How Much Do Consumers Value Fuel Economy and Performance? Evidence from Technology Adoption

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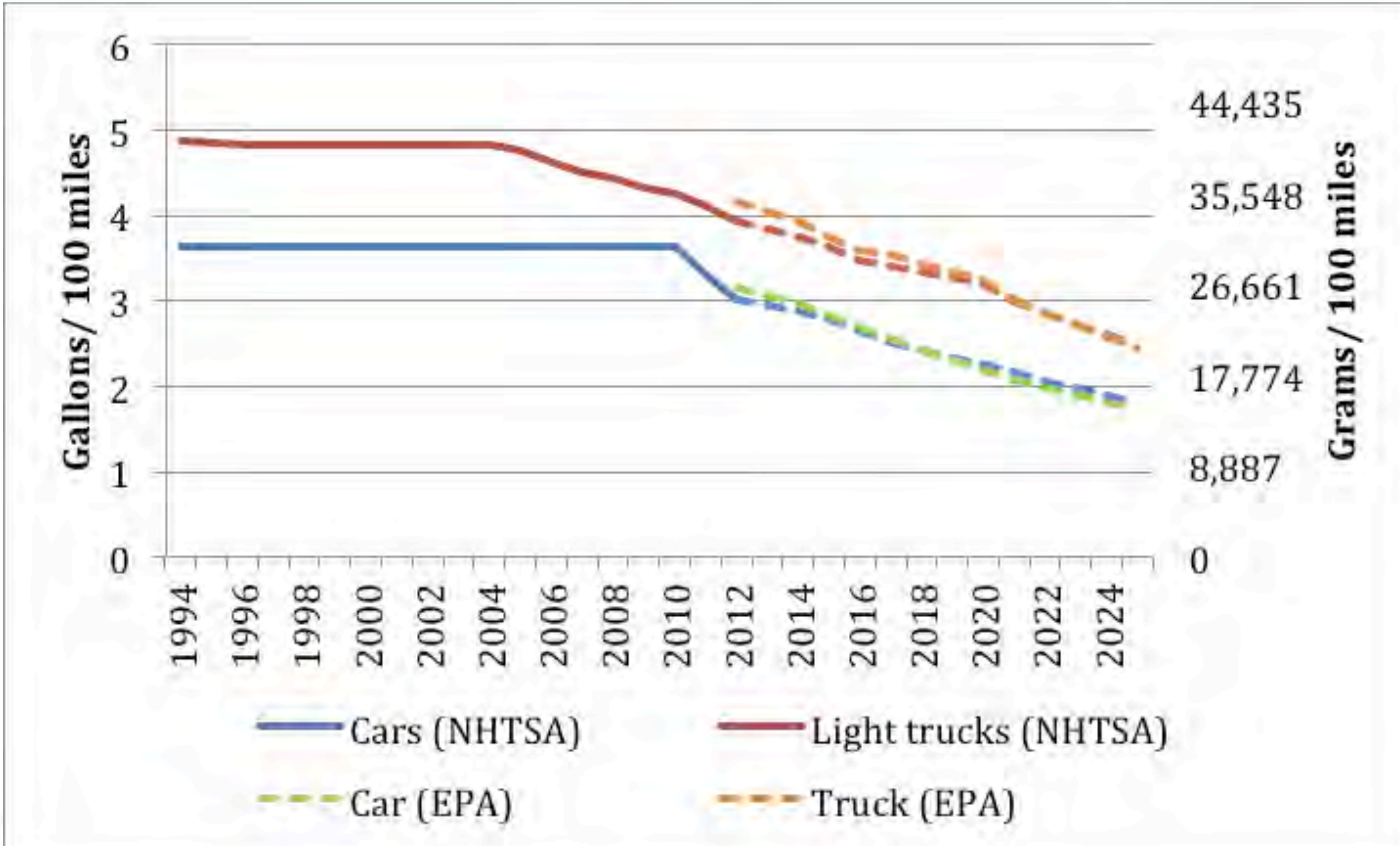
RESOURCES FOR THE FUTURE

Fuel economy and greenhouse gas standards, historical and projected



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Fuel cost savings account for most of the estimated benefits of the standards

Policy rationale for the standards: correcting market failures

- Reduce oil consumption (NHTSA)
- Reduce greenhouse gas emissions (EPA)

(Private) value of fuel savings outweighs the costs

- In EPA and NHTSA analysis, benefits include carbon dioxide reductions, fuel savings and other factors
- Fuel savings from higher fuel economy account for 70 percent of benefits, and exceed costs by several times (EPA 2010, 2012, and 2016)
- This conclusion rests on a market failure for fuel economy, known as the energy efficiency gap: failure to adopt technologies despite value of fuel savings exceeding costs

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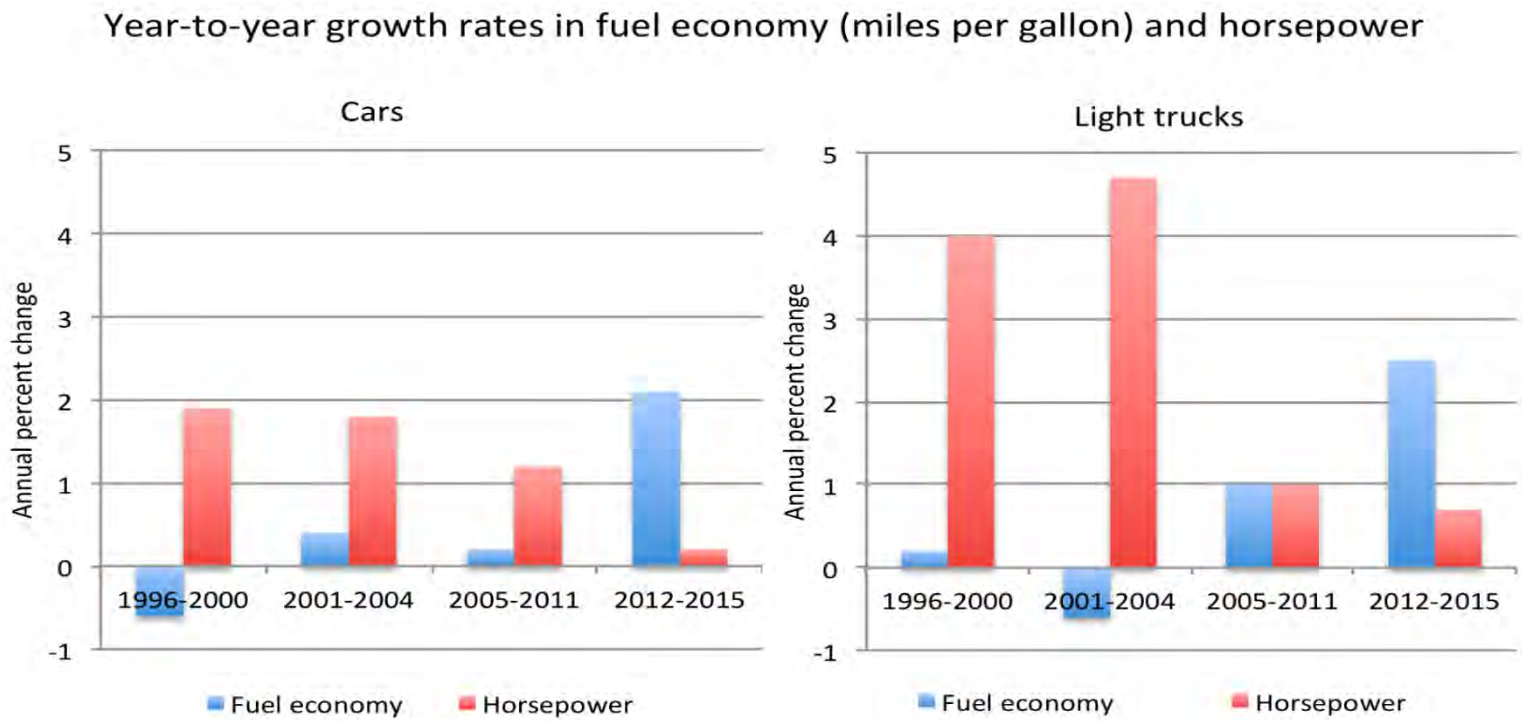
Our paper: Quantify value of foregone performance due to tighteningstandards

Fuel economy performance tradeoff

- A manufacturer can use fuel-saving technology to boost fuel economy or performance (or both)
- Opportunity cost: the foregone consumer valuation of the performance
- Total cost of raising fuel economy includes technology cost (redesign and production costs) and opportunity cost



Prior Methods for Estimating WTP for Performance

2013 Toyota Camry

$24,426 28 mpg 178 hp

2013 Ford F-150

$37,609 18 mpg 365 hp

Prior methods (e.g., BLP 1995, BLP 2004) estimate consumer WTP from differences in attributes across models.

This is problematic because many attributes are unobserved by researchers and are likely correlated with attributes like performance.

Panel Method

Recent economics literature has identified WTP for fuel costs using gasoline price variation over time (Sallee et al. 2016, Allcott and Wozney 2014, Busse et al. 2013).

Since vehicle performance does not change with gasoline prices, we build on these approaches by using engine technology variation over time.

2013 Honda Civic EX-L

$20,389   31.5 mpg   140 hp

2014 Honda Civic EX-L

$21,381   32.3 mpg   143 hp

The 2014 version has a continuously variable transmission installed.

We account for other possible changes by
1) using engine technologies as instruments and
2) including controls for household demographics and stated preferences.

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Data

MaritzCX

- MaritzCX survey of recent new vehicle buyers, Q42009-Q32014
- Final sample includes about 535,000 observations over five years, equally split between cars and light trucks
- Use the reported transaction price and the vehicle identification number (VIN) to obtain characteristics such as torque and weight from Chrome

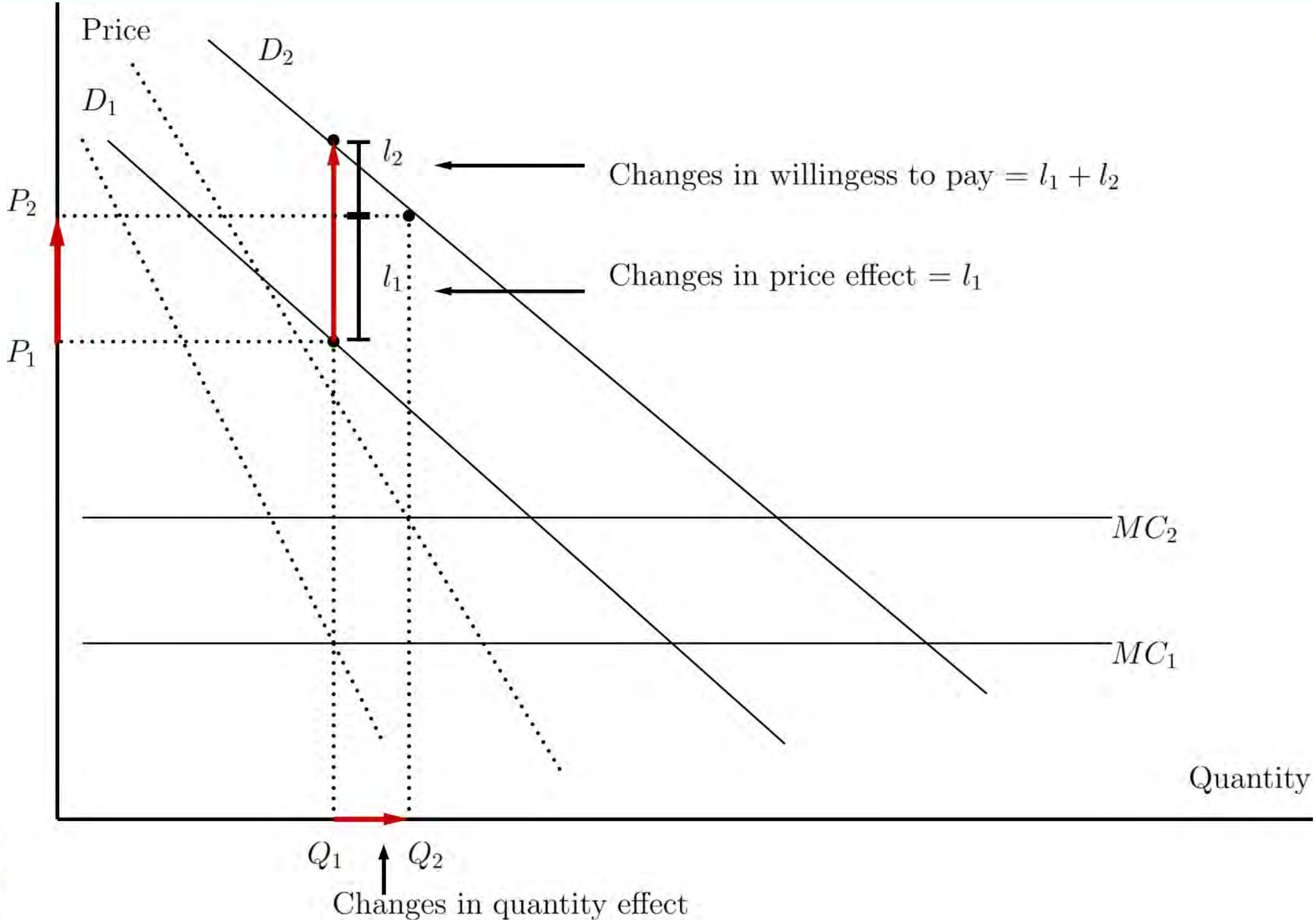
EPA

- Fuel economy and indicator variables for fuel-saving technologies (e.g., cylinder deactivation) from fueleconomy.gov
- Merge data to Maritz/Chrome by stub (year, model, trim, fuel type, drive type, engine displacement, cylinders)

IHS, EIA

- To account for variation in survey response rates across vehicles, weight observations by new vehicle registrations by stub, body type, and quarter
- EIA: monthly gasoline and diesel prices by PADD

Estimation framework



Results

Willingness to pay for fuel cost savings

- Estimates imply that consumers pay $131 for a 1 percent fuel cost decrease
- Baseline estimates suggest implicit discount rate of 13 percent, which is consistent with a valuation ratio below one
- Assuming discount rate = average real APR of loans within the sample of 1.3%, the baseline estimate implies a valuation ratio of 54 percent

Willingness to pay for performance

- Consumers pay about $91 for a 1 percent increase in horsepower or torque to weight (i.e., performance)
- Using empirical relationship between horsepower/weight and 0-60 time, this estimate implies willingness to pay of $1,072 for a 1-second decrease (sample mean = 8.1 seconds)

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Applying results to evaluate fuel economy standards

Estimate the costs and benefits of a 1% change in the standards in a single year.

Assumptions:

- Baseline tech adoption is positive and toward increasing performance.
- In response to 1% tightening, manufacturers adopt tech by 0.12 percentage points more than if the standards had not been tightened (Klier and Linn 2016).
- No mix shifting or changes in weight, size, fuel type…
- Tech costs are fully passed on to consumers.
- Change in consumer welfare per vehicle = fuel cost savings – tech costs – WTP for performance*foregone performance

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Evaluating fuel economy standards

- PV fuel cost savings = $249 per vehicle
- Technology costs of 0.12 percentage point increase in fuel economy = $11 per vehicle (EPA 2012)
- Manufacturers attain the remaining 0.88 percentage points by foregoing performance increases.
    - Opportunity cost = $347 per vehicle (based on combining our WTP estimates with Klier and Linn (2016))
- Net cost of $109 per vehicle = 0.4% of mean transaction price
- Caveats: This calculation does not include social benefits, innovation, or other market failures.

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Conclusions and future research

Consumers undervalue fuel economy, with an implied discount rate of about 13 percent. This is consistent with Allcott and Wozney (2014) and our implied discount rate falls within the range found in Busse et al. (2013).

Consumers have high willingness to pay for performance.

Implications

- Consumers pay more for performance than fuel economy.
- Accounting for foregone performance implies standards have approximately zero net effect on private consumer welfare.

Future research

- Does willingness to pay vary across consumers or vehicles?
- What have been the welfare and distributional effects of the 2012-2016 fuel economy/emissions standards?

Thank you!

We address two empirical issues

- Objective: estimate consumer willingness to pay for fuel economy and performance, addressing endogeneity
- Consumer responses to fuel economy rather than fuel prices
  - Recent findings rest on gasoline price-induced consumer substitution and vehicle price and quantity changes
  - But, that isn't the right question; valuation of fuel economy *per se* is directly relevant to benefits of standards

Price Equation

Dependent variable: log transaction price

$$\ln p_{ijt} = \alpha_f \ln fc_{ijt} + \alpha_p \ln perf_{jt} + X_{ijt}\delta + \eta_j + \varepsilon_{ijt}$$

Instrumental variables (IV) strategy: use fuel-saving technologies to instrument for fuel costs and performance

- Stub fixed effects control for time-invariant quality
- First stage: predict fuel costs and performance using variable valve lift and timing, turbocharger, supercharger, gasoline direct injection, cylinder deactivation, continuously variable transmission, and other advanced transmissions

Identifying assumption: instruments are uncorrelated with within-stub quality variation

- Variation in fuel-saving technology adoption: standards tightening 2-3 times faster than historical adoption, combined with staggered vehicle redesign
- Stub fixed effects control for common practice of testing technologies in high-end vehicles.

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Quantity equation

Dependent variable: new registrations by vehicle and quarter

$$\ln q_{jt} = \beta_f \ln fc_{ijt} + \beta_p \ln perf_{jt} + X_{ijt}\gamma + \xi_j + \nu_{ijt}$$

Identification and interpretation of fuel cost and performance coefficients

- Fuel costs and performance are the same as in price equation
- Similar interpretation to price regression, but no predictions on coefficient signs because both marginal costs and demand shift up

Addressing endogeneity

- Similar concerns about endogeneity as for price regression
- Use same fixed effects and instruments

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Key coefficient estimates in quantity regression

Dependent variable: log registrations

	(1)	(2)
Estimated by	OLS	IV
Log fuel cost (dollars per mile)	-0.636 (0.045)	-0.338 (0.116)
Log performance (hp or nm per lb)	-0.030 (0.028)	0.371 (0.083)

Results are robust to including demographics and other proxies for unobserved quality.

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Key coefficient estimates in price regression

Dependent variable: log transaction price

	(1)	(2)
Estimated by	OLS	IV
Log fuel cost (dollars per mile)	-0.156 (0.020)	-0.354 (0.075)
Log performance (hp or nm per lb)	-0.230 (0.020)	0.203 (0.074)

Notes: Standard errors are clustered by model by state. Observations are weighted by national registrations.

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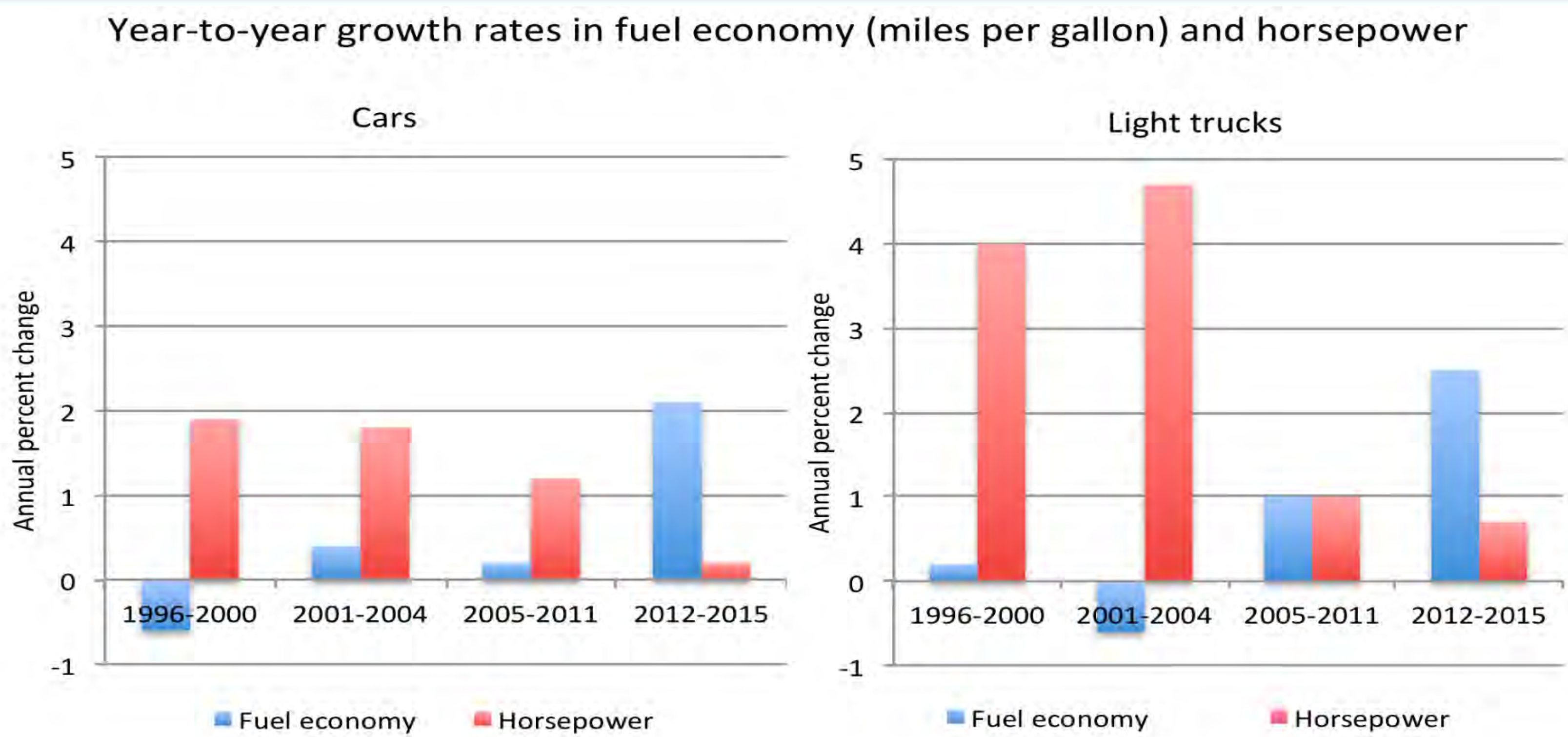
Applying results to evaluate fuel economy standards (1)



- In response to tightening standards, manufacturers forego horsepower improvements to increase fuel economy.

- We combine our results with those from Klier and Linn (2016) to estimate welfare effects.

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Figure 2. Fuel economy, weight, horsepower, and torque

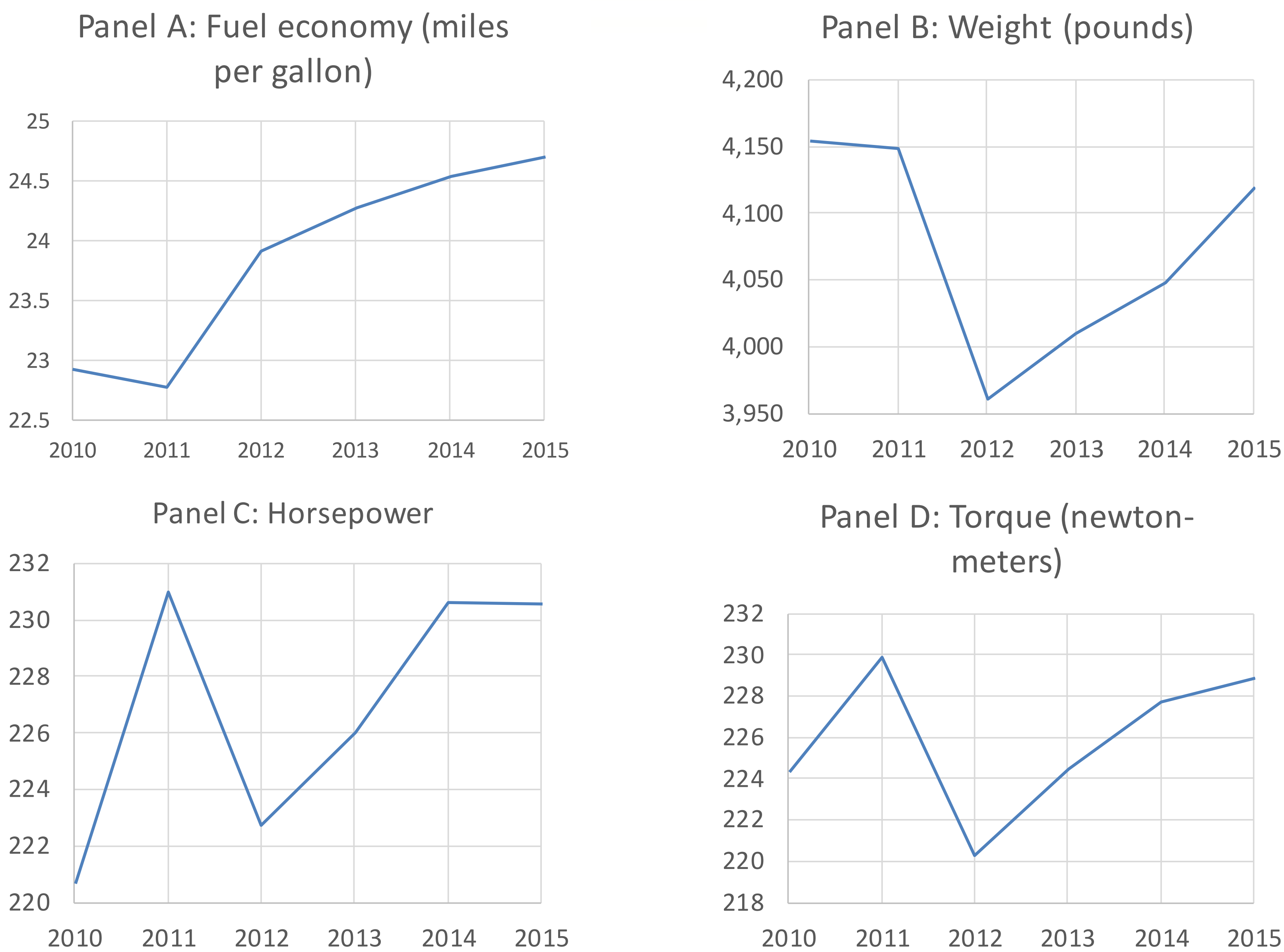


Figure 3. Market shares of selected fuel-saving technologies

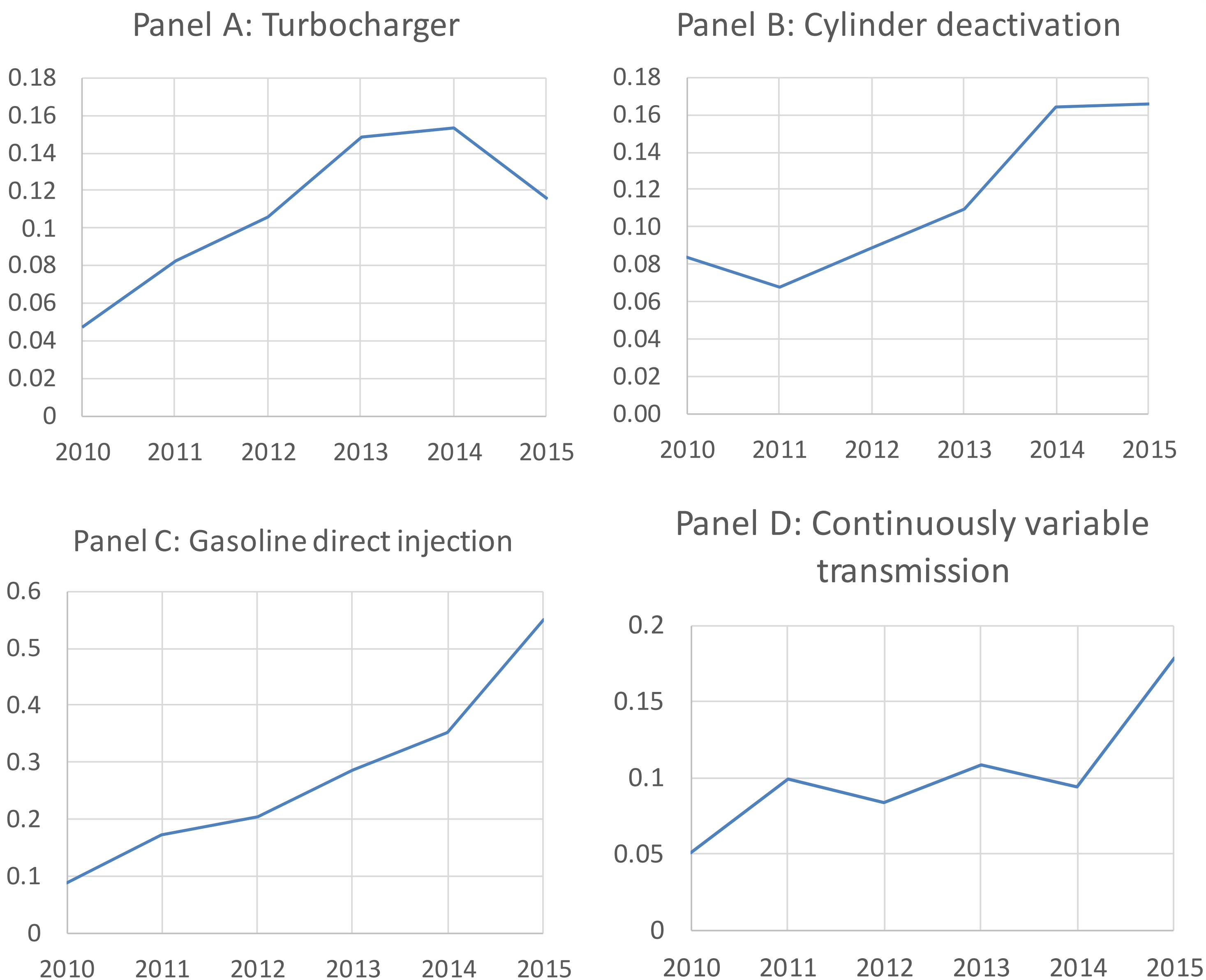
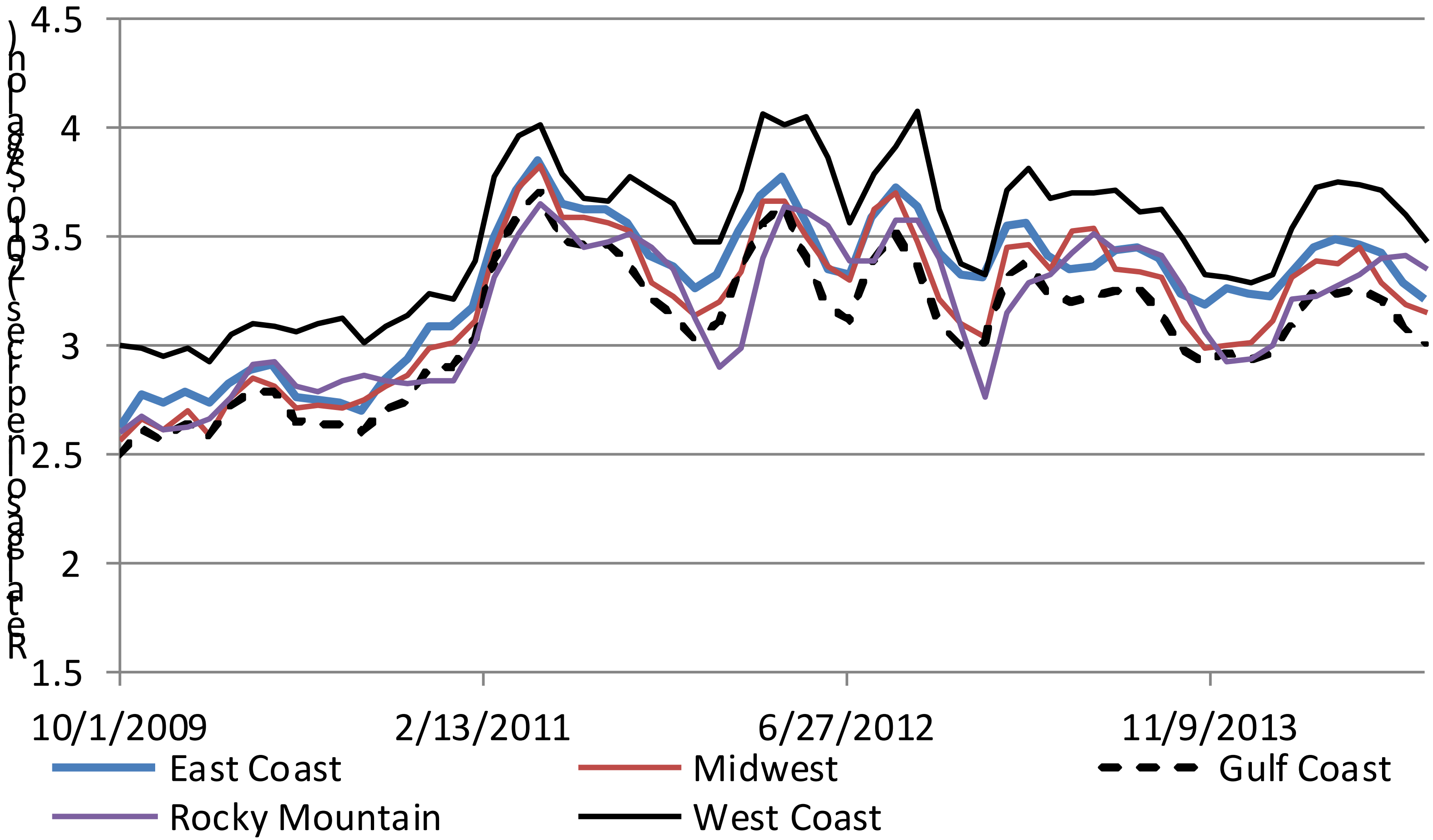


Figure 4. Regional gasoline prices



Methodology

Objective: estimate marginal willingness to pay for fuel economy and performance

- Opportunity costs depend on relative valuation of fuel economy and performance
- Literature has yielded a huge range of estimated willingness to pay for these attributes (Whitefoot and Skerlos 2012 and Greene et al. 2016)

Framework

- Define willingness to pay for fuel economy (or performance) as vertical shift in demand curve caused by an increase in the attribute
- Similar to Busse et al. (2013), estimate separate price and quantity regressions, combining results to derive willingness to pay

Literature on energy efficiency gap

Technology literature suggests an energy efficiency gap

- National Academy of Sciences (e.g., NAS 2015): for many fuel-saving technologies, value of fuel savings exceeds costs
- Two implications:
  - If regulation compels manufacturers to adopt technologies, positive consumer net benefits
  - Standards could be more efficient than a carbon price

Vehicle demand literature has yielded a range of conclusions

- Most studies analyze consumer responses to fuel cost variation, focusing on whether consumers undervalue fuel cost savings (pay less than $1 for $1 worth of savings)
- Undervaluation would be consistent with an energy efficiency gap
- Literature has generated a wide range of estimates, from zero to overvaluation (Greene 2010 and Helfand and Wolverton 2009)
- Busse et al. (2013) and Allcott and Wozny (2014) suggest consumers fully value or somewhat undervalue fuel cost savings

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Overview of our findings

Our approach

- Construct an integrated data set with 535,000 observations of new vehicle buyers for model years 2010-2014
- Identify valuation of fuel economy and performance, using underlying technologies to address endogeneity

How much do consumers value fuel economy?

- On average, consumers pay $131 for a one percent fuel economy increase (0.24 mpg)
- Implicit real discount rate: 13 percent, compared to market rate of 1 percent, implying undervaluation

How much do consumers value performance?

- On average, holding weight constant, consumers pay $91 for a one percent increase in horsepower
- Equivalent to paying $1,072 for 1-second decrease in 0-60 mph time

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Implications

Manufacturer choices of fuel economy and performance

- Historically, during periods of unchanging fuel economy standards manufacturers have used fuel-saving technology to boost performance
- Consumers are willing to pay three times as much for performance as for fuel economy, consistent with observed manufacturer behavior

No energy efficiency gap after including opportunity costs

- Undervaluation of fuel economy would seem to imply a gap
- But total cost of raising fuel economy exceeds value, and fuel economy standards may reduce consumer welfare

Consumer demand for new vehicles

- "Consumer acceptance" has been a focus of policy controversy
- Standards apply to new but not existing vehicles (Gruenspecht 1982 and Stavins 2005), potentially reducing aggregate vehicle demand
- Tightening standards 4.5 percent in one year reduces willingness to pay 1.4 percent

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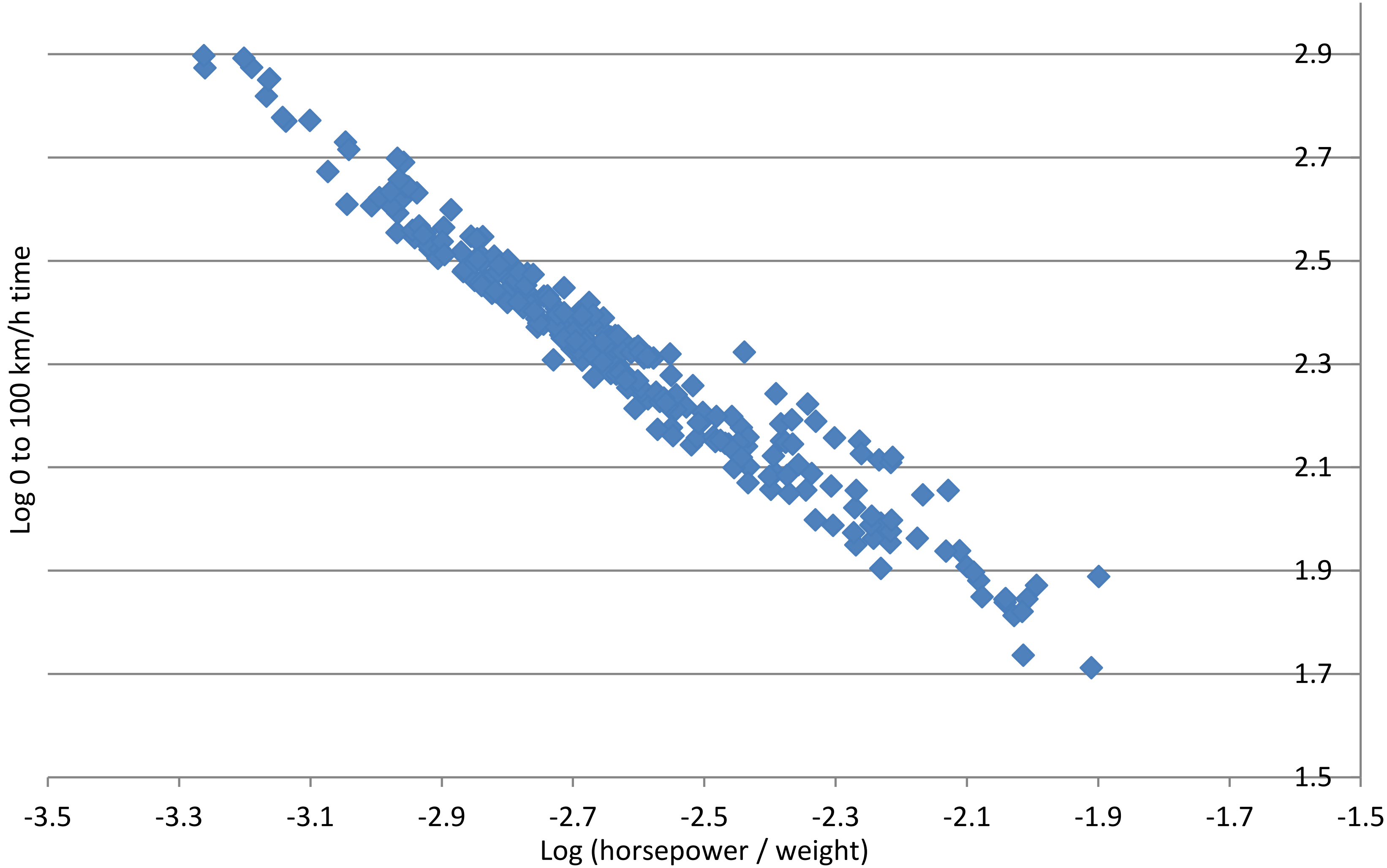
Figure 6. The relationship between acceleration time and horsepower/weight (UK)



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Summary information about the data

Sample information		
Number of observations	535,130	
Number of unique models	450	
Number of unique stubs	2,166	

Summary statistics	Mean	Standard deviation
Transaction price (2010 dollars)	28,693	11,402
Fuel economy (EPA combined)	23.9	6.6
Horsepower	226	78
Weight (lb)	4,055	1,264

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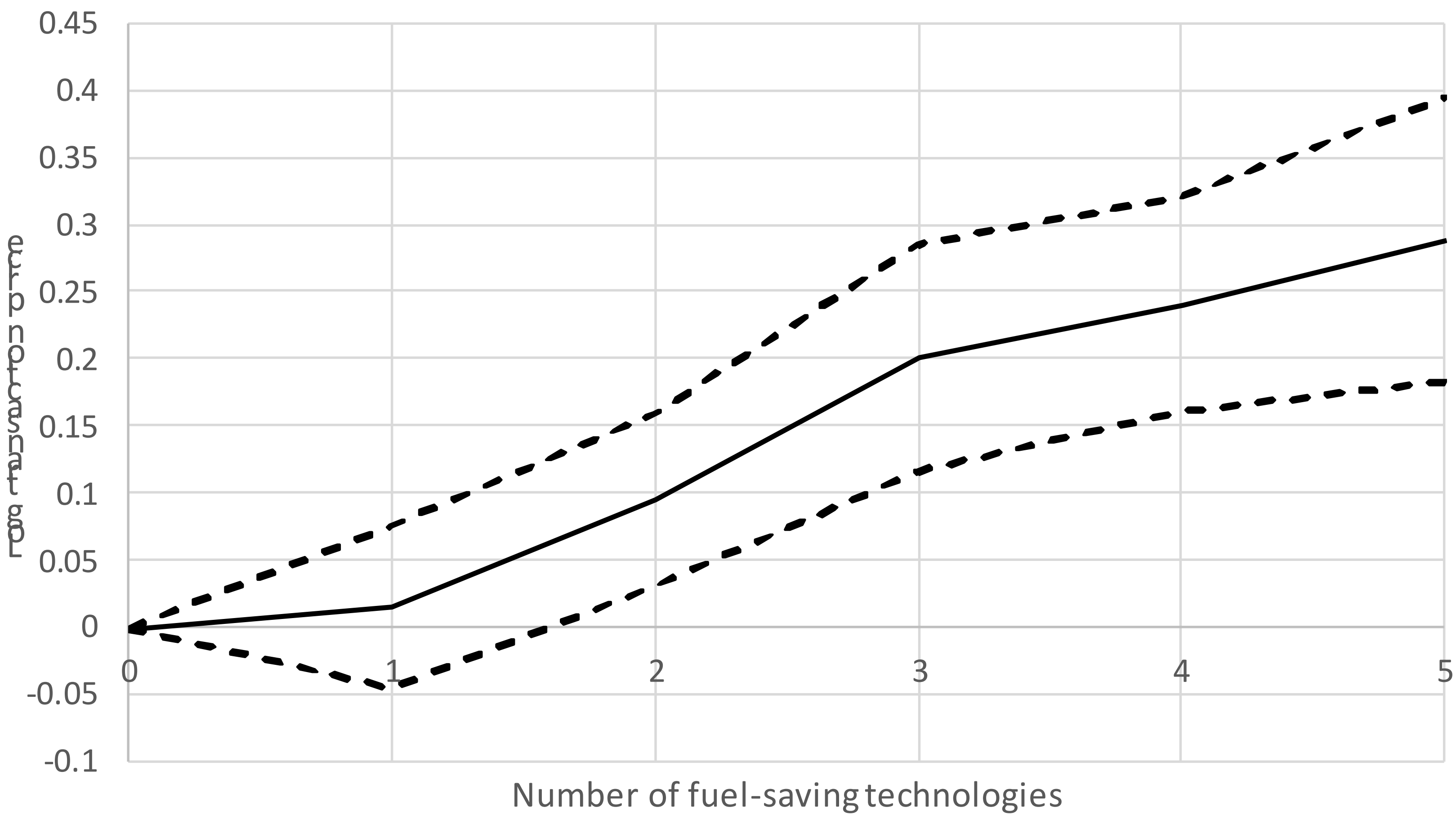
Figure 7. Reduced form: Transaction price vs. number of fuel-saving technologies



Comparison with the literature

Undervaluation contrasts with Busse et al. (2013)

- Busse et al. (2013) estimate implicit discount rates of -1 to 9 percent, suggesting full valuation
- Allcott and Wozny estimate valuation ratio of 0.74, suggesting some undervaluation

Sensitivity to alternative assumptions (see paper)

- Our results are based on updated estimates of miles traveled and scrappage rates, which affect discounted fuel savings
- A range of assumptions yields undervaluation
- We obtain similar results using Busse et al. (2013) methodology, and our data

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Implications (3): Vintage differentiated regulation

Do fuel economy or emissions standards reduce consumer demand for new vehicles?

- Consumer acceptance is a major point of contention for manufacturers
- Regulating new vehicles but not existing vehicles should reduce aggregate demand (Gruenspecht 1982)
- Lower consumer demand would reduce benefits of the regulations by slowing the turnover of the vehicle fleet

How do standards affect consumer demand?

- Between 2012 and 2016, fuel economy increased by about 4.5 percent per year
- Klier and Linn (2016) suggest that about 2.5 percentage points comes from faster technology adoption, and 2 percentage points from trading off performance for fuel economy
- Combining those estimates with willingness to pay, tightening standards 4.5 percent reduces willingness to pay for new vehicles by 1.4 percent

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Supporting the IV strategy

Proxies for unobserved quality

- If instruments are correlated with (time-varying) quality, we expect demographics to be correlated with quality
- Example: households with higher income/wealth are likely to have higher willingness to pay for add-ons such as navigational systems
- In that case, controlling for demographics or adding demographics as instruments would affect the results
- We obtain similar results, as we do if we include other proxies for quality or allow for geographic quality variation (see paper)

Reduced form

- Expect positive and monotonic relationship between number of technologies and vehicle price
- Might observe non-monotonic relationship if technologies are correlated with quality
- After including other controls, transaction prices increase monotonically with the number of technologies

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Price equation

Dependent variable: log transaction price by household, vehicle, and month

$$\ln p_{ijt} = \alpha_f \ln fc_{ijt} + \alpha_p \ln perf_{jt} + X_{jt}\delta + \varepsilon_{ijt}$$

Identification and interpretation

- Fuel costs are the ratio of fuel price to fuel economy
- Performance is the ratio of horsepower to weight (cars) or torque to weight (light trucks)
- Coefficients are elasticities, expecting negative for fuel costs and positive for performance

Other independent variables

- Vehicle attributes: engine size, drive type, fuel type, transmission speeds, flex fuel, car/truck
- Other controls: state, model year, PADD-month-fuel type, lease, CAFE stringency

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Instrumenting for fuel economy and performance

Fuel economy and performance are likely to be correlated with the error term

- Manufacturers jointly choose fuel economy, performance, and other attributes
- Example: high-performance vehicles may have more comfortable seating or better sound systems than other vehicles
- Define “quality” as combined consumer valuation of unobserved attributes (seating comfort, sound system, etc.)
- OLS estimates are likely to be biased by omitted variables

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