Searching for Hidden Costs: A Technology-Based Approach to the Energy Efficiency Gap in Light-Duty Vehicles

Gloria Helfand,* Kevin Bolon,* Jean-Marie Revelt,* Michael McWilliams,** Lawrence Reichle,** Mandy Sha,*** Amanda Smith,*** and Robert Beach***

*U.S. Environmental Protection Agency

**Oak Ridge Institute for Science and Education (ORISE) Participant

**RTI International

Do GHG-reducing/fuel-saving technologies have undesirable effects on vehicle characteristics?

- This Talk
  - Policy Context
  - Content Analysis
  - Results to Date
  - Summary/Conclusion

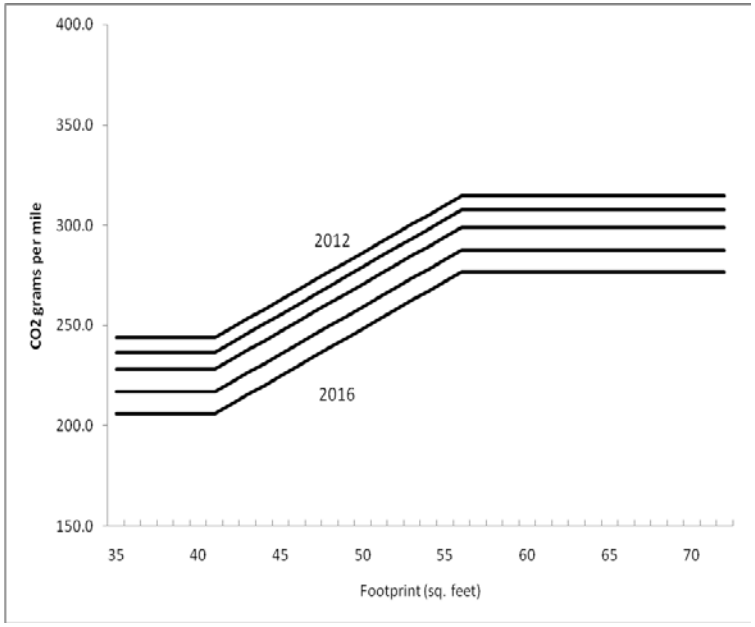
Policy Context: EPA/NHTSA's Light Duty Greenhouse Gas-Fuel Economy Standards

- EPA has the responsibility to regulate air pollutants
  - *Massachusetts v. EPA* concluded that EPA could regulate GHG under the Clean Air Act
- National Highway Traffic Safety Administration (NHTSA, Dept. of Transportation) has the responsibility to regulate fuel economy of vehicles
- The primary way to reduce GHG emissions from vehicles is to improve fuel economy
- The rules are increasing fuel economy & reducing GHG emissions from MY 2012-2025 vehicles
  - MY 2012-16 standards issued in 2010
  - MY 2017-2025 standards issued in 2012
  - http://www.epa.gov/otaq/climate/regs-light-duty.htm

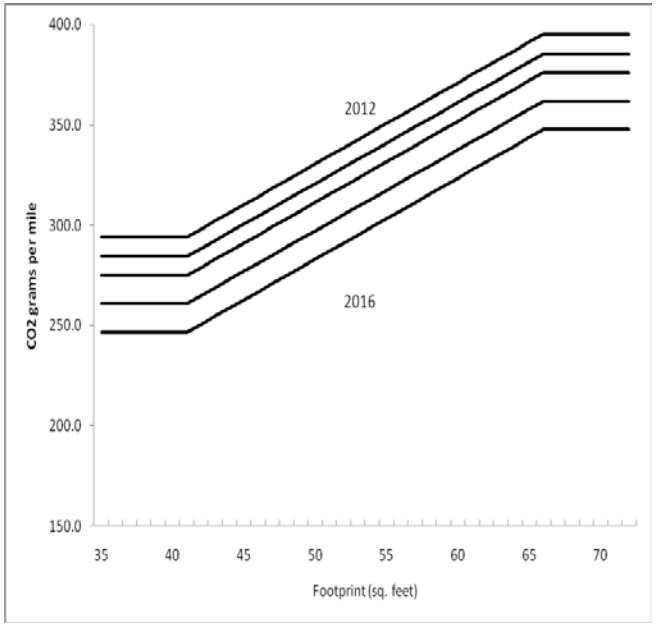
MY 2012-16 EPA Standards

Footprint standard in CO_2 (g/mi) space

Car



Truck



Source: Federal Register 75(88) (May 7, 2010): 25334-7

Benefits predicted greatly to exceed costs, with largest benefits from fuel savings (MY 2012-16 standards; Millions of 2007 dollars)

	2020	2030	2040	2050	NPV, 3%	NPV, 7%
Vehicle Compliance Costs	$15,600	$15,800	$17,400	$19,000	$345,900	$191,900
Fuel Savings	$35,700	$79,800	$119,300	$171,200	$1,545,600	$672,600
Reduced CO_2 Emissions at each assumed SCC value						
Avg SCC at 5%	$900	$2,700	$4,600	$7,200	$34,500	$34,500
Avg SCC at 3%	$3,700	$8,900	$14,000	$21,000	$176,700	$176,700
Avg SCC at 2.5%	$5,800	$14,000	$21,000	$30,000	$299,600	$299,600
95th percentile SCC@3%	$11,000	$27,000	$43,000	$62,000	$538,500	$538,500
Criteria Pollutant Benefits	na	$1,200-1,300	$1,200-1,300	$1,200-$1,300	$21,000	$14,000
Energy Security Impacts (price shock)	$2,200	$4,500	$6,000	$7,600	$81,900	$36,900
Reduced Refueling	$2,400	$4,800	$6,300	$8,000	$87,900	$40,100
Value of Increased Driving	$4,200	$8,800	$13,000	$18,400	$171,500	$75,500
Accidents, Noise, Congestion	$2,300	$4,600	$6,100	$7,800	$84,800	$38,600
Quantified Net Benefits at each assumed SCC value						
Avg SCC at 5%	**$27,500**	**$81,500**	**$127,000**	**$186,900**	**$1,511,700**	**$643,100**
Avg SCC at 3%	**$30,300**	**$87,700**	**$136,400**	**$200,700**	**$1,653,900**	**$785,300**
Avg SCC at 2.5%	**$32,400**	**$92,800**	**$143,400**	**$209,700**	**$1,776,800**	**$908,200**
95th percentile SCC at 3%	**$37,600**	**$105,800**	**$165,400**	**$241,700**	**$2,015,700**	**$1,147,100**

"Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards: Regulatory Impact Analysis." US EPA, EPA-420-R-10-009, April 2010, Chapter 8.4

Is there an energy paradox/efficiency gap in the LD vehicle market?

- The efficiency gap: for various technologies,

PV(Fuel savings) – Technology costs – "Hidden Costs" > 0?

  - Hidden costs: undesirable impacts of the new technologies
  - I.e., is it possible that private markets are not providing all the GHG/fuel-saving technology that pays for itself?
  - I.e., Is it possible to save people money without harming cars?
- The standards are in effect now
  - We can look at costs, effectiveness, hidden costs
- This study focuses on whether there are hidden costs of the technologies

Method: Content Analysis of Auto Reviews

- A method to analyze written material in order to make systematic, repeatable, and measurable inferences from texts
- It commonly involves
  - Searching for key words or ideas and coding them
    - e.g., mention of 6-speed transmissions
  - Making inferences about their meanings in context
    - e.g., are there problems with the transmission
  - Conducting quantitative analysis of the data
    - e.g., are 6-speed transmissions generally evaluated positively or negatively?

- We used auto reviews 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

Websites used

- Selected based on
  - Professional reviews with test drive
  - Number of views of the websites

Website	Review Counts
automobilemag.com	144
autotrader.com	225
caranddriver.com	218
consumerreports.org	88
edmunds.com	112
motortrend.com	221
Total	1008

Codes: Efficiency technologies

- Engine
  - Cylinder deactivation
  - Diesel
  - Electronic power steering
  - Full electric
  - Gasoline Direct Injection
  - Hybrid
  - Plug-in hybrid electric
  - Stop-start
  - Turbocharged
  - General Engine
- General Powertrain
- Transmission
  - Continuously Variable Transmission
  - Dual-Clutch Transmission
  - High speed automatic transmission
  - General Transmission
- Active air dam
- Active grill shutters
- Active ride height
- Electric assist or low drag brakes
- Lighting-LED
- Low rolling resistance tires
- Mass reduction
- Passive aerodynamics

Codes: Operational characteristics

- Driveability
  - Handling
    - Steering feel/ Controllability/ Responsiveness
    - General Drivability
    - General handling
  - Acceleration
    - Acceleration feel/ Smoothness/ Responsiveness
    - Acceleration capability/ Power/Torque
    - General acceleration
  - Braking
    - Brake feel/Responsiveness
    - Stopping ability
    - General Braking
- Noise
  - Tire/Road
  - Wind
  - Interior
  - Powertrain
  - General noise
- Vibration
  - Chassis
  - Powertrain
  - General vibration
- Ride comfort
- Fuel economy
- Range
- Charging

Coding

- "We like the effortless power and the smooth transmission, but the auto start/stop system has more delay than some, the throttle can be a bit on the jumpy side and the light steering is disconcerting. "
  - Positive for high-speed automatic [transmission type noted elsewhere]
  - Negative for stop/start
  - Positive for acceleration capability
  - Negative for steering feel-controllability-responsiveness

Technologies

Operational Characteristics

- Multiple coders, with testing for replicability

The Data

- MY 2014 light-duty vehicles
- 1008 reviews (less 5 VW/Audi diesel)
- 16,158 codes
  - 3575 (about 22%) of the codes are about fuel-saving technologies
  - The remainder are about operational characteristics
- Results at the level of the codes include all mentions of each technology
  - E.g., 2 negative codes for EPS = 2 negative codes for EPS
- Results at the level of the reviews aggregate all mentions of a technology with multiple codes and the same evaluation to one
  - E.g., 2 negative codes for EPS = 1 review-level negative code
  - E.g., 2 negative codes and 1 positive code for EPS = 1 review-level negative code and 1 review-level positive code
- Because results are very similar, we present results from review-level data

Auto reviews by make

Make	In Data	Market Share	Model share	Make	In Data	Market Share	Model Share	Make	In Data	Market Share	Model Share
Chevrolet	8.0%	12.2%	6.0%	Honda	3.0%	8.4%	2.0%	Land Rover	1.0%	0.3%	1.0%
Mercedes	7.0%	2.2%	7.0%	Porsche	3.0%	0.3%	4.0%	Bentley	1.0%		1.0%
BMW	7.0%	2.1%	8.0%	Jaguar	3.0%	0.1%	2.0%	Mini Cooper	1.0%	0.4%	4.0%
Toyota	6.0%	12.2%	5.0%	Buick	3.0%	1.3%	1.0%	Rolls Royce	1.0%		1.0%
Mazda	5.0%	1.9%	2.0%	Infiniti	2.0%	0.8%	2.0%	Fiat	1.0%	0.3%	1.0%
Ford	5.0%	14.9%	7.0%	Subaru	2.0%	3.0%	2.0%	Ferrari	1.0%		1.0%
Kia	4.0%	3.5%	3.0%	Acura	2.0%	1.0%	1.0%	Ram	1.0%	2.6%	1.0%
Jeep	4.0%	3.9%	3.0%	Dodge	2.0%	3.6%	3.0%	Lincoln	1.0%	0.6%	1.0%
Nissan	4.0%	7.6%	4.0%	Lexus	2.0%	1.9%	2.0%	Volvo	0.5%	0.3%	1.0%
Audi	4.0%	1.1%	4.0%	Hyundai	2.0%	4.5%	3.0%	Chrysler	0.4%	1.8%	1.0%
Volkswagen	4.0%	2.3%	4.0%	GMC	2.0%	2.9%	3.0%	Scion	0.4%	0.4%	1.0%
Cadillac	4.0%	1.1%	3.0%	Mitsubishi	2.0%	0.5%	2.0%	Smart	0.1%	0.1%	0.3%

Reviews are not conducted in proportion to sales, but are roughly proportional to models available by make

Market share data are Ward's sales figures for Sept. 2013 – Aug. 2014. Bentley, Rolls Royce, & Ferrari were not in those data. Model share data are from fueleconomy.gov.

Efficiency Technology Totals (Review Level)

Assessment	Total	Percent	Total, Excluding "General"	Percent, Excluding "General"
Positive	1681	68%	1047	68%
Neutral	399	16%	256	17%
Negative	388	16%	242	16%
Total	2468	100%	1545	100%

More than 4 out of 5 comments about the technologies at the level of auto review were favorable or neutral.

Very similar results at code level

Technology results (review level)

- For all technologies, positive ratings exceeded negative ratings
  - Most positively reviewed technologies by percentage

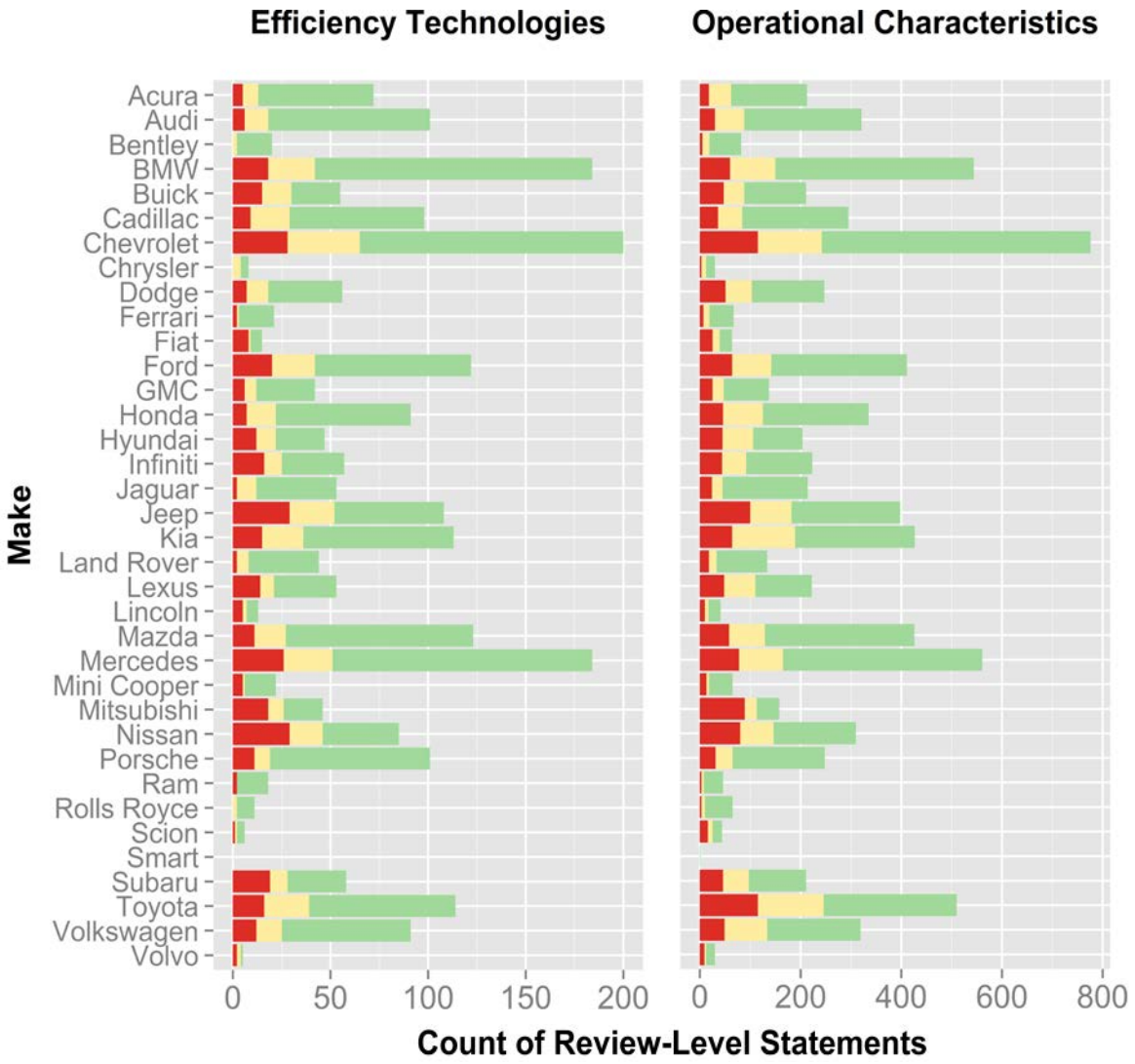
Active air dam	100% of 6 reviews
Active grill shutters	100% of 1 review
Mass reduction	88% of 76 reviews
Cylinder deactivation	86% of 35 reviews
LED lights	85% of 20 reviews
GDI	82% of 66 reviews
Turbocharging	81% of 225 reviews

Very similar results at code level

  - Most negatively reviewed technologies by percentage:
  - The most negative are still reviewed positively more than negatively

CVT	32% of 114 reviews
Stop-start	29% of 52 reviews
Low rolling resistance tires	24% of 17 reviews
DCT	23% of 70 reviews
Hybrid	23% of 71 reviews
Electronic power steering	22% of 210 reviews

Results by Make



Variation in % negative ratings for both tech, char. from 0 to ~55%

80% Correlation between % negative reviews of technologies and % negative reviews of characteristic

Do the technologies affect the quality of operational characteristics?

- Linear probability model to estimate the effects of each coded efficiency technology on the probability of a negative review for each operational characteristic *j*.

$$P\left(NegOpChar_{i,j}\right) = \sum_{k} \beta_k \, 1\left(ReviewTech_{i,k}\right) + m_i + w_i + c_i + \epsilon_{i,j}$$

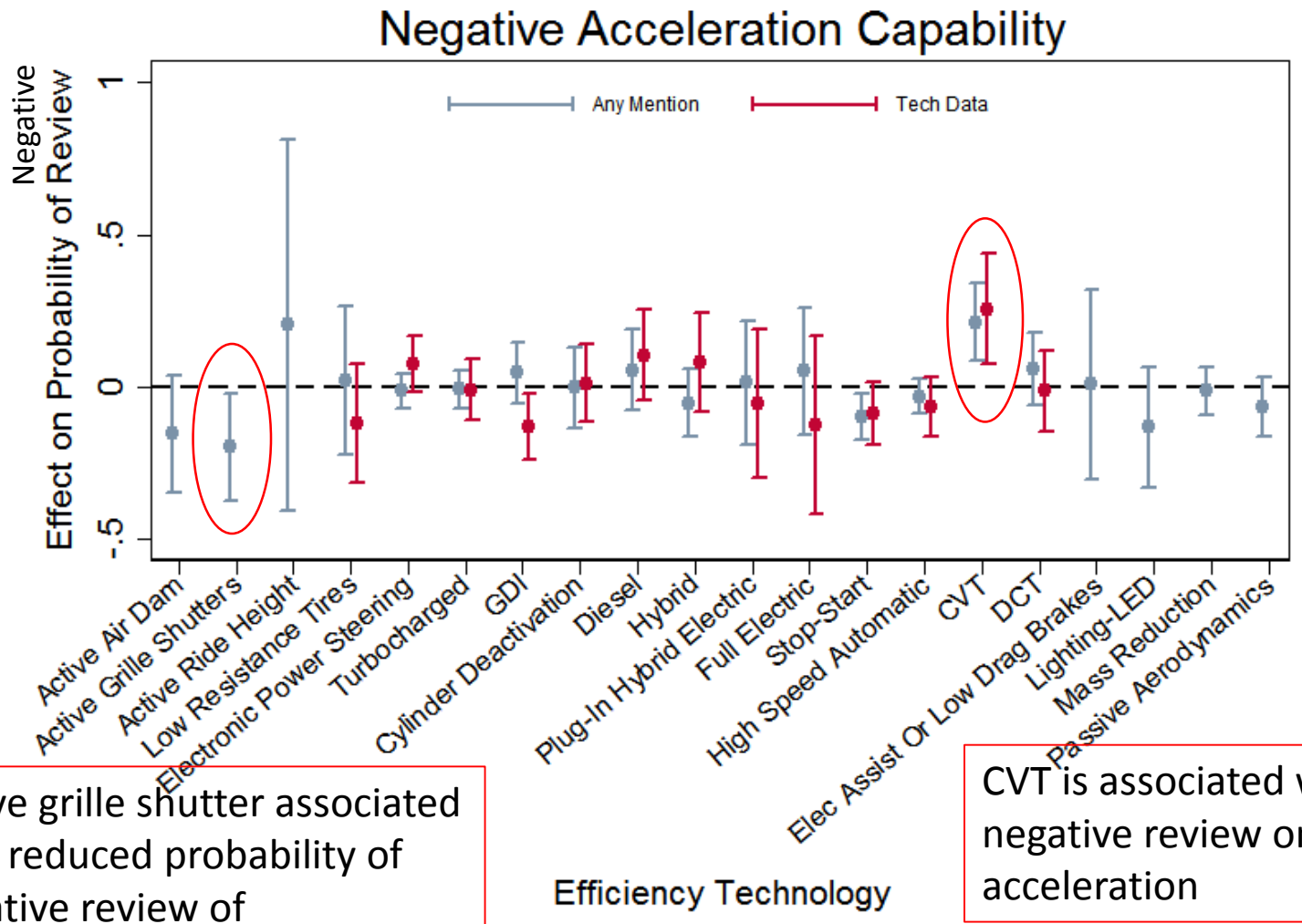
m_i - Vehicle Make Fixed Effects
c_i - Vehicle Class Fixed Effects
w_i - Website Fixed Effects

- 6 total specifications

	Tech mentioned in review	Vehicle linked to tech data (71% match)	Vehicle linked to tech data + addit. tech fixed effects
One tech included			
All techs included	X	X	

X: in example slide that follows

Effects on Acceleration Capability



Active grille shutter associated with reduced probability of negative review of acceleration

CVT is associated with negative review on acceleration

Results: Existence of tech

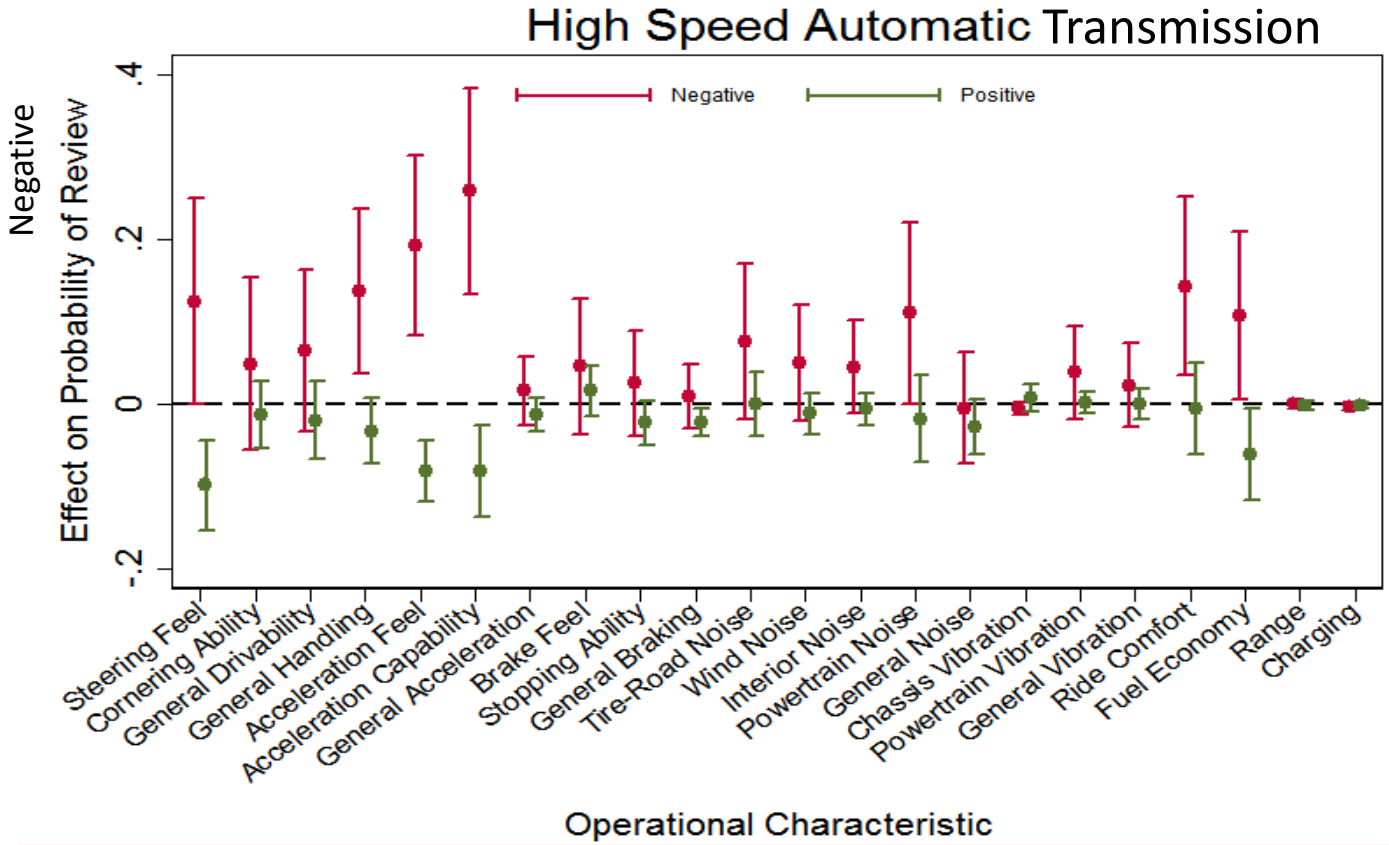
CVT assoc. with acceleration capability

Number of Significant Estimates across specifications	1	2	3	4	5	6
Positive Correlations with Negative Effects	37	21	12	7	2	1
Negative Correlations with Negative Effects	108	71	24	17	4	1
Mixed Correlations	1	1	0	0	0	0
Total	146	93	36	24	6	2

Diesel assoc. with general driveability

- Out of 440 technology-characteristic combinations, a minority show any evidence of a relationship
- Technologies' presence *reduces* the likelihood of negative operational characteristics (negative) in more cases than it *increases* that likelihood (positive).
- The results are not very robust to specification
- Correlation; we haven't demonstrated causality

Does tech implementation affect operational characteristics? – High speed automatic transmission



Perhaps how the high-speed automatic transmission is implemented is associated with the quality of operational characteristics?

Relationship of Rating of Technologies with Neg. Operational Characteristics

	All Mentions	Negative Tech	Neutral Tech	Positive Tech
Active Air Dam				
Active Grille Shutters				
Active Ride Height				
Low Resistance Tires	1	2		
Electronic Power Steering	1	1		
Turbocharged		2		
GDI		1		
Cylinder Deactivation		2	1	
Diesel		2		
Hybrid		3		
Plug-In Hybrid Electric	1			1
Full Electric		1		
Stop-Start				
High Speed Automatic Transm		7		
CVT	4	7		
DCT		1		
Elec Assist Or Low Drag Brakes		3		
Lighting-LED		2		
Mass Reduction			1	
Passive Aerodynamics		1		

The problem may not be the presence of the tech, but rather poor implementation of the tech

Some limitations of this work

- Vehicles reviewed are proportional to models offered by make, not proportional to vehicles sold
  - Results may not be proportional to consumers' experiences
  - The technologies are of primary interest, and all are covered
- There is some inherent subjectivity in the coding
  - We believe, though, that auto reviewers are not trying to trick anyone in their evaluations of the technologies
- How reviewers evaluate vehicles may not correspond to how vehicle owners respond to the technologies
  - We suspect that auto reviewers are generally harder to please, and more likely to notice, than the general public
  - Vehicle owners will spend more time with their autos than reviewers
- The reviews will not capture longer-term issues, such as reliability or maintenance

Summary

- Content analysis of professional auto reviews for MY 2014 vehicles does not provide evidence of any systematic hidden costs associated with fuel-saving technologies
  - For all technologies, positive/neutral reviews exceed negative reviews
  - Positive/neutral reviews outnumber negative reviews, on average, 4+:1.
  - Any problems may be due to (temporary?) implementation rather than an inherent feature of the technology
- We don't find evidence that hidden costs provide an explanation of the energy paradox for MY 2014 light-duty vehicles