Consumer Myopia in Vehicle Purchases: Evidence from a Natural Experiment

Sébastien Houde

Joint work with

Kenneth Gillingham* and Arthur van Benthem**

IAEE Conference

June 2021

Motivation: Fuel Economy Standards

- They are widely considered to be a second-best policy as they have perverse incentives on driving and the used car fleet:
    - Rebound effect
    - Gruenspecht (scrappage) effect
    - Vehicle fleet too large
- Fuel economy standards are perhaps the most prominent policy to reduce carbon emissions from transport
- Not first best, but justified in government cost-benefit analyses, predominantly based on the private perspective

A Key Policy Parameter: Consumers' Valuation of Fuel Operating Costs

For the design of environmental/energy policy, the weight that consumers put on future fuel operating costs is akin of the elasticity of labor supply for labor economists.

A crucial parameter for determining policies and a never ending debate about how to measure it and what it should be.

Are Consumers Optimizing?

How do economists usually think about standards?

- The new vehicles get more expensive but more efficient (and perhaps with different attributes)
- Consumers receive fuel savings

By revealed preference, we would expect the private costs to exceed the benefits if consumers are optimizing

An Ongoing Debate: Are Consumers Myopic?

Spurred by the question of the energy efficiency gap and the credibility revolution, quantifying undervaluation of fuel economy has received a lot of attention. A consensus (for certain) may have emerged :

- Busse et al. (2013): 1.33 (r = 6%)
- Allcott and Wozny (2014): 0.76 (r = 6%)
- Sallee et al. (2017): 1.01 (r = 5%)
- Grigolon et al. (2018): 0.91 (r = 6%)
- Leard et al. (2018): 0.54 (r = 1.3%)

Most of these papers examine the equilibrium vehicle price response to gasoline prices to estimate undervaluation.

Our Work on Undervaluation

This work is the first to exploit a large unexpected restatement of fuel economy ratings

- We examine the equilibrium effects of the restatement to ask: How do consumers value fuel economy?
- Our identification strategy shed new light on an (un-)settled question
- Our source of variation is different and better mimic the source of variation that a fuel economy standard would induce (especially in comparison of papers that used gas prices).
- We find strong undervaluation: baseline estimates of 0.15-0.38.

Preview of Findings

We find:

- Equilibrium vehicle prices drop by 1.2% or $294
- No statistical evidence for negative effect on sales
- Consumers indifferent between $1 in discounted fuel costs and 15-38 cents in the purchase price when discounting at 4%

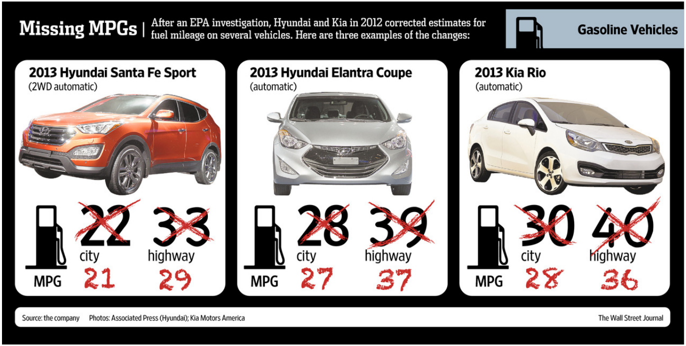
Fuel Economy Ratings

In addition to the ratings on all websites, there is the mandatory label:

Hyundai and Kia Restatement

- A random audit led EPA to discover that 13 vehicle models by Hyundai and Kia had overstated fuel economy values
- The automakers blamed engineering “procedural errors” in the mileage tests
- Over 1.6 million vehicles in the 2011, 2012, and 2013 model years were affected ($\sim$44% of vehicles sold by these automakers)
- Largest restatement in history
- Average change $\sim$ 1.5 mi/gal

Restatement Effects



Restatement Was Abrupt and Unexpected

- Announced with an EPA press release in November 2012
- Restatement came as a surprise
- Comparison websites like www.fueleconomy.gov and www.edmunds.com were immediately updated
- Labels on dealer lots were quickly updated, too
- Hyundai and Kia advertised high fuel economy until shortly before the restatement

Our Opportunity

- Restatement provides a unique opportunity to exploit the equilibrium effects of an exogenous and unexpected change in fuel economy ratings – the vehicles themselves remain identical

- We are the first to perform a valuation exercise using variation in fuel economy, rather than gasoline prices

Data

- Sales and transaction prices at U.S. dealers for all vehicles August 2011-June 2014
  - Includes dealer rebates
  - Detailed vehicle attributes to identify affected models
  - Source: R.L. Polk, DataOne
- Gasoline prices
  - Source: U.S. Energy Information Administration
- Vehicle driving (VMT)
  - National Household Travel Surveys

Summary Statistics

	Affected Models		Not Affected Models		
	Hyundai	Kia	Hyundai	Kia	Others
	(1)	(2)	(3)	(4)	(5)
Panel A: Sales and Transaction Prices					
Total Sales (1000s)	1,041	516	944	1,001	26,300
Price (1000s $)	21.6	20.0	24.1	23.5	28.6
# of Models by Model-Year	16	10	49	36	1,131
Panel B: Selected Vehicle Characteristics					
Fraction Sport	0.01	0.00	0.03	0.00	0.04
Fraction Small Car	0.71	0.18	0.16	0.22	0.33
Fraction Large Car	0.09	0.03	0.62	0.41	0.31
Fraction Crossover	0.19	0.80	0.19	0.36	0.33
Engine cylinders	4.17	4.00	4.23	4.25	4.70
Displacement (liters)	2.02	1.98	2.39	2.34	1.72
Gross Vehicle Weight	2.89	2.96	3.28	3.23	3.47
MSRP (1000s $)	20.8	18.9	24.1	22.8	28.7
Fuel Economy (mi/gal)	29.5	25.8	27.0	27.0	26.4

Empirical Strategy

We use the following specification for vehicle VIN10 j sold in region r and year-month t:

$$\begin{aligned} Price_{jrt} =& \beta 1(Post\ Restatement)_t \times 1(Affected\ Model)_j + \rho_{t \times Class_j} + \mu_{t \times Make_j} \\ & + \eta_r + \eta_r \times 1(Post\ Restatement)_t + \omega_j + \epsilon_{jrt}. \end{aligned}$$

where

- VIN10 is a model-trim-engine combination (differs across model-years)
- Region r = Nielsen “designated market area” (DMA)
- Regression is sales-weighted

Identification

Our diff-in-diff specification is comparing affected car models before and after the restatement to other car models of the same brand and car models of other brands in a similar car segment

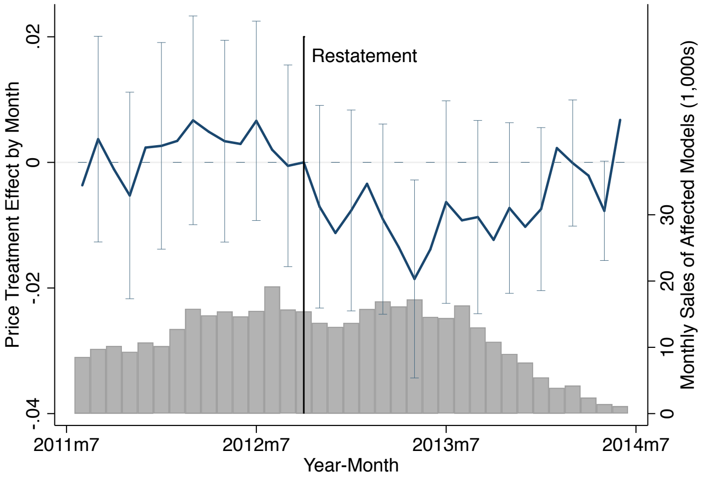
- Identification is based on trends across the affected and non-affected models being similar after accounting for differing trends by car segment and brands
- SUTVA also must hold, so there are no spillovers, such as competitive effects SUTVA Robustness Checks
- We perform a series of other robustness checks More Robustness Checks

Effect of Restatement on Transaction Prices

	(1)	(2)	(3)	(4)	(5)	(6)
		Logs			**Levels**	
Panel A: Primary Results						
$1(\textit{Post Restatement})_t \times 1(\textit{Affected Model})_j$	-0.010	-0.010	-0.012	-150	-259	-294
	(0.004)	(0.004)	(0.003)	(80)	(94)	(91)
Year-Month × Class FE		Y	Y		Y	Y
Year-Month × Make FE	Y	Y	Y	Y	Y	Y
VIN10 FE	Y	Y	Y	Y	Y	Y
DMA FE	Y		Y	Y		Y
1(Post Restatement) × DMA FE	Y		Y	Y		Y
R-squared	0.95	0.92	0.95	0.96	0.95	0.96
N	1.52m	1.52m	1.52m	1.52m	1.52m	1.52m

Notes: Dependent variable is log or level of the transaction price (in dollars). An observation is a year-month-DMA-VIN10. VIN10 refers to a trim-engine combination. All estimations are weighted by monthly sales. *Post Restatement* refers to the year-month being during or after November 2012. Standard errors are clustered at the VIN10 level.

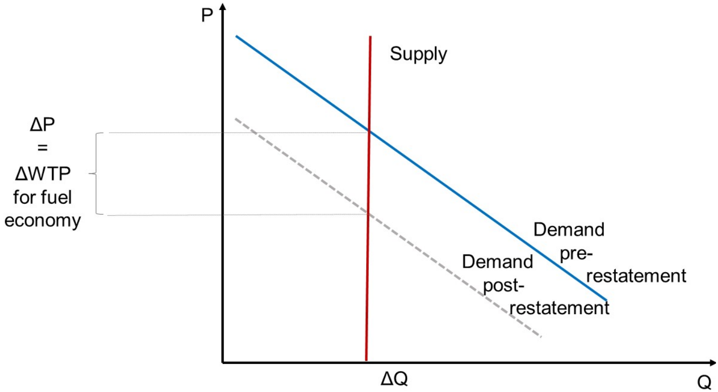
Effect by Month for Equilibrium Price



Quantity Effects?

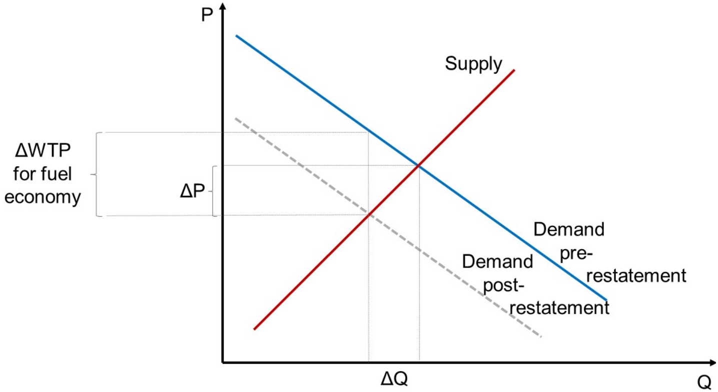
- Should we see much in the way of quantity effects?
- Recall: a vertical shift in demand = change in willingness-to-pay

Inelastic Supply



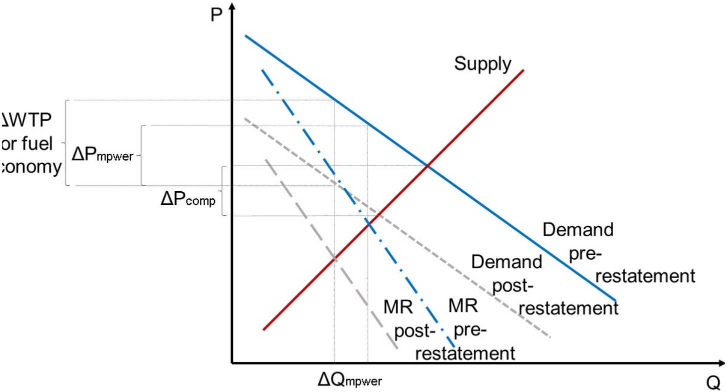
- Good approximation for MY 2011-2012
- Also holds under imperfect competition

Normal Upward-Sloping Elastic Supply



- Could apply to MY 2013

Imperfect Competition and Upward-sloping Supply



- Might apply to MY 2013

No Clear Negative Effect on Sales

	(1) Incl. Outliers	(2) <50%	(3) <40%	(4) <30%	(5) <25%
$1(\textit{PostRestatement})_t \times 1(\textit{AffectedModel})_j$	0.15	0.05	0.04	0.05	0.06
	(0.08)	(0.04)	(0.05)	(0.05)	(0.05)
Year-Month $\times$ Class FE	Y	Y	Y	Y	Y
Year-Month $\times$ Make FE	Y	Y	Y	Y	Y
VIN10 Year FE	Y	Y	Y	Y	Y
DMA Year FE	Y	Y	Y	Y	Y
1(Post Restatement) $\times$ DMA FE	Y	Y	Y	Y	Y
R-squared	0.46	0.53	0.53	0.52	0.51
N	4.00m	3.52m	3.62m	3.70m	3.75m

Notes: Dependent variable is log of sales. An observation is a year-month-DMA-VIN10. VIN10 refers to a trim-engine combination. The first column presents the results using the full sample. The remaining columns present the results excluding observations if the monthly sales are less than some percentage of average sales, as given in the heading. Standard errors are clustered at the VIN10 level.

Why No Sales Effects?

Our finding: Direct estimation is noisy, with positive but insignificant point estimate and a 95% C.I. of (-0.03, 0.13)

Several possibilities:

1. For MY 2011-2012 vehicles it is impossible to build more—inventory already built
2. Costly physical adjustment costs and renegotiation with suppliers
3. Firms may be trying to maintain market share from this temporary shock: changing prices or advertising
4. “All publicity is good publicity?”

Undervaluation persists even assuming large quantity effects

Estimating Valuation of Fuel Economy

Approaches in the literature:

1. Implicit discount rate (e.g., see Hausman 1979)
2. Hedonic approach
3. Undervaluation parameter
    - Assume a discount rate
    - Ratio of how the future fuel savings are valued in the market (willingness-to-pay) to the calculated discounted future fuel savings

Estimating Valuation of Fuel Economy

Consider the following specification for vehicle trim j sold in region r and year-month t:

$$Price_{jrt} = \gamma \Delta G_{jt} + \rho_{t \times Class_j} + \mu_{t \times Make_j} + \eta_r + \eta_r \times 1(Post\ Restatement)_t + \omega_j + \epsilon_{jrt}.$$

where

- ΔG is the change in the expected discounted future fuel costs due to the restatement [Assumptions for G]
- γ is the willingness-to-pay for \$1 of discounted fuel savings (if quantities do not adjust; can be relaxed: [Details])

Estimates of the Valuation of Fuel Economy

Panel A: Exact Valuation Parameter Estimation Results from the Restatement

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$r = 1\%$		$r = 4\%$		$r = 7\%$		$r = 12\%$	
$1(\Delta \textit{Lifetime Fuel Costs})_{jt} \times$	-0.14		-0.17		-0.20		-0.25	
$1(\textit{Affected Model})_j$	(0.05)		(0.06)		(0.06)		(0.08)	
$1(\Delta \textit{Lifetime Fuel Costs})_{jt} \times$		-0.32		-0.38		-0.44		-0.56
$1(2011-2012 \textit{ Affected Model})_j$		(0.16)		(0.19)		(0.23)		(0.29)
$1(\Delta \textit{Lifetime Fuel Costs})_{jt} \times$		-0.13		-0.15		-0.18		-0.22
$1(2013 \textit{ Affected Model})_j$		(0.05)		(0.05)		(0.06)		(0.08)
Year-Month $\times$ Class FE	Y	Y	Y	Y	Y	Y	Y	Y
Year-Month $\times$ Make FE	Y	Y	Y	Y	Y	Y	Y	Y
VIN10 FE	Y	Y	Y	Y	Y	Y	Y	Y
DMA FE	Y	Y	Y	Y	Y	Y	Y	Y
1(Post Restatement) $\times$ DMA FE	Y	Y	Y	Y	Y	Y	Y	Y
R-squared	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
N	1.52m	1.52m	1.52m	1.52m	1.52m	1.52m	1.52m	1.52m

Notes: Dependent variable is the transaction price (in dollars). The main regressor is the change in lifetime fuel costs at the time of the restatement event (ΔG). Lifetime fuel costs are computed using annual U.S. gasoline prices, survival probabilities from Jacobsen & van Benthem (2015), and VMT from NHTSA (2018). A coefficient of -1 implies that a one dollar increase in lifetime fuel costs reduces the transaction price by one dollar. Values between -1 and 0 imply that consumers undervalue future fuel costs.

Comparing to the Literature

Panel B: Comparison with Recent Studies

	r	γ
Studies using exact valuation parameter		
Sallee et al. (2016)	5%	1.01
Allcott and Wozny (2014)	6%	0.76
Own Estimate from Restatement	5%	[0.17-0.42]
Own Estimate from Restatement	6%	[0.18-0.44]
Studies using approximate valuation parameter		
Busse et al. (2013)	6%	1.33
Grigolon et al. (2018)	6%	0.91
Leard et al. (2018)	1.3%	0.54
Own Estimate from Restatement	6%	[0.40-1.01]
Own Estimate from Restatement	1.3%	[0.31-0.77]

Notes: We report a range of our own estimates that accounts for heterogeneity between model-years 2011-2012 versus 2013.

Possible Explanations for the Difference

Why might our estimates be different?

- We use a different source of identification
- New Hyundai and Kia cars rather than used or all new cars
- Sample period is slightly different
- Consumers already knew?
- Mean of ratios versus ratio of means

Outline

Conclusions

- We examine an unexpected change to consumer fuel economy labels
- This change implies a valuation parameter of 0.15-0.39
  - Of course a wide range of estimates depending on assumptions, but our range lies almost fully below 0.50
- This deviates from much (but not all) of the recent literature
- Findings emphasize the need to update the analysis of the U.S. CAFE standards

Back-up slides

SUTVA Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)
		Logs			**Levels**	
Panel B: Robustness Checks for SUTVA Assumption						
$1(\textit{PostRestatement})_t \times 1(\textit{Affected Model})_j$	-0.011	-0.014	-0.013	-261	-365	-342
	(0.004)	(0.003)	(0.003)	(94)	(83)	(84)
Year-Month × Class FE	Y	Y	Y	Y	Y	Y
Year-Month × Make FE	Y	Y	Y	Y	Y	Y
VIN10 FE	Y	Y	Y	Y	Y	Y
DMA FE	Y	Y	Y	Y	Y	Y
1(Post Restatement) × DMA FE	Y	Y	Y	Y	Y	Y
Exclude close substitutes of same make	Y			Y		
Exclude close substitutes other makes		Y			Y	
Exclude all close substitutes			Y			Y
R-squared	0.95	0.95	0.95	0.96	0.96	0.96
N	1.50m	1.41m	1.39m	1.50m	1.41m	1.39m

Notes: Dependent variable is log or level of the transaction price (in dollars). An observation is a year-month-DMA-VIN10. VIN10 refers to a trim-engine combination. All estimations are weighted by monthly sales. *Post Restatement* refers to the

Effect on Transaction Prices Excluding the Months Closest to the Restatement

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Number of Post-Months Excluded											
	0 (base)	1	2	3	4	5	6	7	8	9	10	11
$1(\textit{Post Restatement})_t \times 1(\textit{Affected Model})_j$	-0.012	-0.012	-0.013	-0.013	-0.015	-0.016	-0.016	-0.013	-0.012	-0.012	-0.011	-0.010
(Logs)	(0.003)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.007)	(0.008)	(0.009)
$1(\textit{Post Restatement})_t \times 1(\textit{Affected Model})_j$	-294	-310	-324	-341	-389	-408	-415	-368	-347	-364	-330	-320
(Levels)	(91)	(98)	(106)	(115)	(125)	(136)	(147)	(158)	(171)	(185)	(204)	(229)
N	1.52m	1.47m	1.43m	1.38m	1.34m	1.29m	1.25m	1.20m	1.16m	1.11m	1.07m	1.02m
Year-Month × Class FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year-Month × Make FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
VIN10 FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
DMA FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
1(Post Restatement) × DMA FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Robustness Checks With Alternative Class FE

	(1)	(2)	(3)	(4)	(5)	(6)
		Logs			**Levels**	
$1(\textit{Post Restatement})_t \times 1(\textit{Affected Model})_j$	-0.012	-0.011	-0.011	-294	-283	-240
	(0.003)	(0.004)	(0.004)	(91)	(93)	(90)
Year-Month × Class FE	Y			Y		
Year-Month × Finer Class FE		Y			Y	
Year-Month × Coarser Class FE			Y			Y
Year-Month × Make FE	Y	Y	Y	Y	Y	Y
VIN10 FE	Y	Y	Y	Y	Y	Y
DMA FE	Y	Y	Y	Y	Y	Y
1(Post Restatement) × DMA FE	Y	Y	Y	Y	Y	Y
R-squared	0.95	0.95	0.95	0.96	0.96	0.96
N	1.52m	1.52m	1.52m	1.52m	1.52m	1.52m

Notes: Dependent variable is log or level of the transaction price (in dollars). An observation is a year-month-DMA-VIN10. VIN10 refers to a trim-engine combination. All estimations are weighted by monthly sales. *Post Restatement* refers to the year-month being during or after November 2012. Standard errors are clustered at the VIN10 level.

Further Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)
		Logs			Levels	
$1(\textit{Post Restatement})_t \times 1(\textit{Affected Model})_j$	-0.016	-0.010	-0.011	-295	-279	-336
	(0.005)	(0.003)	(0.004)	(92)	(89)	(81)
Year-Month $\times$ Class FE	Y	Y	Y	Y	Y	Y
Year-Month $\times$ Make FE	Y	Y	Y	Y	Y	Y
VIN10 FE	Y	Y	Y	Y	Y	Y
DMA FE	Y	Y	Y	Y	Y	Y
1(Post Restatement) $\times$ DMA FE	Y	Y	Y	Y	Y	Y
Include prices $<=$ $5,000	Y			Y		
Exclude price outliers		Y			Y	
Hyundais and Kias only			Y			Y
R-squared	0.86	0.98	0.92	0.96	0.98	0.93
N	1.52m	1.48m	0.14m	1.52m	1.48m	0.14m

Notes: Dependent variable is log or level of the transaction price (in dollars). An observation is a year-month-DMA-VIN10. VIN10 refers to a trim-engine combination. All estimations are weighted by monthly sales. The "exclude price outliers" specification excludes outliers less than 67% of the mean price and greater than 150% of the mean price. *Post Restatement* refers to the year-month being during or after November 2012. Standard errors are clustered at the VIN10 level.

Heterogeneous Effects By Model Year and GPM

	Primary		Model Year		$\triangle$ GPM	
	(1)	(2)	(3)	(4)	(5)	(6)
	logs	levels	logs	levels	logs	levels
$1(\textit{PostRestatement})_t \times 1(\textit{Affected Model})_j$	-0.012	-294				
	(0.003)	(91)				
$1(\textit{PostRestatement})_t \times 1(2011-2012\ \textit{Affected Model})_j$			-0.017	-544		
			(0.006)	(128)		
$1(\textit{PostRestatement})_t \times 1(2013\ \textit{Affected Model})_j$			-0.011	-259		
			(0.004)	(98)		
$1(\textit{PostRestatement})_t \times 1(\textit{Affected Model})_j \times \Delta \textit{GPM}$					-2.92	-66544
					(0.90)	(22470)
Year-Month $\times$ Class FE	Y	Y	Y	Y	Y	Y
Year-Month $\times$ Make FE	Y	Y	Y	Y	Y	Y
VIN10 FE	Y	Y	Y	Y	Y	Y
DMA FE	Y	Y	Y	Y	Y	Y
1(Post Restatement) $\times$ DMA FE	Y	Y	Y	Y	Y	Y
R-squared	0.95	0.96	0.95	0.96	0.95	0.96
N	1.52m	1.52m	1.52m	1.52m	1.52m	1.52m

Notes: Dependent variable is log or level of the transaction price (in dollars). An observation is a year-month-DMA-VIN10. VIN10 refers to a trim-engine combination. All estimations are weighted by monthly sales. ΔGPM refers to the change in the gallons per mile from the

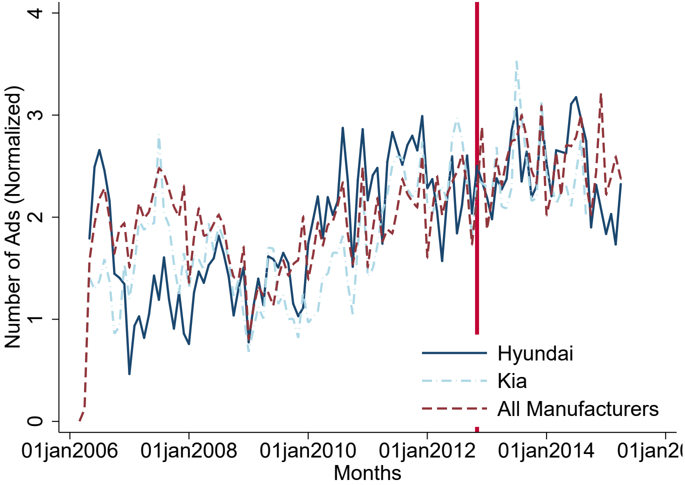
Heterogeneous Effects By Automaker

	Primary		Automaker	
	logs	levels	logs	levels
$1(PostRestatement)_t \times 1(Affected\ Model)_j$	-0.012	-294		
	(0.004)	(91)		
$1(PostRestatement)_t \times 1(Hyundai\ Affected\ Model)_j$			-0.014	-365
			(0.005)	(123)
$1(PostRestatement)_t \times 1(Kia\ Affected\ Model)_j$			-0.010	-212
			(0.004)	(114)
Year-Month × Class FE	Y	Y	Y	Y
Year-Month × Make FE	Y	Y	Y	Y
VIN10 FE	Y	Y	Y	Y
DMA FE	Y	Y	Y	Y
1(Post Restatement) × DMA FE	Y	Y	Y	Y
R-squared	0.95	0.96	0.95	0.96
N	1.52m	1.52m	1.52m	1.52m

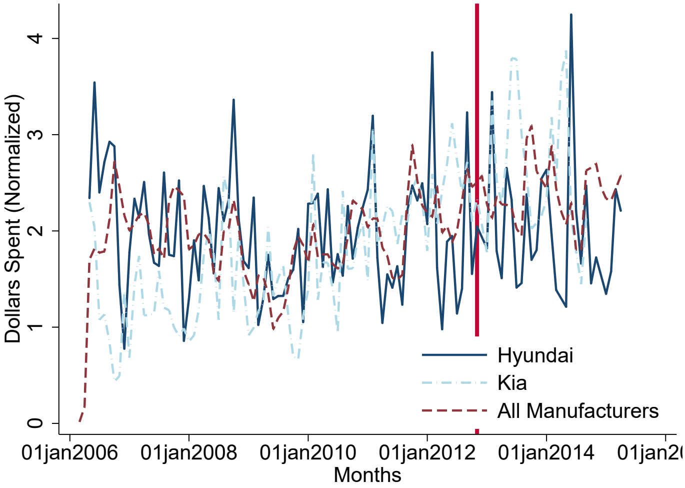
Notes: Dependent variable is log or level of the transaction price (in dollars). An observation is a year-month-DMA-VIN10. VIN10 refers to a trim-engine combination. All estimations are weighted by monthly sales. Standard errors are clustered at the VIN10 level.

Back

Number of Advertisements



Dollars Spent on Advertising



Back

Creating the G variable

We construct the present value of future fuel savings with:

- Yearly survival probabilities from Jacobsen and van Benthem (2015)
- Gasoline prices from EIA (different assumptions about future prices)
- VMT from NHTS 2006 or 2017 surveys
- Several different discount rates

Back