periods under 3 years for the MY 2012-16 standards
 - EPA et al., Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025, Chapters 5, 12.
- Many technologies existed, but were not widely used, prior to the standards
- We have not found consistent evidence of adverse effects on other vehicle attributes
 - More following below
 - Helfand et al. (2016). "Searching for Hidden Costs: A Technology-Based Approach to the Energy Efficiency Gap in Light-Duty Vehicles." *Energy Policy* 98: 590-606.
 - Huang et al. (2018). "Re-Searching for Hidden Costs: Evidence from the Adoption of Fuel-Saving Technologies in Light-Duty Vehicles." *Transportation Research Part D* 65: 194-212.
- The existence of the gap seems to be documented.



U.S EPA (2020). *The 2019 EPA Automotive Trends Report*.
<https://nepis.epa.gov/Exe/ZyPDF.cgi/P100OXEO.PDF?Dockey=P100OXEO.PDF>; <https://www.epa.gov/automotive-trends>

Explanations for the Energy Efficiency Gap

- Much of the literature has focused on consumer behavior as the potential explanation of the existence of the gap.
 - If consumers undervalue fuel savings, then the gap may exist.
 - As discussed above, the evidence on consumer valuation of fuel economy is inconclusive.
 - There does not seem to be evidence of consumer resistance or objections to vehicles with technologies that have achieved the standards.
- Little research has been devoted to producer behavior as a possible explanation
 - Some possible pieces of explanations are that automakers:
 - Face enormous fixed costs in changing technologies, so delay undertaking them.
 - Have enough market power that they selectively provide new technologies only in a small number of products as a form of market differentiation.
 - [Helfand and Wolverton \(2011\). "Evaluating the Consumer Response to Fuel Economy: A Review of the Literature." International Review of Environmental and Resource Economics 5: 103-146.](#)
- Although there seems to be sound evidence that the efficiency gap has existed, research has not yet fully explained why it exists.

Benefit-cost analysis in the presence of the gap

Helfand and Dorsey-Palmateer (2015). "The Energy Efficiency Gap in EPA's Benefit-Cost Analysis of Vehicle Greenhouse Gas Regulations: A Case Study," Journal of Benefit-Cost Analysis 6(2): 432-454.

- As long as it is possible to have more of both fuel economy & other attributes, cost estimates can include all opportunity costs of the standards, by holding other attributes at their without-rule levels.
 - EPA staff have not found evidence of foregone vehicle attributes, including performance.
 - It is not necessary to reduce performance to improve fuel economy.
 - Some technologies, such as advanced transmissions, enhance both.
 - More on this to follow.
- Fuel savings are based on "experienced utility," what people pay at the pump, not "decision utility," how people consider fuel economy when buying a vehicle.
 - Decision utility affects vehicle sales, not subsequent fuel savings.
 - If other attributes are not affected, the worst off a vehicle buyer can be is the extra costs due to the fuel-saving technologies.
- Comparing fuel savings to technology costs that incorporate holding other attributes constant provides a reasonable, if not conservative, estimate of net benefits.

Effects of the standards on other vehicle attributes

- If fuel-saving technologies adversely affect other vehicle attributes, avoiding those damages might explain slow adoption of those technologies
- EPA has proposed two approaches to understanding those impacts:
 - Auto reviewers' assessments of technologies and other attributes
 - Consumer satisfaction with vehicles with fuel-saving technologies

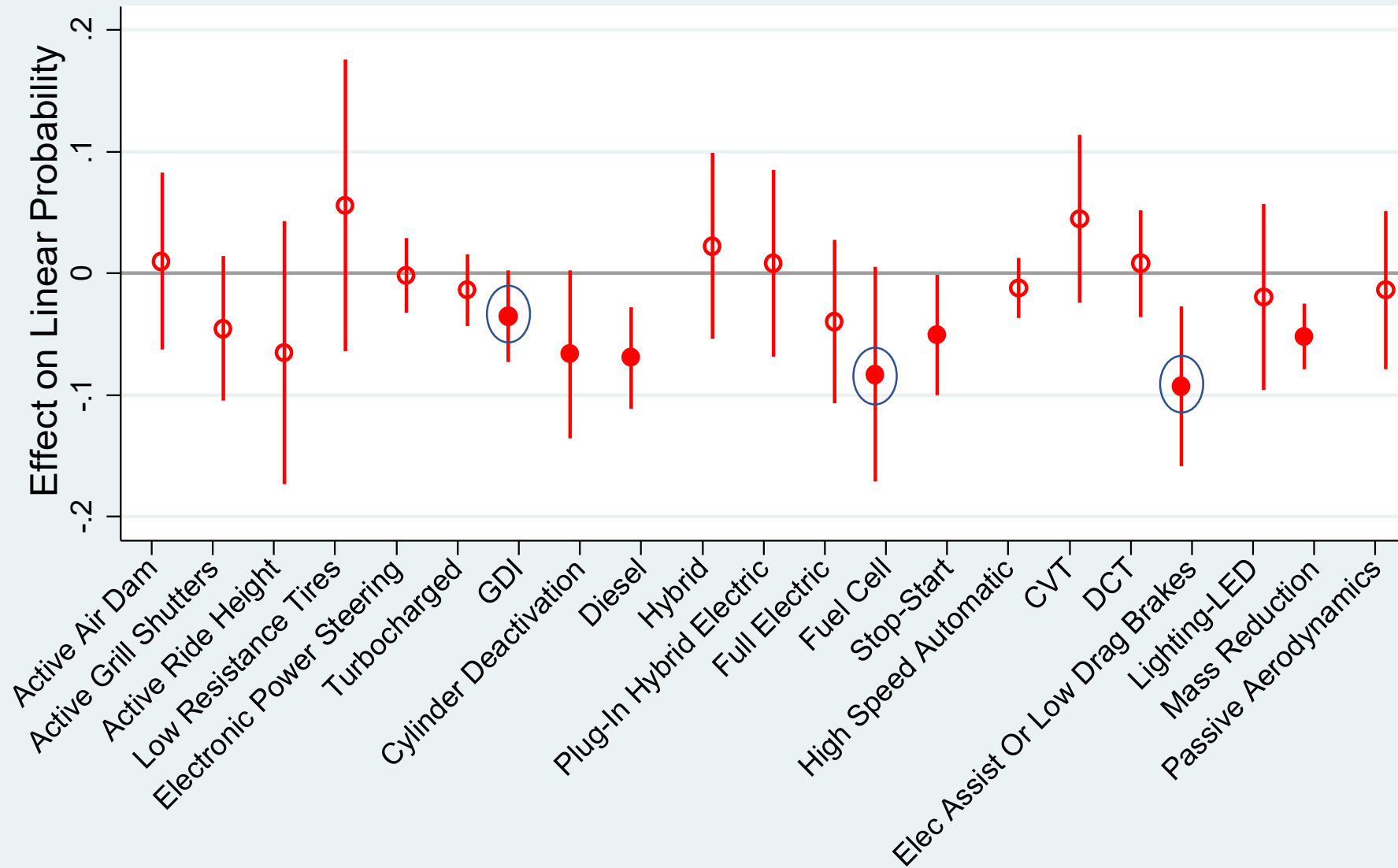
Auto reviews to evaluate impacts of technologies on other vehicle attributes

- We used reviews of MY 2014, 2015 vehicles from professional reviewers, who are
 - Trained to identify positive and negative characteristics of vehicles
 - Likely to be at least as sensitive to vehicle characteristics as average vehicle buyers
- Trained coders evaluated efficiency technologies and operational characteristics as positive, negative, or neutral for each auto review
- Findings:
 - Reviews with positive evaluations of fuel-saving technologies substantially outnumbered those with negative evaluations
 - Very few statistically significant correlations between the presence of a technology and negative evaluations of operational characteristics
 - Far more significant correlations with positive evaluations
 - Negative evaluations of operational characteristics are more likely to be correlated with technologies that are negatively reviewed
 - Might the problem be badly implemented technologies?

Helfand et al. (2016). "Searching for Hidden Costs: A Technology-Based Approach to the Energy Efficiency Gap in Light-Duty Vehicles." [Energy Policy](#) 98: 590-606.

Huang et al. (2018). "Re-Searching for Hidden Costs: Evidence from the Adoption of Fuel-Saving Technologies in Light-Duty Vehicles." [Transportation Research Part D](#) 65: 194-212.

Overall Negative Qualitative Assessment



Average Marginal Effects with 95% CIs with Respect to Technology

- Dependent variable is overall negative qualitative assessment (recommendation to buy or not to buy)
- The presence of some technologies (with solid marker) is related to lower probability of getting overall negative review
- The blue circles indicate statistical insignificance using the maximum of robust & conventional standard errors

Huang et al., "Re-Searching for Hidden Costs with Producer Heterogeneity: Evidence from the Adoption of Fuel-Saving Technologies in Light-Duty Vehicles," presented at the Society for Benefit-Cost Analysis conference, <https://www.epa.gov/sites/production/files/2017-03/documents/sbca-mtg-hidden-costs-2017-03-16.pdf>

Buyer Satisfaction with Vehicles with Fuel Saving Technology

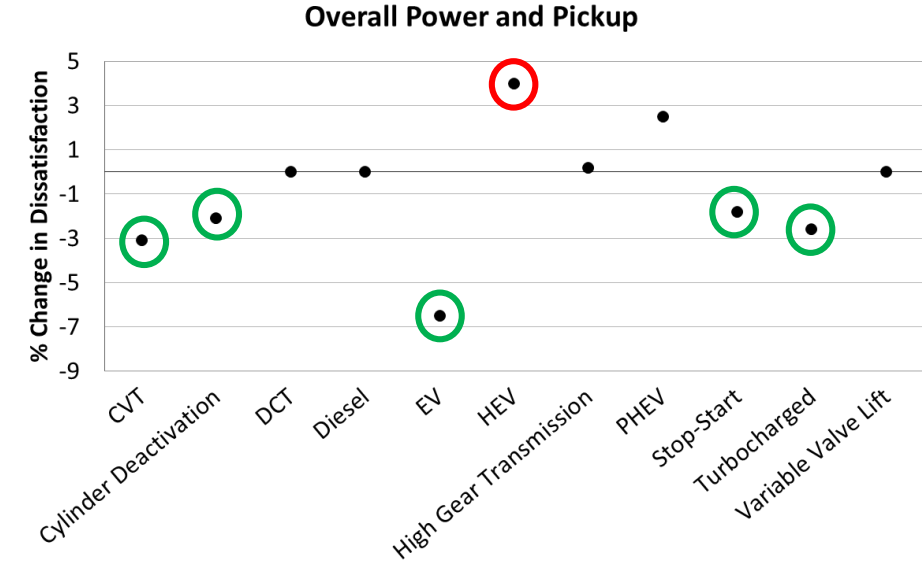
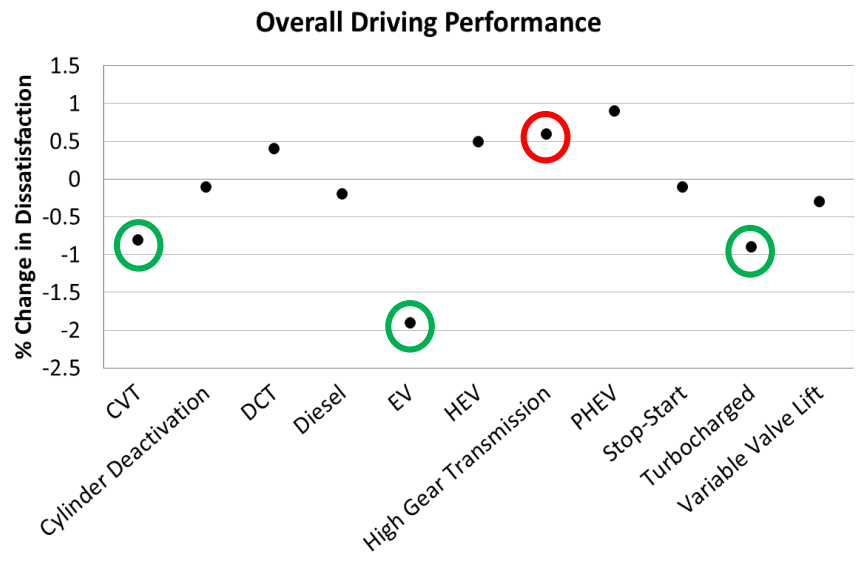
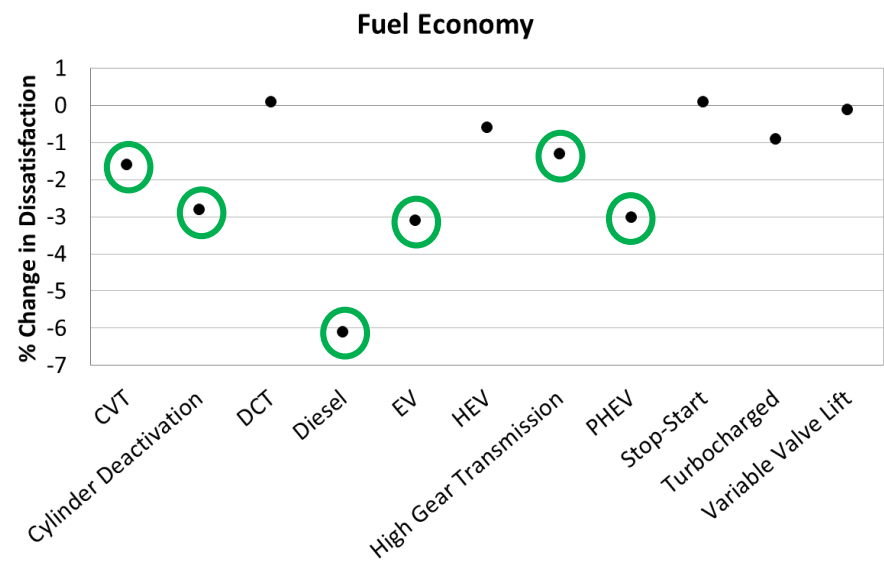
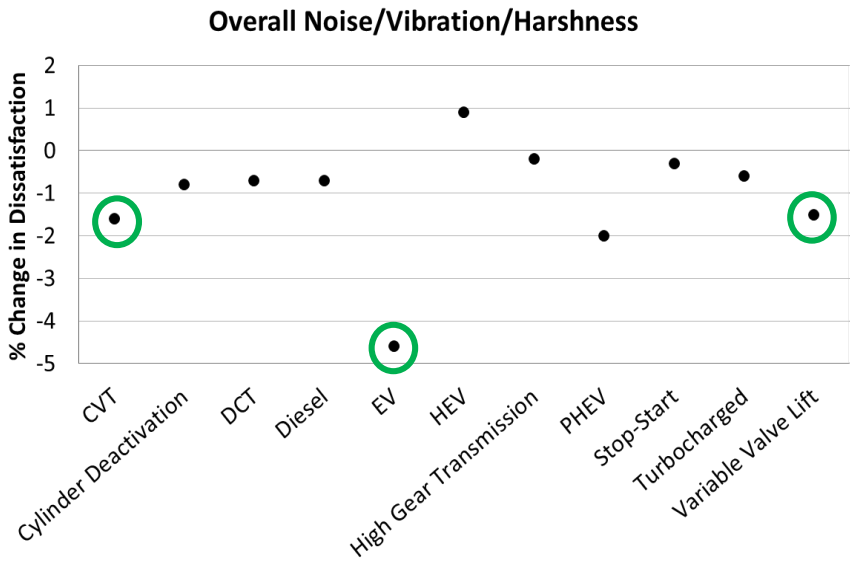
Christian Noyce,* Elizabeth Miller

*ORISE Participant with the US EPA Office of Transportation and Air Quality

Background

- We used data from three years of the New Vehicle Experience Survey from the marketing firm Strategic Vision (2014-2016)
 - Surveys were given to more than 250,000 consumers who had purchased a new vehicle in each year between 2014-2016 within the first 6 months of buying their new vehicle
 - Questions included evaluations of driving performance, power and pickup, noise and vibration, fuel economy and overall satisfaction of the new vehicle in addition to demographics and questions related to their previous vehicle ownership
- This was linked with fuel saving technology available on the vehicles to determine if the existence of fuel-saving technologies impacted rates of dissatisfaction with operational characteristics
 - Probability of dissatisfaction with an operational characteristic (e.g. power and pickup, overall satisfaction, etc.) as a function of the existence of different technologies (e.g. VVT, start-stop, diesel, CVT, hybrid, etc.)
- Findings:
 - Owners experience lower dissatisfaction rates with the adoption of fuel-saving technologies rather than hidden costs
 - Overall dissatisfaction rates with a new vehicle increase when a consumer is dissatisfied with operational characteristics, indicating that effects of fuel saving technology on operational characteristics matter

Overview of Initial Results: Probability of a Negative Review vs. Fuel Saving Technology by Operational Characteristics



- Coefficients are small
 - < 8% change in probability of negative evaluation
- Significant results generally associated with lower probabilities of negative evaluations when fuel saving tech is present
 - E.g.: Lower dissatisfaction rates across all operational characteristics with Continuously Variable Transmission present, greater dissatisfaction rates for overall power and pickup and overall driving performance with HEV

Ongoing work

- There is likely bias in the survey results: buyers choose vehicles they like, which may bias results to lower dissatisfaction rates
 - Though results indicate buyers are able to find vehicles they are generally satisfied with
- We are comparing results for the same models across MYs in vehicles with new fuel saving technology applied in 2015 or 2016
 - For example, the Ford F150 was light-weighted in MY 2015
 - For the 5 models examined to date, dissatisfaction with operational characteristics does not change significantly with the addition of fuel saving technology
- We aim to have a draft manuscript to submit to a journal in Fall 2020

Faster and farther?

Rethinking the performance and fuel economy trade-off for light-duty vehicles

Asa Watten,¹ Gloria Helfand,² Andrew Moskalik²

¹ Oak Ridge Institute for Science and Education Fellow at US EPA; Michigan State University

² United States Environmental Protection Agency

Acknowledgement/disclaimer: This research was supported in part by an appointment to the ORISE research participant program supported by an interagency agreement between EPA and DOE. The research may not necessarily reflect the views of EPA and no official endorsement should be inferred.

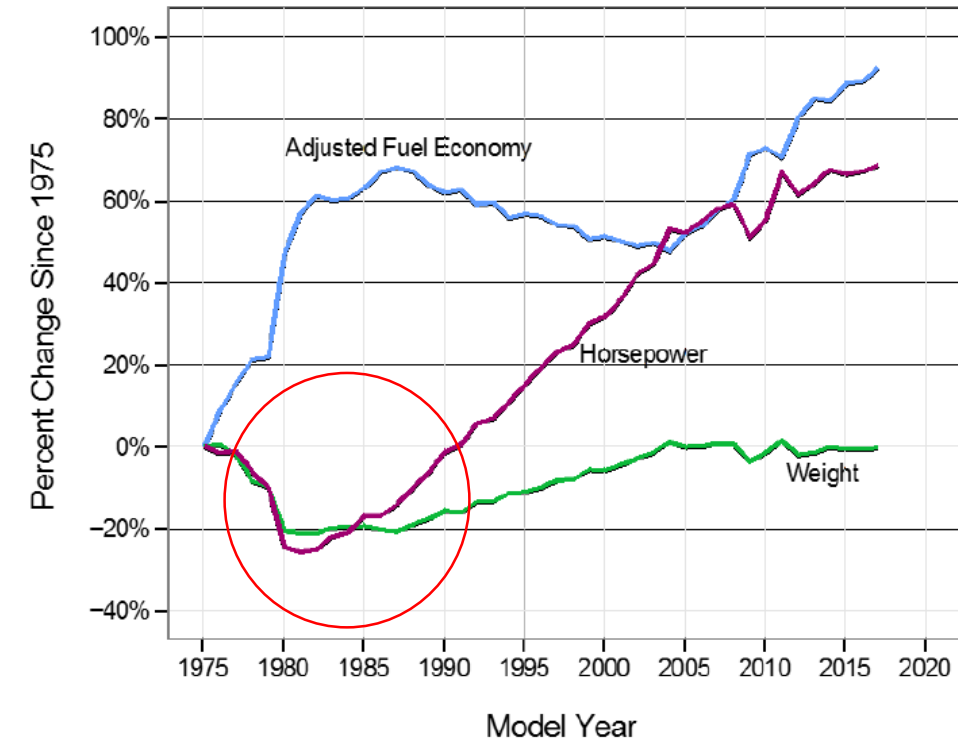
Agenda

- What the engineering literature tells us about the trade-off between performance and fuel economy
- What economics can tell us about the relationship
- Putting the two together

Define an attribute trade-off as: The minimum reduction of one attribute required to increase another without changing the cost of the composite good.

Why we focus on the trade-off between performance and fuel economy

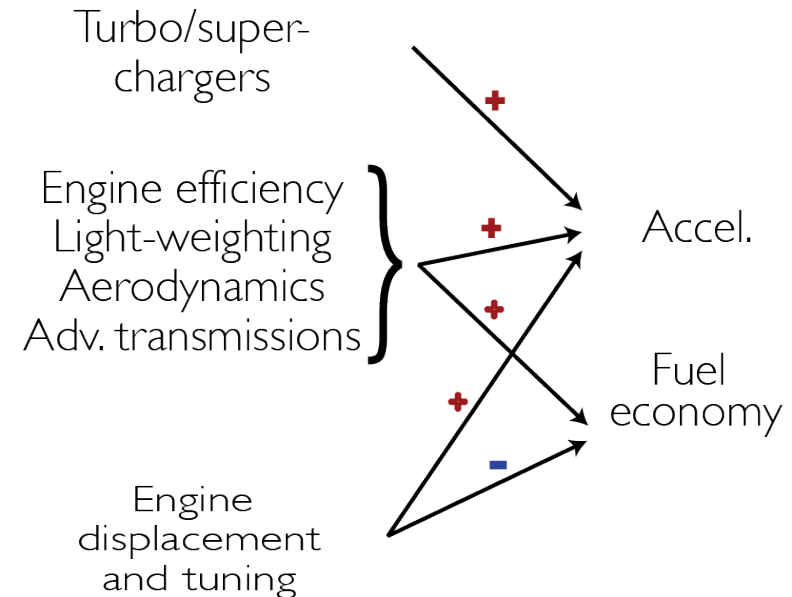
- In the 1970s, improved fuel economy came at the expense of performance
- This implies that cost to consumers of reducing performance was less than the cost of adding technology to improve fuel economy
- To what extent is this still the case?
- Are there forgone improvements to fleet performance caused by fuel economy standards?
- Or, has it become relatively more costly to improve fuel economy by reducing performance than from other design decisions?



Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975-2017, EPA-420-R-18-001, p. 7.

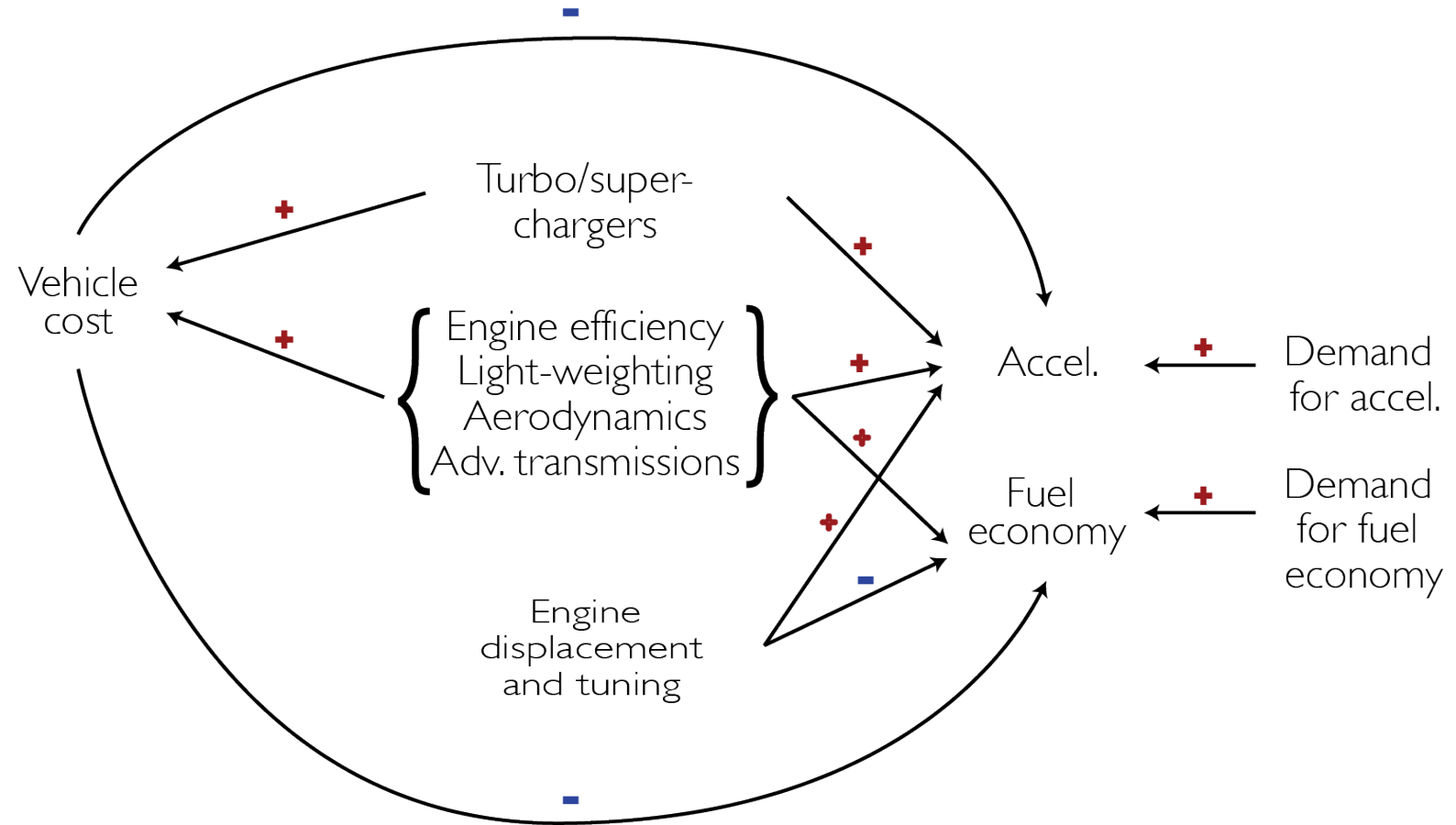
Engineering determinants of performance and fuel economy

- There are multiple design pathways for increasing attributes
- Engine displacement and tuning is the only pathway (that we know of) that improves one attribute at the expense of the other
- Other technologies may increase both or have an isolated effect
- *The diagram is illustrative, not comprehensive*



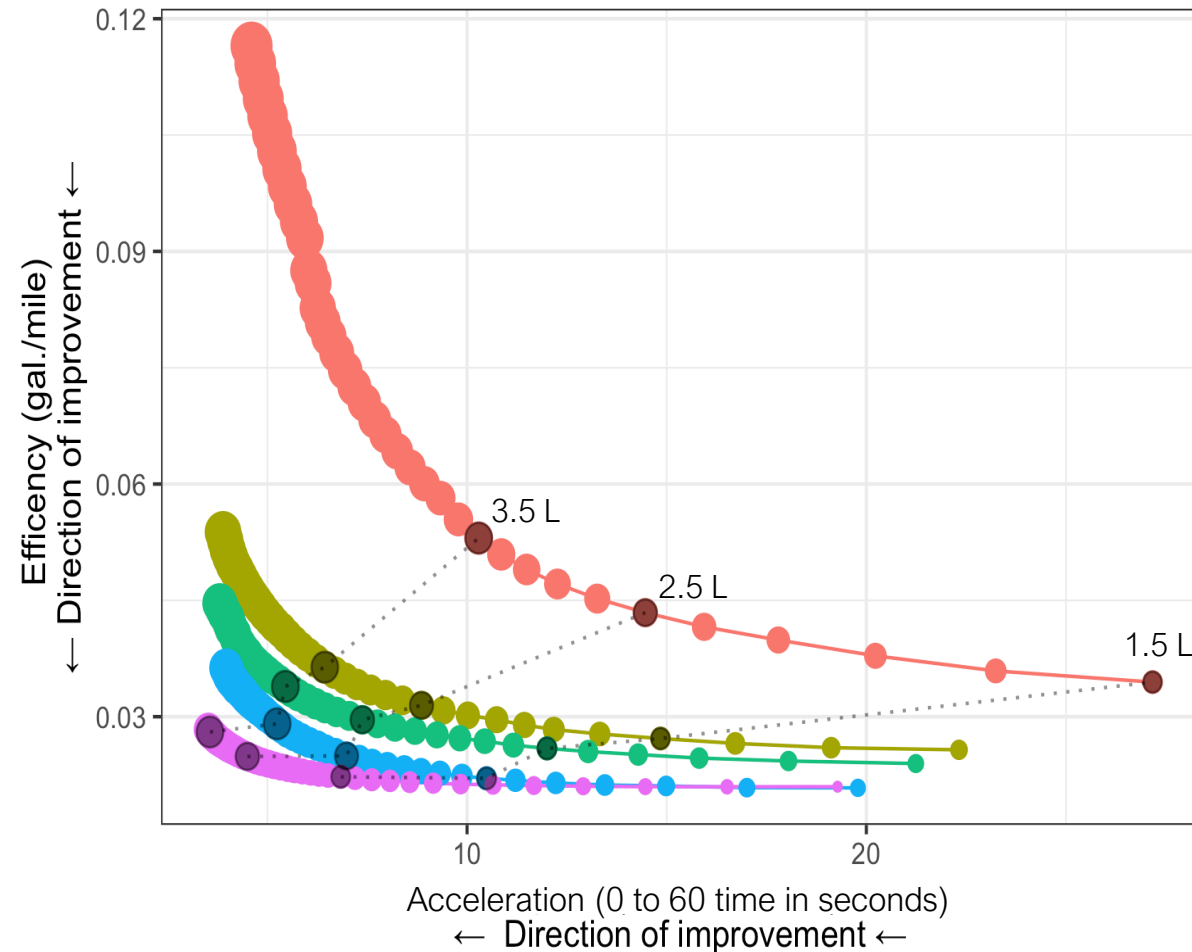
..interact with economic determinants

- Consumers want both attributes
- Technologies and design decisions impose costs
- A trade-off is most apparent through displacement
- To the extent that other technologies favor one attribute over the other, substitution between technologies may also create a trade-off



The effect of engine displacement on efficiency has declined

- A larger engine, all else equal,
 - Is more powerful
 - Uses more fuel
- Over time, the efficiency of engines has improved
- In contemporary vehicles, a marginal increase in engine size has a **smaller and decreasing effect** on efficiency compared to the past



Engine

- 1980s carbureted engine, 3AT
- 2007 PFI engine, 5AT
- 2013 GDI engine, 6AT
- 2017 Atkinson engine, 8AT
- Future 24bar turbo engine, 8AT

ALPHA physics model simulations using representative drivetrains in a fixed vehicle body.

Dekraker et al., 2018.
Constructing engine maps for full vehicle simulation modeling. SAE Technical Paper No. 2018-01-1412.

Power, fuel economy, and economics

- Modeling the relationship between performance and fuel economy must take into account that vehicles on the market are meant to meet demands of **heterogeneous buyers**
 - Producers take into account what vehicle buyers want when they design vehicles
 - Vehicles produced thus are not likely to be representative of all technology possibilities, but many market equilibria
- This project seeks to analyze this market taking into account both consumer preferences and producer consideration of those preferences
- We develop a parsimonious model and use it to
 - Develop economic intuition (appendix)
 - Estimate the trade-off elasticity in two time periods (1990-94 and 2015-19)

This model: producers

- Producers maximize profits by choosing attributes:

$$\max_{q_l, g_l, X_l, Z_l} \pi = \sum_l q_l (p_l - c(g_l, X_l, Z_l))$$

- The cost function is linearly separable into efficiency-related and other attributes:

$$c(g_l, X_l, Z_l) = Tc^1(g_l, X_l) + c^2(Z_l)$$

- Cost function of efficiency-related attributes is Cobb-Douglass-like:

$$c^1(g_l, X_l) = c^{\max} - g^{\alpha_g} \prod_j \underline{x}_j^{\alpha_j}$$

Note: $\underline{x}$ indicates a transformation where x is an attribute in “goods space”: $\underline{x}_j = x_j^{\max} - x_j$

Technical Note: Many economic analyses assume a Cobb-Douglas (double-log) functional form. This form *does not provide a unique solution* to the producers’ decision: it provides a minimum, rather than a maximum, achievable profit.

This is
where our
model is
different

This model: consumers

- **Heterogeneous consumers** (representing segments) who trade-off vehicle price for attributes:

$$\max_l u_i \approx v_i(g_l, X_l, Z_l) + y_i - p_l$$

- Value of attribute bundle is locally linear and separable into efficiency related attributes and others:

$$v_i(g_l, X_l, Z_l) = v_i^{\max} + v_i^Z(Z_l) - \underline{X}_l \cdot \beta_i - g_l p_g \phi_i$$

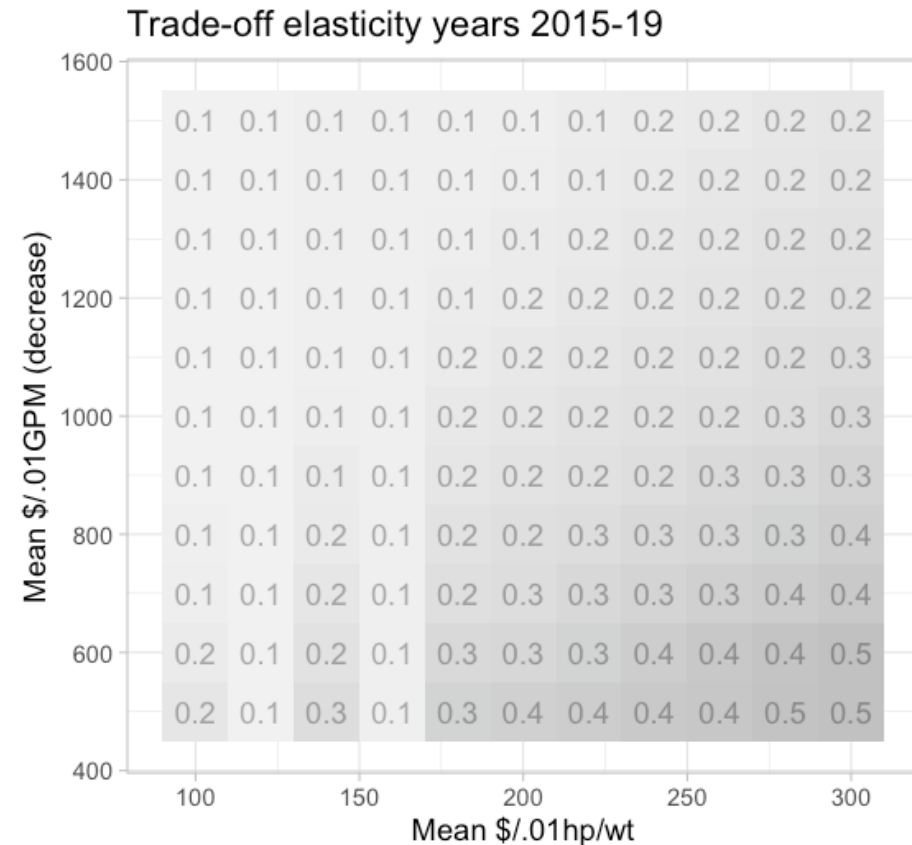
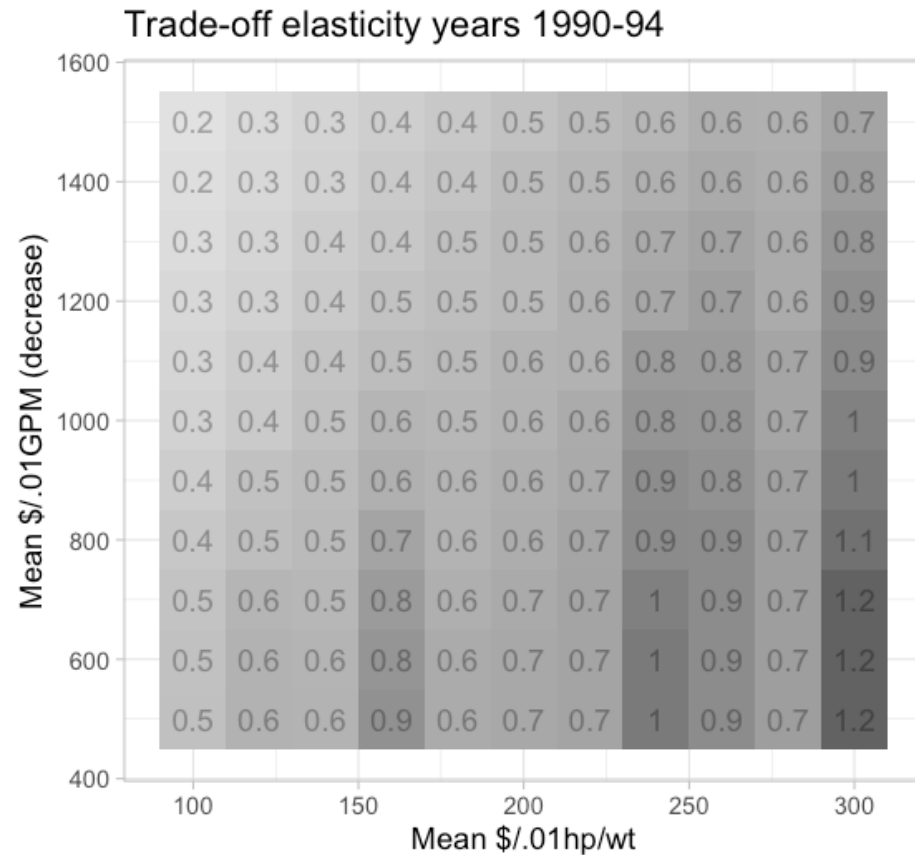
- Plugging in vehicle cost for vehicle price and taking logs we solve for the equilibrium attributes for each consumer:

$$\ln g^* = \frac{1}{\psi} \left(\ln \alpha_g - \ln (\phi_i p_g + \lambda) + \ln T + \sum_j \alpha_j \left(\ln (\phi_i p_g + \lambda) - \ln \beta_{ij} + \ln \frac{\alpha_j}{\alpha_g} \right) \right)$$

Estimation procedure for trade-off elasticity

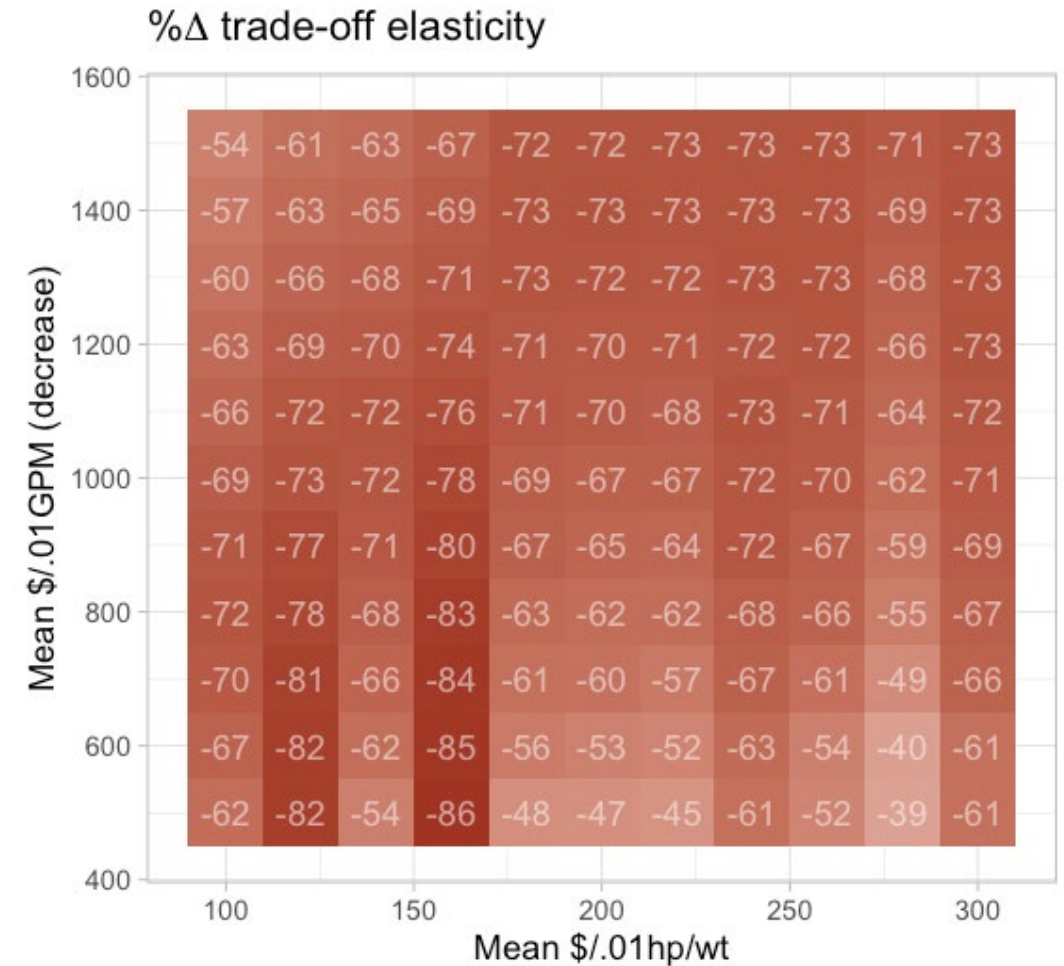
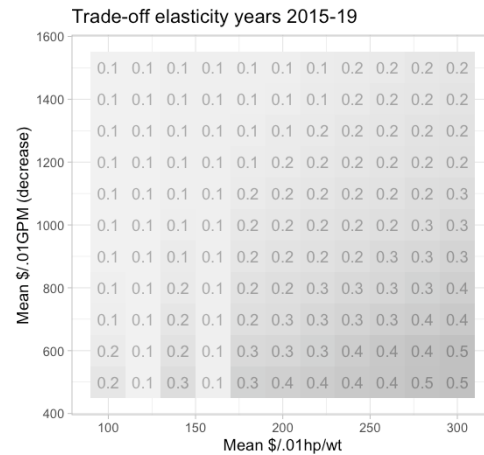
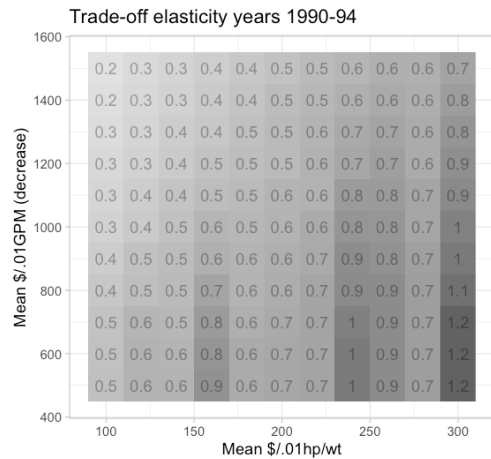
- To estimate model parameters we need to control for either cost data (unavailable) or heterogeneous consumer preferences (not directly measurable)
- We opt for assuming a range of possible mean consumer preference values and estimating the model for many points
- Our range is informed by Greene et al. (2018), which summarizes attribute willingness to pay literature
- The model is estimated (using maximum likelihood) for each **guess at** mean value
 - Both model parameters and the covariance matrix of preference parameters are estimated in an iterative loop
 - This allows for a flexible distribution (assuming the means) of preferences
- Caveats: observations are year-vehicle-sub-model and are **not sales weighted**. Differences between time periods assume mean attribute segment maps to mean attribute realization
- Data source: Wards Automotive (1990 to 2019)

Estimated trade-off elasticities declined substantially between time periods



Each cell is the percent change in gallons per mile resulting from a 1 percent change in net horsepower, assuming a set of mean consumer preferences values. This elasticity is evaluated at 1990-94 mean attribute levels.

Estimated trade-off elasticities declined substantially between time periods



Evidence of substantial (-39 to -86%) flattening of trade-off elasticity for all assumed mean preference parameters between the two time periods.

Summary

- Improving fuel economy does not force a decrease in performance
 - It is possible to make a more powerful vehicle more fuel-efficient
- Engineering simulations show that the most obvious pathway for a trade-off, displacement, has changed substantially
- But this does not account for substitution between all possible pathways to improve fuel economy and/or performance
- Using market data, which takes into account all possible technology substitutions, we also see evidence for a substantial flattening of the trade-off
- Improving fuel economy only through performance reduction requires a much larger reduction, making it a more costly pathway for improving fuel economy
- The likely outcome is an increase in the relative profitability of adding technologies that increase both performance and fuel economy when designing vehicles to be more fuel efficient

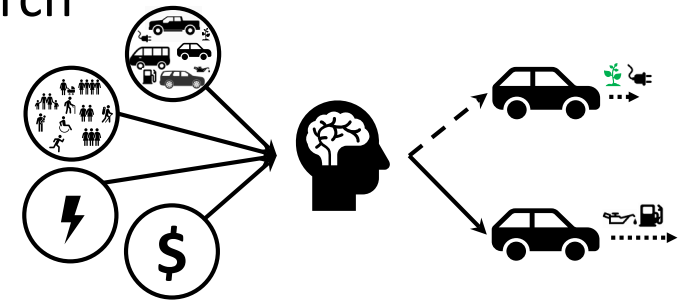
Consumer Acceptance of Electric Vehicles

Dana Jackman

What is involved in electric vehicle (EV) adoption?

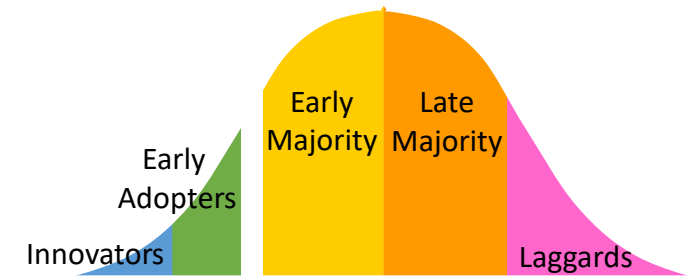
Outline of EPA research approach for light duty

- Categories of obstacles for consumers according to existing research
 - Awareness and acceptance of EVs and EV technology
 - Confidence in and access to charging & infrastructure
 - Complexity, transparency, and magnitude of prices, costs, & incentives
 - Availability and sales practices
- Re-framing analyses in the context of a purchase process
 - Employing three robust frameworks from marketing, psychology, and economic literature to clarify objectives and organize analysis
 - Focusing on the mainstream new vehicle buyers
 - Identifying ways to bridge the gaps between awareness, acceptance, and adoption
 - Taking holistic view of the purchase process, one that is cyclical and in which every potential buyer is always at some stage in the purchase process
- Commenced a research program with the objectives of understanding new vehicle buyers and identifying opportunities
 - Conducting market segmentation of new vehicle buyers using latent class analysis



What is involved in EV adoption?

Three robust frameworks for analysis



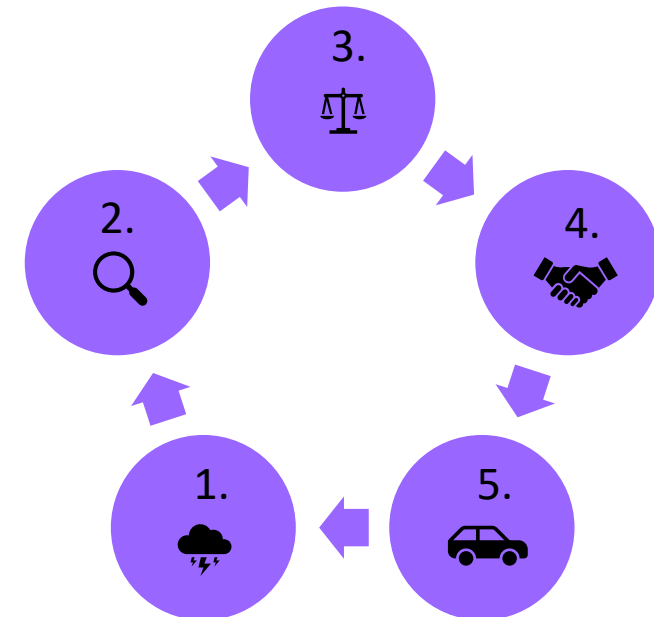
Modified from Rogers, E. M. (2003).
Diffusion of Innovations.

- Population of interest: Mainstream (early and late majority) new vehicle buyers
- Objective: Identify way to close the gaps between awareness, acceptance, and adoption
 - We can measure awareness, acceptance, and adoption;
 - We also want to be able to understand and support the transitions



Analogous to Ajzen, I. (2018). Theory of Planned Behavior

- Approach: Holistic analysis of the vehicle purchase process
 - Consumer decision process model/Vehicle purchase decision process
 - 5 stages
 1. Problem recognition
 2. Search
 3. Alternative evaluation
 4. Purchase
 5. Post-Purchase experience
 - Internal and external factors that influence buyers

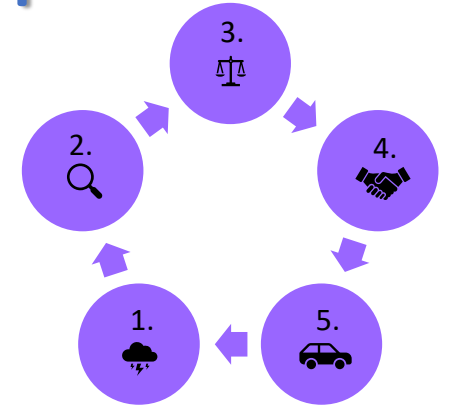


Modified from Taylor, M. and S. Fujita (2018).
Consumer Behavior and the Plug-In Electric
Vehicle Purchase Decision Process.

Understanding Consumers & Identifying Opportunities

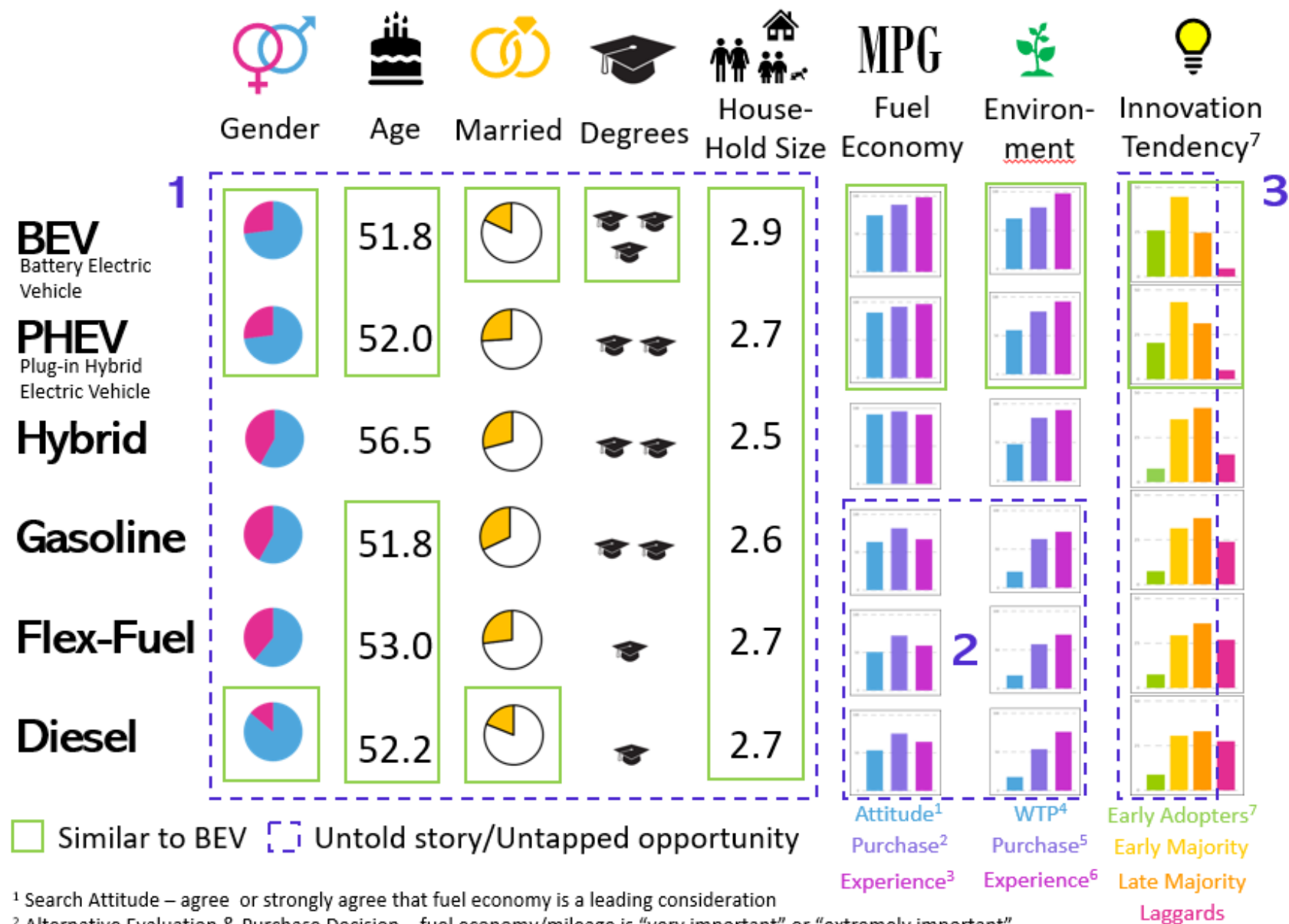
Market Segmentation by Purchase Stage

- Data – Strategic Vision’s New Vehicle Experience Survey (NVES)
 - Survey organized similarly to the multi-stage consumer decision process
 - 1,000+ variables including
 - Vehicle attributes
 - Consumer evaluation of vehicle attributes and new vehicle experience
 - Demographics, psychographics (e.g., attitudes, opinions), and emographics (e.g., self perception, emotional delivery, feelings)
 - 250,000+ new car buyers per year surveyed about their vehicle purchase experience within first 6 months of ownership
 - Calendar years 2014, 2015, and 2016
- Methods – Descriptive Statistics & Latent Class Analysis (LCA) for each purchase stage
 - LCA identifies hidden subgroups and predicts memberships in those subgroups
 - We are conducting multiple LCA for each stage in the purchase process, as well as
 - For all years and by year
 - With all new vehicle buyers and by fuel type
 - With and without covariates such as attitudes (i.e., internal factors) and geography (i.e., external factors)
 - Flow of individuals through the purchase stages



Descriptive Statistics

- Demographically, consumers differ by fuel type, but, arguably, not in policy relevant ways
- Fuel economy & environmental friendliness among gasoline, flex-fuel, and diesel buyers:
 - There appears to be an unmet desire for fuel economy based on the dip in the post-purchase rating of fuel economy compared to search and purchase ratings
 - Many consumers appear to want and enjoy the environmental friendliness of their vehicle even though they report low willingness-to-pay (WTP)
- Mainstream buyers are present in every segment as are innovative/early adopter type buyers.
 - Mainstream consumers buy EVs
 - Innovator and early adopter type consumers buy conventional vehicles



¹ Search Attitude – agree or strongly agree that fuel economy is a leading consideration

² Alternative Evaluation & Purchase Decision – fuel economy/mileage is “very important” or “extremely important”

³ Post Purchase Experience – experience with their new vehicle’s fuel efficiency is “excellent,” “delightful,” or “love it”

⁴ Willingness to Pay (WTP) during Search – agree or strongly agree that they would pay more for an environmentally friendly vehicle

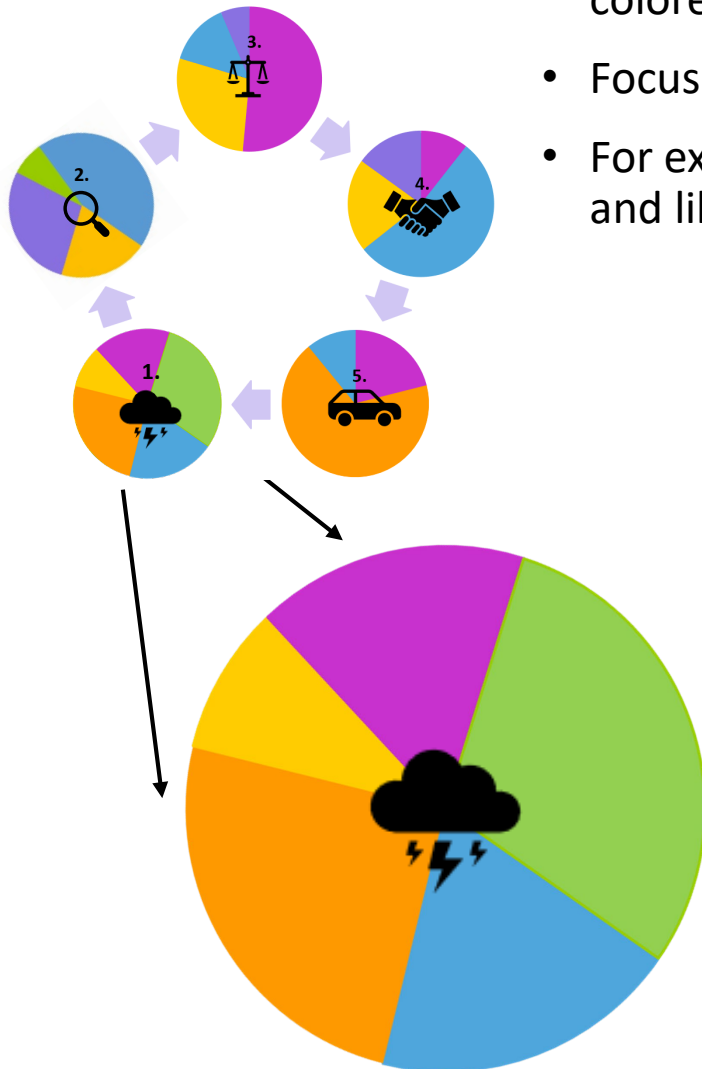
⁵ Alternative Evaluation & Purchase Decision – environmental friendliness is “very important” or “extremely important”

⁶ Post Purchase Experience – environmental friendliness of their new vehicle is “excellent,” “delightful” or “love it”

⁷ Search Attitudes – self-identify as early adopters, early majority, late majority, and laggards

Preliminary & Selected LCA Results for 2016

- There is significant heterogeneity among new vehicle buyers, illustrated by different colored slices for different subgroups within each stage in the purchase decision process
- Focusing on problem recognition, we identified 5 latent classes (“hidden subgroups”)
- For example and preliminarily, we find that 30% of consumers buy due to vehicle failure and likely make purchases in short time frames

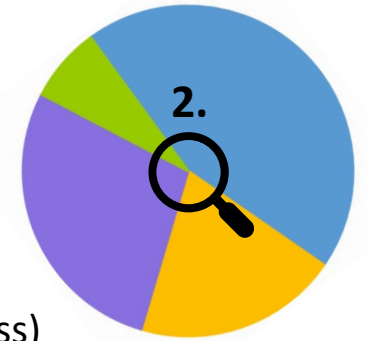


PROBLEM RECOGNITION - 2016
(Proportion Belonging to the Latent class)
Probability of Endorsing an Item Given Latent Class

SURVEY ITEM	LATENT CLASS				
	Regulars (19%)	Prag- matists (25%)	Lease (9%)	Oppor- tunists (17%)	Vehicle Failure (30%)
Vehicle did not fit needs	0.15	0.41	0.05	0.36	0.16
Vehicle was old/needed repairs	0.01	0.12	0.00	0.28	0.42
Prices/rebates were appealing	0.19	0.23	0.17	0.55	0.21
I get a new vehicle regularly	0.34	0.04	0.16	0.11	0.01
Current rates were appealing	0.10	0.17	0.21	0.41	0.15
Lease expired/expiring	0.04	0.02	1.00	0.06	0.00
New model caught my attention	0.29	0.08	0.09	0.50	0.07

Commonality across market segments

Search – Preliminary selected results



SEARCH - 2016

(Proportion Belonging to the Latent class)

Probability of Endorsing an Item Given Latent Class

- Individuals differentiate themselves according to the “touch points” or sources consulted in their search

- Despite notable heterogeneity, we also see commonalities

- Dealership websites play an important role in vehicle search
- Vehicle search is social

SURVEY ITEM	LATENT CLASS			
	Dealer Dominated (45%)	Dealer + Third Party (20%)	Social (28%)	Mainstream Media (7%)
Dealership's website(s)	0.43	0.56	0.22	0.51
Consumer Reports	0.23	0.68	0.16	0.47
Social media	0.04	0.14	0.05	0.27
Edmunds	0.10	0.56	0.01	0.12
TrueCar	0.19	0.50	0.05	0.14
Radio	0.01	0.00	0.01	0.18
Television	0.05	0.05	0.08	0.59
Magazines	0.02	0.09	0.01	0.42
Newspapers	0.01	0.01	0.02	0.25
Brochures	0.04	0.12	0.03	0.32
Word of mouth	0.00	0.19	0.34	0.40
Family / Friends	0.03	0.29	0.47	0.41

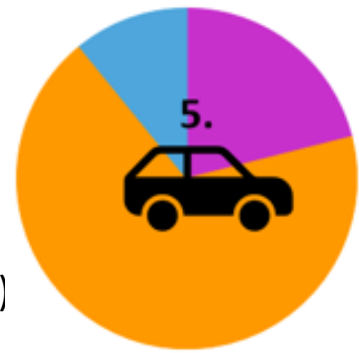
Commonality across purchase stages

Post Purchase – Preliminary selected results

POST PURCHASE - 2016

(Proportion Belonging to the Latent class)

Probability of Endorsing an Item Given Latent



1. Post-purchase, individuals distinguish themselves by
 - Enthusiasm for most, many, or few vehicle attributes
 - Likelihood of problems experienced
2. Image is very often rated as excellent, delightful, or “I love it” by individuals who are generally happy with their new vehicle

SURVEY ITEM	LATENT CLASS		
	"In Love" (65%)	Mixed/ Satisfied (23%)	Not Satisfied (12%)
Overall exterior styling	0.99	0.85	0.37
Overall driving performance	0.99	0.84	0.33
Power and pickup	0.94	0.64	0.23
Interior design	0.99	0.74	0.10
Durability/reliability	1.00	0.80	0.14
Thoughtful engineering	0.99	0.72	0.06
Safety of the vehicle	1.00	0.85	0.18
Environmental friendliness	0.92	0.52	0.08
Value for the money	0.92	0.52	0.14
Brand image	0.99	0.78	0.22
Image of the vehicle	0.99	0.83	0.22
Problems with your new vehicle?	0.17	0.29	0.34

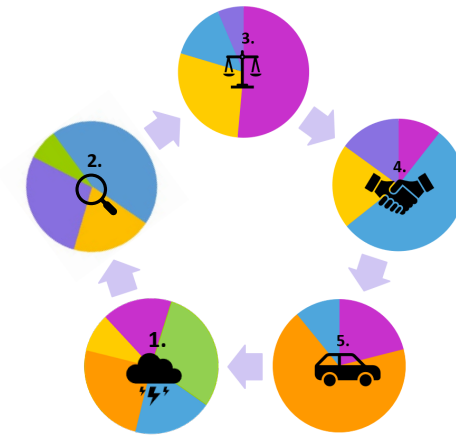
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Preliminary High Level Takeaways

Based on descriptive statistics and preliminary LCA

- New car buyers are ...
 - Heterogeneous, segmenting into different groups at every stage of the purchase process
 - Simple demographics tell an overly simplistic story
- The purchase process is fundamentally social
- Dealership play an important role
- Fuel economy and environmental friendliness factor into some stage of the purchase process for most buyers
 - Appears to be some unmet post-purchase desire for fuel economy
 - Consumers enjoy environmental friendliness even when environmental friendliness did not motivate the purchase
- Mainstream and so called “innovators” and “early adopters” are present in every vehicle segment
 - Self-identified mainstream consumers buy electric vehicles
 - Self-identified innovators and early adopters buy conventional vehicles



On the Horizon

Understanding Mobility Markets and Market Actors

- Vehicle purchase process and heterogeneity among new car buyers
- Adoption and use of vehicles, vehicle technologies, and mobility technologies and services
- Interaction of traditional modes of personal transportation (e.g., personal vehicles, transit) and emerging modes (e.g., micro-mobility, micro-transit, ride-hailing)
- Diffusion of mobility innovations (e.g., vehicle technologies, services, business models) across heterogeneous mobility markets
- Producer side market failures