

# **ECON 8000/9000 Empirical Energy Econ**

## **Topic 09: Energy Efficiency Gap and Energy Paradox**

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# Outline

- ▶ Introduction to Energy Efficiency Gap / Energy Paradox
- ▶ Example 1: Busse, Knittel, & Zettlemeyer (2013) AER
- ▶ Example 2: Gillingham, Houde, & van Benthem (2021) AEJ:EP
- ▶ Example 3: Sallee & Fan (2016) JPubE
- ▶ Example 4: Myers (2019) AEJ-EP
- ▶ Example 5: Myers (2020) JPubE
- ▶ Future directions

# 1. What is "Energy Efficiency Gap"?

A comparison between  $\Delta WTP$  vs  $\Delta$ realized energy cost savings

Big picture questions: For \$1 energy cost savings,

- ▶ Are consumers willing to pay extra \$1?
- ▶ Are firms willing to invest extra \$1?
- ▶ If they are rational and market is efficient, then marginal  $\Delta WTP$  should be \$1!
- ▶ Is  $\Delta WTP = \$1$  (full valuation),  $< \$1$  (undervaluation), or  $> \$1$  (overvaluation)?
- ▶ If  $\Delta WTP < \$1$  (undervaluation)
  - ▶ We can say there is an energy efficiency gap, or an energy paradox
  - ▶ In which industry do we observe it? Vehicles? Large appliance? Etc?
  - ▶ Heterogeneity? Does it differ by different types of consumers or firms?
  - ▶ If there is gap, then what may be plausible reason(s)?

Three main literature surveys:

- ▶ Allcott & Greenstone (2012) JEP, "Is There an Energy-Efficiency Gap"
- ▶ Gerarden, Newell, & Stavins (2017) JEP, "Assessing the Energy-Efficiency Gap"
- ▶ Gillingham & Myers (2025) Handbook of Electricity Regulation, "Economics of Energy Efficiency"

# 1. What is "Energy Efficiency Gap"?

An Example: In simple terms

- ▶ Consider buying product  $j$  over  $k$
- ▶ Suppose  $j$  and  $k$  has identical attributes expect that  $j$  is more energy efficient
- ▶ Suppose the marginal energy cost savings in present value equal to \$1, aka  $\Delta NPV = \$1$
- ▶ If consumer is completely rational and if no additional friction, we should expect  $\Delta WTP = 1$  all else equal
- ▶ If we estimate consumer WTP, would we find  $\Delta WTP$  less than \$1, exactly equal to \$, or greater than \$1?



## 2. Compare $\Delta WTP$ and $\Delta NPV$

### 2.2 Introduce valuation ratio $\gamma$

Still consider product  $j$  and  $k$  have identical attributes except for energy-efficiency:

$$\Delta WTP = \gamma \cdot \left( \underbrace{\sum_{t=0}^T \frac{p_e \cdot m \cdot e_k}{(1+r)^t}}_{\text{NPV of energy cost for } k} - \underbrace{\sum_{t=0}^T \frac{p_e \cdot m \cdot e_j}{(1+r)^t}}_{\text{NPV of energy cost for } j} \right) \quad (1.2)$$

- ▶  $c$ : extra investment cost to buy good 0 over 1, you can regard it as  $\Delta WTP$
- ▶  $p_e$ : energy price, e.g., gas price for cars, electricity price for homes and buildings
- ▶  $e_j$ : energy consumption rate (usually 1 over energy efficiency), e.g., gallon-per-mile
- ▶  $m_j$ : utilization of energy (intensive margin), e.g., VMT for vehicle, kWh for electricity
- ▶  $T$ : duration for the durable goods or the investment, e.g., lifespan of a vehicle
- ▶  $r$ : interest rate or other inter-temporal discount factor
- ▶ Evidence of full valuation:  $\gamma = 1$
- ▶ Evidence of undervaluation (energy efficiency gap):  $\gamma < 1$

## 2. Compare $\Delta WTP$ and $\Delta NPV$

### 2.3 Introduce implied discount rate $r$

Still consider product  $j$  and  $k$  have identical attributes except for energy-efficiency:

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- ▶  $m_j$ : utilization of energy (intensive margin), e.g., VMT for vehicle, kWh for electricity
- ▶  $T$ : duration for the durable goods or the investment, e.g., lifespan of a vehicle
- ▶ Suppose we let  $\gamma = 1$ , and compute what the implied discount rate  $r$  is
- ▶ **Evidence of full valuation**:  $r$  is exactly around the commonly recognized interest rate
- ▶ **Evidence of undervaluation (energy efficiency gap)**:  $r$  is way way way higher than typical interest rate

## 2. Compare $\Delta WTP$ and $\Delta NPV$

### 2.2-2.3 How to examine if there is an energy efficiency gap using $\gamma$ and $r$

Still consider product  $j$  and  $k$  have identical attributes except for energy-efficiency:

$$\Delta WTP = \gamma \cdot \left( \underbrace{\sum_{t=0}^T \frac{p_e \cdot m \cdot e_k}{(1+r)^t}}_{\text{NPV of energy cost for } k} - \underbrace{\sum_{t=0}^T \frac{p_e \cdot m \cdot e_j}{(1+r)^t}}_{\text{NPV of energy cost for } j} \right) \quad (1.2)$$

- ▶ Suppose you estimate LHS and compute RHS
- ▶ How to examine if there is an energy efficiency gap?
- ▶ **Method 1: Use valuation ratio**
  - ▶ First, use a commonly recognized interest rate or discount factor  $r$  to compute  $\Delta NPV$
  - ▶ Next, compute  $\gamma = \Delta WTP / \Delta NPV$
  - ▶ If  $\gamma < 1$ : Then there is consumer undervaluation (energy-efficiency gap)
- ▶ **Method 2: Use implied discount rate**
  - ▶ First, impose  $\gamma = 1$
  - ▶ Next, compute  $r$  that will justify  $\gamma = 1$  aka  $\Delta WTP = \Delta NPV$
  - ▶ If the implied discount rate  $r$  is way higher than commonly used rate: Then there is consumer undervaluation (energy-efficiency gap)

## 2. Compare $\Delta WTP$ and $\Delta NPV$

### 2.4 Allow for tradeoff costs

Suppose while  $j$  is more energy-efficient than  $k$ ,  $j$  and  $k$  are not identical in other dimensions

- ▶ e.g.,  $j$  may have a lower horsepower than  $k$
- ▶ e.g.,  $j$  may have a lower EV battery range than  $k$
- ▶ While a consumer experiences a rise in WTP for energy efficiency  $\Delta WTP_e$
- ▶ They may experience a reduction in WTP due to the foregone quality consumers have to trade off in exchange for greater energy efficiency

Then undervaluation of energy-cost savings does not necessarily imply an energy paradox

- ▶ Consumer may still undervalue energy cost savings,  $\Delta WTP_e < \Delta NPV$
- ▶ But such undervaluation is consistent with a rational consumer

## 2. Compare $\Delta WTP$ and $\Delta NPV$

### 2.4 Allow for tradeoff costs: undervaluation vs. energy-efficiency gap

Denote the reduction in WTP from foregone quality as  $\xi$ , i.e.,  $\xi = |\Delta WTP_{\text{other quality}}|$

- ▶ Then a rational consumer would fully rationalize  $\Delta NPV$  net out the foregone opportunity cost  $\xi$  in exchange for higher energy efficiency.

$$\Delta WTP_e = \gamma \cdot \left( \underbrace{\sum_{t=0}^T \frac{p_e \cdot m \cdot e_k}{(1+r)^t}}_{\text{NPV of energy cost for } k} - \underbrace{\sum_{t=0}^T \frac{p_e \cdot m \cdot e_j}{(1+r)^t}}_{\text{NPV of energy cost for } j} \right) \quad (1.2)$$

$$\Delta WTP_e = \left( \underbrace{\sum_{t=0}^T \frac{p_e \cdot m \cdot e_k}{(1+r)^t}}_{\text{NPV of energy cost for } k} - \underbrace{\sum_{t=0}^T \frac{p_e \cdot m \cdot e_j}{(1+r)^t}}_{\text{NPV of energy cost for } j} \right) - \underbrace{\xi}_{|\Delta WTP_{\text{other quality}}|} \quad (1.3)$$

- ▶ Suppose you not only can estimate the overall  $\Delta WTP$ , but specifically  $\Delta WTP_e$
- ▶ Suppose we find  $\gamma = 0.8$  from Eq(1.2), suggesting undervaluation
- ▶ **Case 1.** If Eq(1.3) still holds, then no energy paradox
- ▶ **Case 2.** If Eq(1.3) has LHS < RHS, then there is an energy efficiency gap/paradox

## 2. Compare $\Delta WTP$ and $\Delta NPV$

### 2.5 Subtle consideration: accounting for "rebound effect"

Reconsider the simple case with  $j$  and  $k$  being identical except for energy efficiency

$$\Delta WTP_e = \gamma \cdot \left( \underbrace{\sum_{t=0}^T \frac{p_e \cdot m \cdot e_k}{(1+r)^t}}_{\text{NPV of energy cost for } k} - \underbrace{\sum_{t=0}^T \frac{p_e \cdot m \cdot e_j}{(1+r)^t}}_{\text{NPV of energy cost for } j} \right) \quad (1.2)$$

- ▶ Typically when people construct RHS, they estimate yearly VMT from NHTS
- ▶ This implicitly assumes that  $m$  is exogenous
- ▶ However,  $m(e)$  can be function of energy efficiency  $e$   
i.e., the intensive margin of using energy-related product depends on  $e$   
e.g., we may drive more miles per year if we buy a more energy-efficient vehicle
- ▶ There is a whole literature focusing on estimating parameters of the "rebound effect"  
a bit related to the idea of moral hazard  
see Gillingham, Rapson, & Wagner (2015) REEP for a literature survey
- ▶ So if one wants to account for this when constructing the RHS of Eq(1.2), one can allow  $m$  to vary by  $e$

### 3. Typical Explanations

In addition to the possibility of rational consideration of tradeoff cost  $\xi$

- ▶ 1. Consumer may be inattentive
- ▶ 2. Consumer myopia
- ▶ 3. There may be an information problem
- ▶ 4. There may be a financial literacy issue
  - ▶ Issues 3-4 lead to a series of studies evaluating the impact of energy efficiency labels
  - ▶ e.g., "payback period" labels for vehicles
  - ▶ e.g., "energy star" labels for large appliances
- ▶ 5. There could be other frictions such as adjustment costs on the firm or consumer side
- ▶ 6. Bias belief of future energy prices (or fuel prices)  $p_e$  trajectories
- ▶ 7. Bias belief of energy use (or fuel use)  $m$
- ▶ 8. Fail to account for future learning-by-doing which will affect  $m$
- ▶ 9. Liquidity constraint for upfront cost investment
- ▶ 10. Engineering models are wrong
- ▶ etc.

# 4. Importance of Energy Efficiency

It matters for energy consumption across many sectors

Top sectors: (1) transportation (2) industrial (3) residential

Table 1

## U.S. Energy Use

By sector (U.S. EIA 2011a)

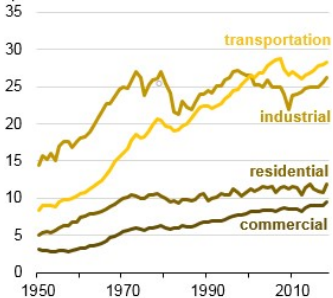
Commercial	19%
Industrial	30%
Transport	29%
Residential	22%

Residential categories (U.S. EIA 2005)

Refrigerators	5%
Air conditioning	8%
Water heating	20%
Space heating	41%
Other appliances and lighting	26%

Source: Data are from U.S. Energy Information Administration (2005, 2011a).

Energy consumption by end-use sector  
quadrillion British thermal units



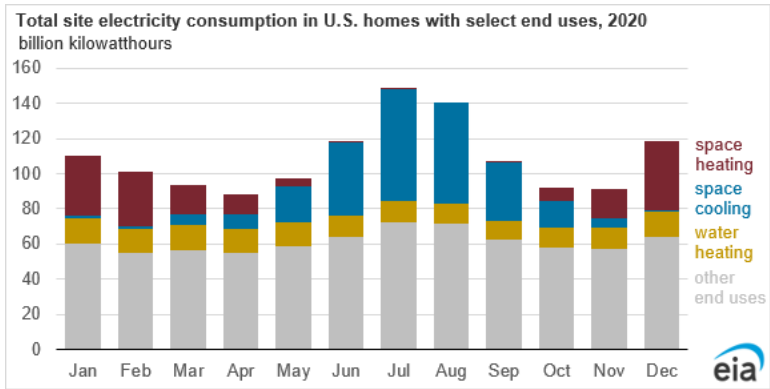
Left: Allcott & Greenstone (2012) Fig 1

Right: EIA 2018

# 4. Importance of Energy Efficiency

It matters for energy consumption across many sectors: residential energy use

Residential energy consumption: mostly heating & cooling



# 5. EE Policies and Justifications

## 5.1 Often: private surplus gain (when EE gap exists)

Table 2  
**Significant U.S. Energy Efficiency Policies**

<i>Name</i>	<i>Year</i>	<i>Magnitude</i>
Corporate Average Fuel Economy Standards	1978–	\$10 billion annual incremental cost from tightened 2012 rule (NHTSA 2010)
Federal Hybrid Vehicle Tax Credit	2006–2010	\$426 million total annual credit (Sallee 2010)
Gas guzzler tax	1980–	\$200 million annual revenues (Sallee 2010)
Federal appliance energy efficiency standards	1990–	\$2.9 billion annual incremental cost (Gillingham, Newell, and Palmer 2006)
Residential and commercial building codes	1978–	
Electricity Demand-Side Management programs	1978–	\$3.6 billion annual cost (US EIA 2010)
Weatherization Assistance Program (WAP)	1976–	\$250 million annual cost (US DOE 2011a)
2009 Economic Stimulus	2009–2011	\$17 billion total (U.S. DOE 2011b)
Additional WAP funding		\$5 billion
Recovery Through Retrofit		\$454 million
State Energy Program		\$3.1 billion
Energy Efficiency and Conservation Block Grants		\$3.2 billion
Home Energy Efficiency Tax Credits		\$5.8 billion credit in 2009 (U.S. IRS 2011)
Residential and Commercial Building Initiative		\$346 million
Energy Efficient Appliance Rebate Program		\$300 million
Autos Cash for Clunkers		\$5 billion



## 6. Other Corrective Possibilities

*The monopolist is the environmentalist's best friend.*

*- often attributed to Milton Friedman and James Buchanan*

- ▶ Market power, often leading to under-allocation, can somewhat correct the over-allocation in the case of pollution or other negative externality
- ▶ E.g., Asker et al. (2024) NBER WP "Two Wrongs Can Sometimes Make a Right: The Environmental Benefits of Market Power in Oil"
- ▶ Typically, a more energy-efficient product/investment is also a less pollution-intensive product/investment
- ▶ It is very similar in the case of the energy efficiency when an EE gap exists
  - ▶ Suppose some market inefficiency leads to such a wedge/gap in energy efficiency
  - ▶ Then the existence of market power (usually regarded as a problem itself) can correct the under-allocation of energy efficiency
  - ▶ Q1. Why?
  - ▶ Q2. Implications?

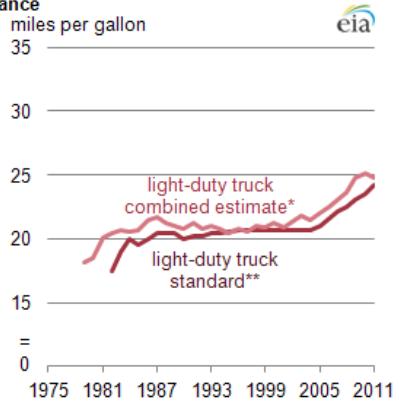
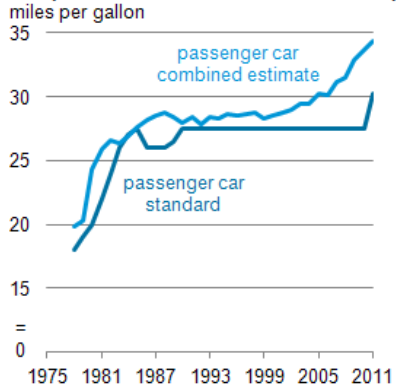




# 1 Background: Time Period 1999-2008

## 1.1 Regulation has been more-or-less flat & non-binding during 1999-2008

Comparison of CAFE Standards and Compliance



# 1 Background: Time Period 1999-2008

1.2 variation in fuel price: a lot of temporal variation and randomness  
 (driven by randomness and volatility in the upstream crude oil market)

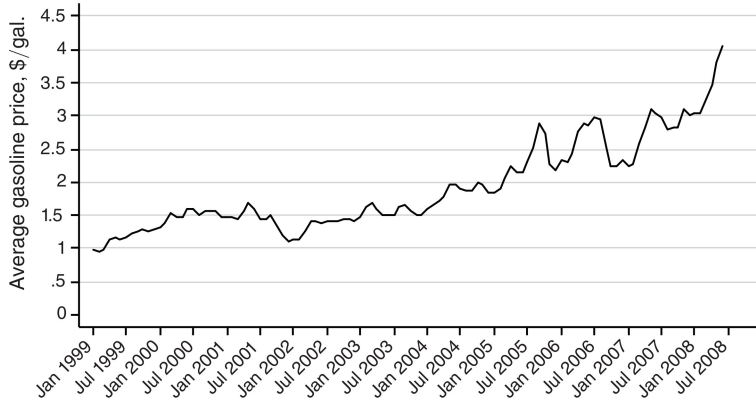


FIGURE 2. MONTHLY AVERAGE GASOLINE PRICES (*National*)

# 1 Background: Time Period 1999-2008

1.2 variation in fuel price: a lot of temporal variation and randomness  
 + cross-sectional variation across zipcode

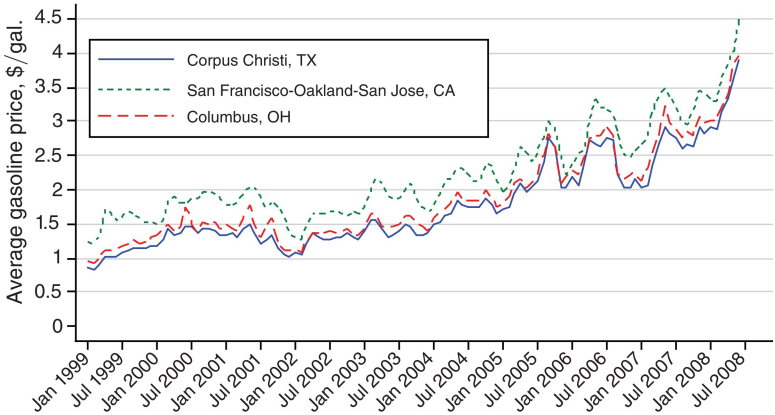


FIGURE 3. MONTHLY AVERAGE GASOLINE PRICES (by DMA)

## 2. Data

Transactional price data ( $\approx 20\%$  of national sales)

- ▶ Both new and used car purchases
- ▶ Also observe consumer demographics

Fuel economy rating data from EPA

- ▶ Available at a trim level, but needs to build a cross-walk to merge this in
- ▶ Usually, transactional level data also reports fuel economy (miles-per-gallon, MPG)  
But the best practice is to merge EPA MPG ratings.

Daily zipcode level gas price from OPIS

- ▶ To merge to transactional level data, they aggregate OPIS fuel price to Nielsen Designated Market Areas (DMA) level
- ▶ Nielsen define DMAs using common TA-viewing habit
- ▶ Roughly 210 DMAs in the US

# 3. Empirical Strategy

## 3.1 Regression 1: Price Regression for WTP (Both New and Used Cars)

For transaction  $i$  in region  $r$  on date  $t$  for vehicle  $j$ , the authors estimate:

$$P_{irjt} = \lambda_0 + \lambda_1(\text{GasPrice}_{it} \cdot \text{MPG Quartile}_j) + \lambda_2 \text{Demog}_{it} + \lambda_3 \text{PurchaseTiming}_{jt} + \delta_j + \tau_{rt} + \mu_{rt} + \epsilon_{irjt} \quad (2-3)$$

- ▶  $P$ : price
- ▶  $MPG \text{ Quartile}$ : 4 dummies, Q1 = lowest MPG in the model year, Q4 = the greatest
- ▶  $GasPrice$ : DMA-by-month gas price
- ▶ Seasonality:
  - ▶  $PurchaseTime$ : dummies for weekend, end of month FE, end of year  
also for new car:  $\Delta Year$  if model year = 2005 and bought in 2004  
also for used car: odometer spline X segment X PADD region
  - ▶ Location X Time FE: PADD region by year ( $\tau$ ), Padd X month-of-year ( $\mu$ )
- ▶  $\delta_j$ : Vehicle FE
- ▶ Q1. What are they comparing?
- ▶ Q2. What does  $\delta_j$  do here?

# 3. Empirical Strategy

## 3.2 Regression 2: Quantity Regression (New Cars)

For dealer  $d$  in region  $r$  on month  $t$  for vehicle in an MPG Quartile  $k$ , the authors estimate:

$$Q_{drkt} = \gamma_0 + \gamma_1(\text{GasPrice}_{dt} \cdot \text{MPG Quartile}_k) + \gamma_3 \text{MPG Quartile}_k + \delta_d + \tau_{rt} + \mu_{rt} + \epsilon_{dkrt} \quad (6)$$

- ▶  $Q$ : sales at dealer level
- ▶  $MPG \text{ Quartile}$ : 4 dummies, Q1 = lowest MPG in the model year, Q4 = the greatest
- ▶  $GasPrice$ : DMA-by-month gas price
- ▶ Seasonality in Location X Time FE: PADD region by year ( $\tau$ ), Padd X month-of-year ( $\mu$ )
- ▶  $\delta_d$ : Dealer FE
- ▶ Note: sales (or registration) data are typically more aggregated so Eq(6) can only be estimated at a location-product-time level (not a transaction level)
- ▶ Q3. What are they comparing?
- ▶ Q4. Why does Eq(6) need to control for MPG Quartile but Eq(2-3) doesn't need to?
- ▶ Q5: Why do we need Eq(6)? Shouldn't Eq(2-3) be enough for obtaining WTP?

# 3. Empirical Strategy

## 3.3 Converting estimates to $\Delta WTP$

- ▶ Equilibrium price changes  $\Delta P$  does not necessarily mean  $\Delta WTP$
- ▶  $\Delta WTP$  can be visualized as the vertical amount of shift in the demand curve
- ▶  $\Delta P$  can be regarded as  $\Delta WTP$  in used car market
- ▶  $\Delta P$  will be smaller than  $\Delta WTP$

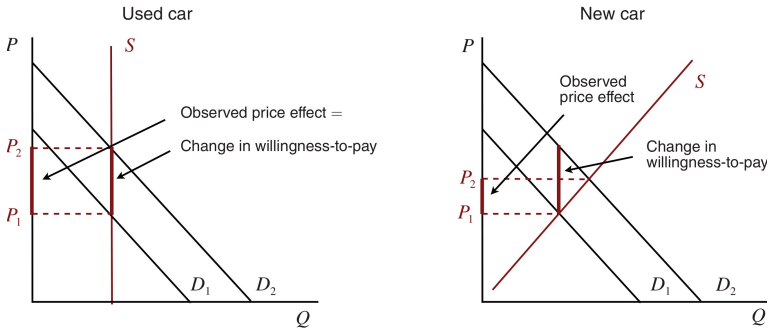


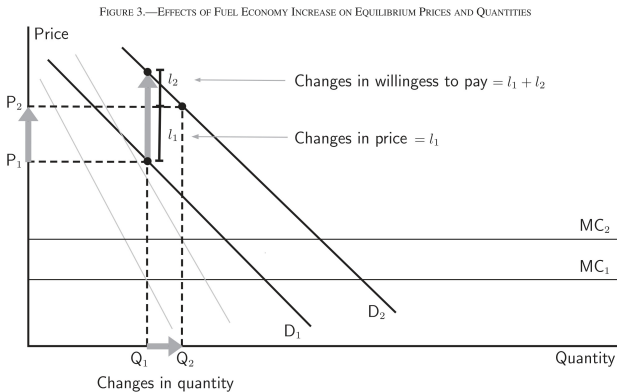
FIGURE 5. EFFECTS OF GASOLINE PRICE CHANGE ON HYPOTHETICAL USED AND NEW CARS

# 3. Empirical Strategy

## 3.3 Converting estimates to $\Delta WTP$ for new car market (imperfect competition)

Under imperfect competition, we need to (i) obtain both  $\Delta Q$  and  $\Delta P$  and (ii) assume an elasticity  $\varepsilon^d$  to compute  $\Delta WTP$

- ▶ Step 1, obtain  $\Delta P$  from Eq(2)  
obtain  $\Delta Q$  from Eq(6)
- ▶ Step 2, use a demand elasticity  $\varepsilon^d$  estimated in the literature to convert  $\Delta Q$  to  $l_2$
- ▶ Step 3,  $\Delta WTP = l_1 + l_2$



Source: Leard et al. (2023) REStat



## 4. Results for WTP

### 4.2 Quantity regressions for new cars

TABLE 6—GASOLINE PRICE COEFFICIENTS FROM DEALER-LEVEL UNIT SALES SPECIFICATION

Fuel economy	Coefficient	SE	Average cars sold per month in dealer	Percent change in sales
MPG Quartile 1 (lowest fuel economy)	-3.1***	(0.091)	11.2	-27.7
MPG Quartile 2	-0.83***	(0.087)	11.1	-7.5
MPG Quartile 3	-0.71***	(0.088)	13.0	-5.5
MPG Quartile 4 (highest fuel economy)	2.1***	(0.11)	17.8	11.8

# 4. Results for WTP

## 4.3 Computing $\Delta WTP$ for used cars (simply just $\Delta P$ ) for a \$1/gal fuel price shock

E.g., consider comparing MPG quartile 2 vs quartile 4:  $\Delta WTP = 763 - (-101) = \$864$

	A	B	C	D	E	F
1	<b>Estimates from paper</b>	<b>Price Effect</b>	<b>MPG</b>			
2	Q1	-1182	16.24			
3	Q2	-101	19.75			
4	Q3	468	22.67			
5	Q4	763	27.88			
6	<b>This is table 4 (price reg for used cars)</b>			Type "Q1" or "Q2"		
7				Type "Q3" or "Q4"		
8	<b>Scenarios</b>					
9	Top fuel efficiency quartile	Q2		Type "1" for NHTSA, "2" for used cars in our transaction data, or "3" for trade-ins in our transaction data (see "Survival-VMT Data" sheet for data)		
10	Top fuel efficiency quartile	Q4				
11	VMT Data Source	3				
12						
13						
14	<b>IPR Calculation</b>	<b>This is using <math>\Delta P</math> as <math>\Delta WTP</math></b>				
15	Estimated relative price change		864	Calculated cell: This is the estimated price change from our		
16	NPV of gasoline savings	970.0052862				
17	Difference	-106.0052862				
18	<b>Implied Discount Rate</b>	11.8%		Calculated cell: The NPV of gasoline savings for the IDR below from shifting from the low FE quartile to the high FE		
19						
20						
21						
22						
23						
24						
25						

Use "Goal Seek" to set the the "Difference" cell (B17) to value 0 by changing this cell (B18). As the IDR decreases,



# 4. Results for WTP

## 4.4 Computing $\Delta WTP$ for new cars (need to do $l_1 + l_2$ ) for a \$1/gal $f_p$ shock

E.g., consider  $|\epsilon^d| = 2$ , convert quantity effect into  $l_2$

This calculates the shift in demand, given a change in supply and changes in price

Quartile	1	2	3	4	5
94 Estimated Change in Price	1	-250			
95 Mean Price	1	31222			
96 %Change in P, Estimated	1	-0.80%			
97 %Change in Supply	1	-27.68%			
98 %Change in P, Old Demand	1	13.84%	9.23%	6.92%	5.54%
99 Level Change in P, Old Demand	1	4321	2881	2160	1728
100 Total Shift in Demand	1	-4571	-3131	-2410	-1978
103 Estimated Change in Price	2	-96			
104 Mean Price	2	28718			
105 %Change in P, Estimated (2023)	2	-0.33%			
106 %Change in Supply	2	-7.48%			
107 %Change in P, Old Demand	2	3.74%	2.49%	1.87%	1.50%
108 Level Change in P, Old Demand	2	1074	716	537	429
109 Total Shift in Demand	2	-1170	-812	-633	-525
112 Estimated Change in Price	3	-11			
113 Mean Price	3	26819			
114 %Change in P, Estimated	3	-0.04%			
115 %Change in Supply	3	-5.46%			
116 %Change in P, Old Demand	3	2.73%	1.82%	1.37%	1.09%
117 Level Change in P, Old Demand	3	732	488	366	293
118 Total Shift in Demand	3	-743	-499	-377	-304
121 Estimated Change in Price	4	104			
122 Mean Price	4	19080			
123 %Change in P, Estimated	4	0.55%			
124 %Change in Supply	4	11.80%			
125 %Change in P, Old Demand	4	-5.90%	-3.93%	-2.95%	-2.36%
126 Level Change in P, Old Demand	4	-1126	-750	-563	-450
127 Total Shift in Demand	4	1230	854	667	554

This is  $D2/E2 = -3.1/11.20 = -0.2789$

This is converting quantity change into  $l_2$

This is computing  $\Delta WTP = l_1 + l_2$

# 4. Results for WTP

## 4.4 Computing $\Delta WTP$ for new cars (need to do $I_1 + I_2$ ) for a \$1/gal $f_p$ shock

E.g., consider  $|\epsilon^d| = 2$ , convert compare  $\Delta WTP$  from Quartile 1 to 4:

This calculates the shift in demand, given a change in supply and changes in price

	Quartile	1	2	3	4	5
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112	Estimated Change in Price	3	-11			
113	Mean Price	3	26819			
114	%Change in P, Estimated	3	-0.04%			
115	%Change in Supply	3	-5.46%			
116	%Change in P, Old Demand	3	2.73%	1.82%	1.37%	1.09%
117	Level Change in P, Old Demand	3	732	488	366	293
118						
119	Total Shift in Demand	3	-743	-499	-377	-304
120						
121	Estimated Change in Price	4	104			
122	Mean Price	4	19080			
123	%Change in P, Estimated	4	0.55%			
124	%Change in Supply	4	11.80%			
125	%Change in P, Old Demand	4	-5.90%	-3.93%	-2.95%	-2.36%
126	Level Change in P, Old Demand	4	-1126	-750	-563	-450
127						
128	Total Shift in Demand	4	1230	854	667	554

This is  $D2/E2 = -3.1/11.20 = -0.2789$

This is converting quantity change into

This is computing  $\Delta WTP = I1 + I2$

Assume elasticity = 2  
Shift in demand between Quartile 1 and Quartile 4:  $4571 + 1230 = \$5810$

# 4. Results for WTP

## 4.4 Computing $\Delta WTP$ for new cars (need to do $l_1 + l_2$ ) for a \$1/gal $f_p$ shock

E.g., similarly consider  $|\varepsilon^d| = 3$ , convert compare  $\Delta WTP$  from Quartile 1 to 4:

This calculates the shift in demand, given a change in supply and changes in price

	Quartile	2	3	4	5	
94	Estimated Change in Price	1	-250			
95	Mean Price	1	31222			
96	%Change in P, Estimated	1	-0.80%			
97	%Change in Supply	1	-27.68%			
98	%Change in P, Old Demand	1	13.84%	9.23%	6.92%	5.54%
99	Level Change in P, Old Demand	1	4321	2881	2160	1728
100						
101	Total Shift in Demand	1	-4571	-3131	-2410	-1978
102						
103	Estimated Change in Price	2	-96			
104	Mean Price	2	28718			
105	%Change in P, Estimated	2	-0.33%			
106	%Change in Supply	2	-7.48%			
107	%Change in P, Old Demand	2	3.74%	2.49%	1.87%	1.50%
108	Level Change in P, Old Demand	2	1074	716	537	429
109						
110	Total Shift in Demand	2	-1170	-812	-633	-525
111						
112	Estimated Change in Price	3	-11			
113	Mean Price	3	26819			
114	%Change in P, Estimated	3	-0.04%			
115	%Change in Supply	3	-5.46%			
116	%Change in P, Old Demand	3	2.73%	1.82%	1.37%	1.09%
117	Level Change in P, Old Demand	3	732	488	366	293
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119	Total Shift in Demand	3	-743	-499	-377	-304
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121	Estimated Change in Price	4	104			
122	Mean Price	4	19080			
123	%Change in P, Estimated	4	0.55%			
124	%Change in Supply	4	11.80%			
125	%Change in P, Old Demand	4	-5.90%	-3.93%	-2.95%	-2.36%
126	Level Change in P, Old Demand	4	-1126	-750	-563	-450
127						
128	Total Shift in Demand	4	1230	854	667	554

Assume elasticity = 3

Shift in demand between Quartile 1 and Quartile 4: 854 + 3131 = \$3985

# 5. Consumer Valuation

## 5.1 Need to compute NPVs now

Still consider product  $j$  and  $k$  have identical attributes except for energy-efficiency:

$$\Delta WTP = \gamma \cdot \left( \underbrace{\sum_{t=0}^T \frac{p_e \cdot m \cdot e_k}{(1+r)^t} \cdot Prob(survive_t)}_{\text{NPV of energy cost for } k} - \underbrace{\sum_{t=0}^T \frac{p_e \cdot m \cdot e_j}{(1+r)^t} \cdot Prob(survive_t)}_{\text{NPV of energy cost for } j} \right) \quad (1.2)$$

- ▶  $p_e$ : energy price, e.g., gas price for cars, electricity price for homes and buildings
  - ▶ Use current fuel price for all future periods
  - ▶ Justification: Anderson, Kellogg, & Sallee (2013) JEEM: study on Michigan Surveys of Consumers (MSC)
- ▶  $e_j$ : energy consumption rate: gallon-per-mile (i.e., 1/mpg)
- ▶  $m_j$ : VMT per year, estimated from NHTSA (baseline)
- ▶  $Prob(survive)$ : Estimated from NHTSA survey
- ▶  $T$ : Estimated from NHTSA survey
- ▶ Suppose we let  $\gamma = 1$ , and compute what the implied discount rate  $r$  is
- ▶ **Evidence of full valuation**:  $r$  is exactly around the commonly recognized interest rate
- ▶ **Evidence of undervaluation (energy efficiency gap)**:  $r$  is way way way higher than typical interest rate

# 5. Consumer Valuation

## 5.1 VMT and Survival Probability: Estimated from NHTSA

	A	B	C	D	E	F	G	H	I	J
1	Cars					Trucks				
2	NHTSA Our Data Used Our Data All Tradeins					NHTSA Our Data Used Our Data All Tradeins				
3	Vintage	Survival Probability	VMT	VMT	VMT	Vintage	Survival Probability	VMT	VMT	VMT
4	1	0.9900	14,231	13440.02	10289.55	1	0.9741	16,085	11773.716	11600.789
5	2	0.9831	13,961	7470	11476.162	2	0.9603	15,782	9622.368	11822.672
6	3	0.9731	13,669	10969.271	13843.01	3	0.9420	15,442	13160.624	14383.616
7	4	0.9593	13,357	8600.024	13901.745	4	0.9190	15,069	10442.334	14678.356
8	5	0.9413	13,028	11297.035	14398.994	5	0.8913	14,667	12586.604	14588.514
9	6	0.9188	12,683	11651.548	13020.48	6	0.8590	14,239	12185.382	13141.949
10	7	0.8918	12,325	9825.615	11541.626	7	0.8226	13,790	11067.108	11906.399
11	8	0.8604	11,956	8934.048	10047.73	8	0.7827	13,323	10230.651	10419.275
12	9	0.8252	11,578	8483.017	8741.613	9	0.7401	12,844	9886.713	9378.01
13	10	0.7866	11,193	7384.775	7267.24	10	0.6956	12,356	8918.04	7837.77
14	11	0.7170	10,804	6164.867	5878.01	11	0.6501	11,863	7455.45	6478.08
15	12	0.6125	10,413	5311.2	4644.28	12	0.6040	11,369	6167.72	5014.68
16	13	0.5094	10,022	4373.89	3671.01	13	0.5517	10,879	3725.38	3521.19
17	14	0.4142	9,633	2867.14	2485.08	14	0.5009	10,396	2623.68	2409.81
18	15	0.3308	9,249	1848.06	1328.67	15	0.4522	9,924	310.4	744.85
19	16	0.2604	8,871	940.04	787.37	16	0.4062	9,468	-580.21	-513.83
20	17	0.2028	8,502	34.3	-453.1	17	0.3633	9,032	676.3	-693.84
21	18	0.1565	8,144	-990.51	-103.95	18	0.3236	8,619	-4129.13	-1308.13
22	19	0.1200	7,799	-824.77	-1461.79	19	0.2873	8,234	251.25	-968.78
23	20	0.0916	7,469	-3025.37	-759.49	20	0.2542	7,881	-3441.25	-1330.3
24	21	0.0696	7,157	-320.49	-2712.72	21	0.2244	7,565	-1962.22	-3680.88
25	22	0.0527	6,866	-2886.37	-3010.86	22	0.1975	7,288	-1905.99	-4522.84
26	23	0.0399	6,596	-4602.32	-1411.11	23	0.1735	7,055	-2798.08	-1051.8
27	24	0.0301	6,350	-1897.01	-146.63	24	0.1522	6,871	-1992.5	-1705.14
28	25	0.0227	6,131	-2583.04	-1922.11	25	0.1332	6,739	2489.19	1105.48
29						26	0.1165	6,663		
30						27	0.1017	6,648		
31						28	0.0887	6,648		
32						29	0.0773	6,648		
33						30	0.0673	6,648		
34						31	0.0586	6,648		
35						32	0.0509	6,648		
36						33	0.0443	6,648		
37						34	0.0385	6,648		
38						35	0.0334	6,648		
39						36	0.0290	6,648		

# 5. Consumer Valuation

## 5.1 Use VMT and Survival Probability to Compute Fuel Savings (in gallon)

	A	B	C	D	E	F	G	H	I	J
1	Estimates from paper	Price Effect	Average Price	Quantity Effect	Average Quantity	MPG				
2	Q1	-250	31222	-3.10	11.20	16.24				
3	Q2	-96	28718	-0.83	11.10	19.75				
4	Q3	-11	26819	-0.71	13.00	22.67				
5	Q4	104	19080	2.10	17.80	27.88				
6										
7										
8	Scenarios									
9	Top fuel efficiency quartile	Q1								
10	Top fuel efficiency quartile	Q4								
11	VMT Data Source	2								
12	Assumed elasticity	3								
13										
14	IPR Calculation									
15	Estimated relative price change	3984.94								
16	NPV of gasoline savings	3984.94								
17	Difference	0.00								
18	Implied Discount Rate	-3.0%								
19										
20										
21										
22										
23										
24										
25										
26										
47	Bottom quartile MPG	16.24								
48	High quartile MPG	27.88								
49										
50										
51										
52										
53										
54	Vintage	Survival Probability	VMT	Survival Probability	VMT	Weighted SP	Weighted VMT	Fuel Savings	Discounted Savings	Summed Savings
55	1	0.9900	13,440	0.9741	11,774	0.9822	12405.56671	318.9266377	318.9266377	318.9266377
56	2	0.9831	7,470	0.9603	9,622	0.9719	8273.092465	212.6875479	219.1949309	538.1215686
56	3	0.9731	10,969	0.9420	13,161	0.9579	11518.52161	296.1221728	314.5196701	852.6412388

Type "Q1" or "Q2"

Type "Q3" or "Q4"

Type "1" for NHTSA, "2" for used cars in our transaction data, or "3" for trade-ins in our transaction data

Type "2", "3", "4", or "5"

Calculated cell: This is the estimated price change from our

Calculated cell: The NPV of gasoline savings for the IDR below from shifting from the low FE quartile to the high FE

Use "Goal Seek" to set the the "Difference" cell (B17) to value 0 by changing this cell (B18). As the IDR decreases,

$m * e = \text{VMT (miles)} * \text{efficiency (gallon-per-mile)}$   
 $= \text{VMT} * (1/\text{mpg})$   
 $m * e = \text{fuel use in gallon}$

**E.g., cell H54**  
**fuel use in year 1**  
 $= \text{VMT}(\text{yr1})/\text{mpg}(\text{j}) - \text{VMT}(\text{yr2})/\text{mpg}(\text{k})$   
 $= 12406/16.24 - 12406 / 27.88$   
 $= 319 \text{ gallon}$



This is from our transaction data. Is used t

# 5. Consumer Valuation

## 5.1 Fuel Savings (in gallon) is also Fuel Cost Savings (in \$) for \$1/gal *fp* shock

	A	B	C	D	E	F	G	H	I	J
1	Estimates from paper	Price Effect	Average Price	Quantity Effect	Average Quantity	MPG				
2	Q1	-250	31222	-3.10	11.20	16.24				
3	Q2	-96	28718	-0.83	11.10	19.75				
4	Q3	-11	26819	-0.71	13.00	22.67				
5	Q4	104	19080	2.10	17.80	27.88				
6										
7										
8	Scenarios									
9	Top fuel efficiency quartile	Q1								
10	Top fuel efficiency quartile	Q4								
11	VMT Data Source	2								
12	Assumed elasticity	3								
13										
14	IPR Calculation									
15	Estimated relative price change	3984.94								
16	NPV of gasoline savings	3984.94								
17	Difference	0.00								
18	Implied Discount Rate	-3.0%								
19										
20										
21										
22										
23										
24										
25										
26										
47	Bottom quartile MPG	16.24								
48	High quartile MPG	27.88								
49										
50										
51										
52										
53										
54	Vintage	Survival Probability	VMT	Survival Probability	VMT	Weighted SP	Weighted VMT	Fuel Savings	Discounted Savings	Summed Savings
55	1	0.9900	13,440	0.9741	11,774	0.9822	12405.56671	318.9266377	318.9266377	318.9266377
56	2	0.9831	7,470	0.9603	9,622	0.9719	8273.092465	212.6875479	219.1949309	538.1215686
56	3	0.9731	10,969	0.9420	13,161	0.9579	11518.52161	296.1221728	314.5196701	852.6412388

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Calculated cell: This is the estimated price change from our

Calculated cell: The NPV of gasoline savings for the IDR below from shifting from the low FE quartile to the high FE

Use "Goal Seek" to set the the "Difference" cell (B17) to value 0 by changing this cell (B18). As the IDR decreases,

$m * e = \text{VMT (miles)} * \text{efficiency (gallon-per-mile)}$   
 $= \text{VMT} * (1/\text{mpg})$   
 $m * e = \text{fuel use in gallon}$

E.g., cell H54  
 fuel use in year 1  
 $= \text{VMT}(\text{yr1})/\text{mpg}(\text{j}) - \text{VMT}(\text{yr2})/\text{mpg}(\text{k})$   
 $= 12406/16.24 - 12406 / 27.88$   
 $= 319 \text{ gallon}$



This is from our transaction data. Is used t

# 5. Consumer Valuation

## 5.1 Compute cumulating savings (i.e., NPV) for an assumed implied discount factor

	A	B	C	D	E	F	G	H	I	J
1	Estimates from paper	Price Effect	Average Price	Quantity Effect	Average Quantity	MPG				
2	Q1	-250	31222	-3.10	11.20	16.24				
3	Q2	-96	28718	-0.83	11.10	19.75				
4	Q3	-11	26819	-0.71	13.00	22.67				
5	Q4	104	19080	2.10	17.80	27.88				
6										
7										
8	Scenarios									
9	Top fuel efficiency quartile	Q1								
10	Top fuel efficiency quartile	Q4								
11	VMT Data Source	2								
12	Assumed elasticity	3								
13										
14	IPR Calculation									
15	Estimated relative price change	3984.94								
16	NPV of gasoline savings	3984.94								
17	Difference	0.00								
18	Implied Discount Rate	-3.0%								
19										
20										
21										
22										
23										
24										
25										
26										
47	Bottom quartile MPG	16.24								
48	High quartile MPG	27.88								
49										
50										
51										
52										
53										
54	Vintage	Survival Probability	VMT	Survival Probability	VMT	Weighted SP	Weighted VMT	Fuel Savings	Discounted Savings	Summed Savings
55	1	0.9900	13,440	0.9741	11,774	0.9822	12405.56671	318.9266377	318.9266377	318.9266377
56	2	0.9831	7,470	0.9603	9,622	0.9719	8273.092465	212.6875479	219.1949309	538.1215686
56	3	0.9731	10,969	0.9420	13,161	0.9579	11518.52161	296.1221728	314.5196701	852.6412388

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Calculated cell: This is the estimated price change from our

Calculated cell: The NPV of gasoline savings for the IDR below from shifting from the low FE quartile to the high FE

Use "Goal Seek" to set the the "Difference" cell (B17) to value 0 by changing this cell (B18). As the IDR decreases,

$m^* = \text{VMT (miles)} * \text{efficiency (gallon-per-mile)}$   
 $= \text{VMT} * (1/\text{mpg})$   
 $m^* = \text{fuel use in gallon}$

E.g., cell H54  
 fuel use in year 1  
 $= \text{VMT}(\text{yr1})/\text{mpg}(\text{j}) - \text{VMT}(\text{yr2})/\text{mpg}(\text{k})$   
 $= 12406/16.24 - 12406 / 27.88$   
 $= 319 \text{ gallon}$

Cumulative savings

This is from our transaction data... used t

# 5. Consumer Valuation

## 5.1 Adjust implied discount factor (IDR) till $\Delta WTP = \Delta NPV$

	A	B	C	D	E	F	G	H	I	J
1	Estimates from paper	Price Effect	Average Price	Quantity Effect	Average Quantity	MPG				
2	Q1	-250	31222	-3.10	11.20	16.24				
3	Q2	-96	28718	-0.83	11.10	19.75				
4	Q3	-11	26819	-0.71	13.00	22.67				
5	Q4	104	19080	2.10	17.80	27.88				
8	Scenarios									
9	Top fuel efficiency quartile	Q1								
10	Top fuel efficiency quartile	Q4								
11	VMT Data Source	2								
12	Assumed elasticity	3								
14	IPR Calculation									
15	Estimated relative price change	3984.94								
16	NPV of gasoline savings	3984.94								
17	Difference	0.00								
18	Implied Discount Rate	-3.0%								
47	Bottom quartile MPG		16.24							
48	High quartile MPG		27.88							
53										
54	<b>Vintage</b>	<b>Survival Probability</b>	<b>VMT</b>	<b>Survival Probability</b>	<b>VMT</b>	<b>Weighted SP</b>	<b>Weighted VMT</b>	<b>Fuel Savings</b>	<b>Discounted Savings</b>	<b>Summed Savings</b>
55	1	0.9900	13,440	0.9741	11,774	0.9822	12405.56671	318.9266377	318.9266377	318.9266377
56	2	0.9831	7,470	0.9603	9,622	0.9719	8273.092465	212.6875479	219.1949309	538.1215686
56	3	0.9731	10,969	0.9420	13,161	0.9579	11518.52161	296.1221728	314.5196701	852.6412388

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Use "Goal Seek" to set the the "Difference" cell (B17) to value 0 by changing this cell (B18). As the IDR decreases,

$$m * e = \text{VMT (miles)} * \text{efficiency (gallon-per-mile)} = \text{VMT} * (1/\text{mpg})$$

$m * e = \text{fuel use in gallon}$

E.g., cell H54

$$\text{fuel use in year 1} = \text{VMT}(\text{yr1})/\text{mpg}(j) - \text{VMT}(\text{yr2})/\text{mpg}(k)$$

$$= 12406/16.24 - 12406 / 27.88$$

$$= 319 \text{ gallon}$$

Cumulative savings

This is from our transaction data... used t

# 5. Consumer Valuation

## 5.2 Results for implied discount rate (IDR): Consistent with full valuation

TABLE 9—NEW AND USED CARS: IMPLICIT DISCOUNT RATES

	Market	Assumed demand elasticity	NHTSA VMT, NHTSA survival rates (%)	VMT from used car transactions, NHTSA survival rates (%)	VMT from trade-ins, NHTSA survival rates (%)
Q1 versus Q4	Used	NA	11.8	4.4	7.3
	New	-2	-4.0	-6.8	-6.2
	New	-3	1.0	-3.0	-1.9
	New	-4	5.5	0.5	2.1
	New	-5	9.8	3.7	5.8
Q1 versus Q3	Used	NA	5.9	0.1	1.9
	New	-2	-3.6	-6.6	-5.9
	New	-3	1.5	-2.6	-1.5
	New	-4	6.1	0.9	2.5
	New	-5	10.4	4.2	6.3
Q2 versus Q4	Used	NA	20.9	11.0	16.2
	New	-2	0.3	-3.5	-2.5
	New	-3	6.7	1.4	3.1
	New	-4	12.6	5.8	8.3
	New	-5	18.3	10.0	13.2

- ▶ Compare to plausible interest rate (or real APR with CPI adjusted)
- ▶ New cars: APR from 1.9% to 11.6%; real APR from -0.9% to 9.0%
- ▶ Used cars: APR from 5.5% to 19.7%; real APR from 2.8% to 16.9%

# Outline

- ▶ Introduction ✓
- ▶ Example 1: Busse, Knittel, & Zettlemeyer (2013) AER ✓
- ▶ Example 2: Gillingham, Houde, & van Benthem (2021) AEJ:EP
- ▶ Example 3: Sallee & Fan (2016) JPubE
- ▶ Example 4: Myers (2019) AEJ-EP
- ▶ Example 5: Myers (2020) JPubE
- ▶ Future directions





# Models Detected by EPA for MY 2011-2013

Hyundai: Accent, Azera, Elantra, Genesis, Santa Fe, Sonata, Tucson, Veloster

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Model	Model Year	Trim	Engine	Drive	Tran.	Original City Hwy miles-per-gallon	Rating City Hwy MPG	Comb. MPG	Restated City MPG	Rating Hwy MPG	Comb. MPG
Elantra	2011		1.8L		Automatic	29	40	33	28	38	32
Elantra	2011		1.8L		Manual	29	40	33	28	38	32
Sonata HEV	2011		2.4L		Automatic	35	40	37	34	39	36
Accent	2012		1.6L		Automatic	30	40	33	28	37	31
Accent	2012		1.6L		Manual	30	40	34	28	37	32
Azera	2012		3.3L		Automatic	20	29	23	20	28	23
Elantra	2012		1.8L		Automatic	29	40	33	28	38	32
Elantra	2012		1.8L		Manual	29	40	33	28	38	32
Genesis	2012		3.8L		Automatic	19	29	22	18	28	22
Genesis	2012		4.6L		Automatic	17	26	20	16	25	19
Genesis	2012		5.0L		Automatic	17	26	20	17	25	20
Genesis	2012		5.0L R-Spec		Automatic	16	25	19	16	25	18
Sonata HEV	2012		2.4L		Automatic	35	40	37	34	39	36
Tucson	2012		2.0L	2WD	Automatic	23	31	26	22	29	25
Tucson	2012		2.0L	2WD	Manual	20	27	23	20	26	22
Tucson	2012		2.4L	2WD	Automatic	22	32	25	21	30	25
Tucson	2012		2.4L	4WD	Automatic	21	28	23	20	27	23
Veloster	2012		1.6L		Automatic	29	38	32	27	35	30
Veloster	2012		1.6L		Manual	28	40	32	27	37	31
Accent	2013		1.6L		Automatic	30	40	33	28	37	31
Accent	2013		1.6L		Manual	30	40	34	28	37	32
Azera	2013		3.3L		Automatic	20	30	24	20	29	23
Elantra	2013		1.8L		Automatic	29	40	33	28	38	32
Elantra	2013		1.8L		Manual	29	40	33	28	38	32
Elantra	2013	Coupe	1.8L		Automatic	28	39	32	27	37	31
Elantra	2013	Coupe	1.8L		Manual	29	40	33	28	38	32
Elantra	2013	GT	1.8L		Automatic	28	39	32	27	37	30
Elantra	2013	GT	1.8L		Manual	27	39	31	26	37	30
Genesis	2013		3.8L		Automatic	19	29	22	18	28	22
Genesis	2013		5.0L R-Spec		Automatic	16	25	19	16	25	18
Santa Fe	2013		2.0L Turbo	2WD	Automatic	21	31	25	20	27	23
Santa Fe	2013		2.4L	2WD	Automatic	22	33	26	21	29	24
Santa Fe	2013		2.0L Turbo	4WD	Automatic	20	27	22	19	24	21
Santa Fe	2013		2.4L	4WD	Automatic	21	28	23	20	26	22
Tucson	2013		2.0L	2WD	Automatic	23	31	26	22	29	25
Tucson	2013		2.0L	2WD	Manual	20	27	23	20	26	22
Tucson	2013		2.4L	2WD	Automatic	22	32	25	21	30	25
Tucson	2013		2.4L	4WD	Automatic	21	28	23	20	27	23
Veloster	2013		1.6L		Automatic	29	40	33	28	37	31
Veloster	2013		1.6L Turbo		Automatic	25	34	29	24	31	28
Veloster	2013		1.6L		Manual	28	40	32	27	37	31
Veloster	2013		1.6L Turbo		Manual	26	38	30	24	35	28

# Models Detected by EPA for MY 2011-2013

Kia: Optima Hybrid, Rio, Sorento, Soul, Sportage

(1) Model	(2) Model Year	(3) Trim	(4) Engine	(5) Drive	(6) Tran.	(7) (8) (9) Original Rating			(10) (11) (12) Restated Rating		
						City MPG	Hwy MPG	Comb. MPG	City MPG	Hwy MPG	Comb. MPG
Optima HEV	2011		2.4L	2WD	Automatic	35	40	37	34	39	36
Rio	2012		1.6L	2WD	Automatic	30	40	33	28	36	31
Rio	2012		1.6L	2WD	Manual	30	40	34	29	37	32
Sorento	2012	GDI	2.4L	2WD	Automatic	22	32	25	21	30	24
Sorento	2012	GDI	2.4L	4WD	Automatic	21	28	23	20	26	22
Soul	2012		1.6L	2WD	Automatic	27	35	30	25	30	27
Soul	2012		1.6L	2WD	Manual	27	35	30	25	30	27
Soul	2012		2.0L	2WD	Automatic	26	34	29	23	28	25
Soul	2012		2.0L	2WD	Manual	26	34	29	24	29	26
Soul	2012	ECO	1.6L	2WD	Automatic	29	36	32	26	31	28
Soul	2012	ECO	2.0L	2WD	Automatic	27	35	30	24	29	26
Sportage	2012		2.0L	2WD	Automatic	22	29	24	21	28	24
Sportage	2012		2.4L	2WD	Automatic	22	32	25	21	30	25
Sportage	2012		2.4L	2WD	Manual	21	29	24	20	27	23
Sportage	2012		2.0L	4WD	Automatic	21	26	23	20	25	22
Sportage	2012		2.4L	4WD	Automatic	21	28	24	20	27	23
Optima HEV	2012		2.4L	2WD	Automatic	35	40	37	34	39	36
Rio	2013		1.6L	2WD	Automatic	30	40	33	28	36	31
Rio	2013		1.6L	2WD	Manual	30	40	34	29	37	32
Rio	2013	ECO	1.6L	2WD	Automatic	31	40	34	30	36	32
Sorento	2013	GDI	2.4L	2WD	Automatic	22	32	25	21	30	24
Sorento	2013	GDI	2.4L	4WD	Automatic	21	28	23	20	26	22
Soul	2013		1.6L	2WD	Automatic	27	35	30	25	30	27
Soul	2013		1.6L	2WD	Manual	27	35	30	25	30	27
Soul	2013		2.0L	2WD	Automatic	26	34	29	23	28	25
Soul	2013		2.0L	2WD	Manual	26	34	29	24	29	26
Soul	2013	ECO	1.6L	2WD	Automatic	29	36	32	26	31	28
Soul	2013	ECO	2.0L	2WD	Automatic	27	35	30	24	29	26
Sportage	2012		2.0L	2WD	Automatic	22	29	24	21	28	24
Sportage	2012		2.4L	2WD	Automatic	22	32	25	21	30	25
Sportage	2012		2.4L	2WD	Manual	21	29	24	20	27	23
Sportage	2012		2.0L	4WD	Automatic	21	26	23	20	25	22
Sportage	2012		2.4L	4WD	Automatic	21	28	24	20	27	23

# Models with Inflated MPG from Hyundai & Kia

Potential strategic choices at the model level across market segments

TABLE 1—MEAN SALES, PRICES, AND CHARACTERISTICS ACROSS AUTOMAKERS

	Affected models		Not affected models		
	Hyundai (1)	Kia (2)	Hyundai (3)	Kia (4)	Others (5)
<i>Panel A. Sales and transaction prices</i>					
Total sales (1,000s)	1,041	516	944	1,001	26,300
Price (1,000s \$)	21.6	20.0	24.1	23.5	28.6
Number of models by model year	16	10	49	36	1,131
<i>Panel B. Selected vehicle characteristics</i>					
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 (1,000s \$)	20.8	18.9	24.1	22.8	28.7
Fuel economy (miles/gallon)	29.5	25.8	27.0	27.0	26.4

- ▶ Carmakers deciding which model to inflate is not random
- ▶ EPA deciding which model gets audited is plausibly random

# Data

## Transactional price data from RL Polk (now IHS Markit)

- ▶ New car purchases August 2011 - June 2014
- ▶ Also observe consumer demographics
- ▶ Observe VIN for each car: Can extract attributes

## Fuel economy rating data + Fuel economy restatement from EPA

- ▶ Available at a trim level, can be merged in as in BKZ (2013)

## Other data

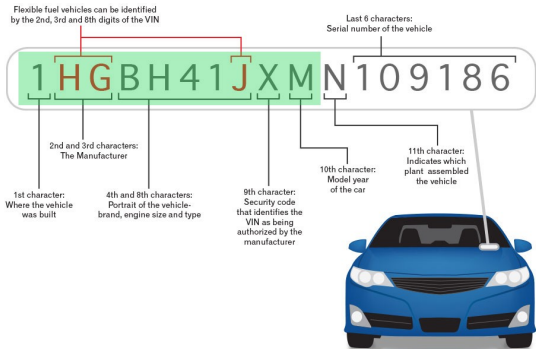
- ▶ National gas price by year from EIA
- ▶ 210 Nielsen designated Market Area (DMA) by Nielsen as in BKZ (2013)

## Data for computing the NPV

- ▶ VMT: NHTSA (base), BKZ's survey (robustness)
- ▶ Vehicle survival rate: RP Polk (base), NHTSA (robustness), BKZ's survey (robustness)
- ▶ Gas price: annual national by EIA (base), state X month by EIA (robustness)

# Define a product $j$

Using VIN10, the first 10 digits of VIN out of 17 digits



- ▶ Many past studies use trim as product  $j$  (e.g., Accord LX vs Accord SE)
- ▶ Or at best using model-variant as  $j$  (e.g., trim X fuel type X body type X engine size)
- ▶ There may still be product differences below a typical model-variant level
- ▶ This study uses **VIN 10** as  $j$ , effectively **the finest model-variant X model year**

# Empirical Strategy

## Two regressions

### Regression 1: An Equilibrium Price Regression

$$P_{rjt} = \beta \mathbf{1}(\text{Affected Models})_j \times \mathbf{1}(\text{Post Restatement})_t + \text{Controls} + \text{FEs} + \varepsilon_{rjt}$$

- ▶ Focus on  $\beta$ : the effect of restatement on equilibrium price

### Regression 2: An Equilibrium Price Regression on changes in NPV

$$P_{rjt} = \gamma \Delta G_{jt} + \text{Controls} + \text{FEs} + \varepsilon_{rjt}$$

- ▶ Focus on  $\gamma$ : the effect of  $\Delta NPV$  from restatement on equilibrium price
- ▶  $\gamma$  is the valuation ratio (in some context)
- ▶  $\gamma$  is almost the valuation ratio in this study
- ▶ We will cover a brief part from Allcott & Wozney (2014) REStat to explain this part

# Empirical Strategy

## A price regression using DID estimator

Define a product  $j$  is defined by VIN 10 (aka model variant VIN 9 X model year)

For all transactions in DMA region  $r$  on year-month  $t$  for vehicle  $j$ , the authors estimate:

$$P_{ijt} = \beta \mathbf{1}(\text{Affected Models})_j \times \mathbf{1}(\text{Post Restatement})_t + \eta_r \mathbf{1}(\text{Post Restatement})_t + \rho_{t,class} + \mu_{t,make} + \omega_j + \eta_r + \varepsilon_{ijt} \quad (1)$$

- ▶  $P$ : price
- ▶  $\omega_j$ : vehicle FE
- ▶  $\eta_r$ : DMA region FE
- ▶ Seasonality FE: class X year month FE  $\rho_{t,class}$   
make X year month FE  $\mu_{t,make}$
- ▶ Note: calendar year  $\neq$  model year
- ▶ Q1. What are they comparing?  
What variation is responsible for identification?

# Price Regression Results

Effect of restatement: Price would be lower by 1.2% or \$294

TABLE 2—EFFECT OF RESTATEMENT ON TRANSACTION PRICES

	logs			Levels		
	(1)	(2)	(3)	(4)	(5)	(6)
$\mathbf{1 (Post Restatement)}_i \times \mathbf{1 (Affected Model)}_j$	-0.010 (0.004)	-0.010 (0.004)	<b>-0.012</b> <b>(0.003)</b>	-150 (80)	-259 (94)	<b>-294</b> <b>(91)</b>
Year-month $\times$ class fixed effects		Yes	Yes		Yes	Yes
Year-month $\times$ make fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
VIN10 fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
DMA fixed effects	Yes		Yes	Yes		Yes
$\mathbf{1(Post Restatement)} \times$ DMA fixed effects	Yes		Yes	Yes		Yes
$R^2$	0.95	0.92	0.95	0.96	0.95	0.96
Observations	1.52m	1.52m	1.52m	1.52m	1.52m	1.52m

Notes: Dependent variable is the log or level of the transaction price (in dollars). An observation is a year-month-DMA-VIN10. VIN10 refers to the VIN prefix, which is a trim-engine combination. DMA refers to a Nielsen Designated Market Area, which is an area covering several counties. Class refers to the vehicle class. Post Restatement refers to the year-month being during or after November 2012. All estimations are weighted by monthly sales. Standard errors clustered by VIN10.

# Price Regression Results

## Event study version

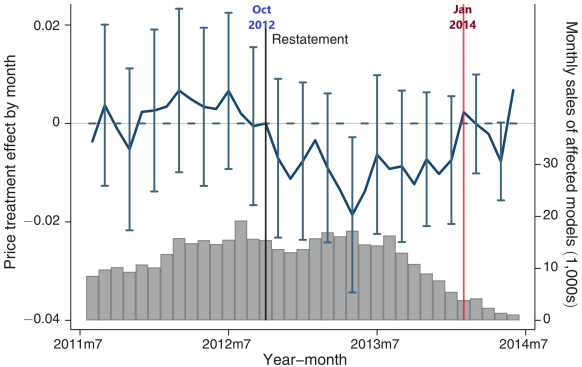


FIGURE 1. THE PRICE EFFECT OF THE RESTATEMENT ON AFFECTED MODELS BY MONTH ALONG WITH THE MONTHLY SALES OF AFFECTED MODELS

- ▶ Despite imprecision (Q2: Do you know why Fig 1 is not precise? Hint: Think about  $j$ )
- ▶ The notable results are that the effect disappears in 15 months after Jan 2014

# Empirical Strategy

## A regression on (almost) valuation ratio

For all transactions in DMA region  $r$  on year-month  $t$  for vehicle  $j$  (defined as a VIN 10), the authors estimate:

$$P_{ijt} = \gamma \Delta G_{jt} + \eta_r \mathbf{1}(\text{Post Restatement})_t + \rho_{t,class} + \mu_{t,make} + \omega_j + \eta_r + \varepsilon_{ijt} \quad (2)$$

- ▶  $P$ : price
- ▶  $\Delta G$ : implied  $\Delta NPV$  given  $\Delta mpg$  generated by the restatement
  - e.g.,  $\Delta G = \$0$  for unaffected models
  - e.g.,  $\Delta G > \$0$  for restated models
- ▶  $\gamma$ : valuation ratio parameter if no sales effect (aka no  $l_2$  in Slide 26)
  - i.e.,  $|\gamma|$  can be regarded as the valuation ratio if the data are on used vehicles
- ▶  $\omega_j$ : vehicle FE
- ▶  $\eta_r$ : DMA region FE
- ▶ Seasonality FE: class X year month FE  $\rho_{t,class}$   
make X year month FE  $\mu_{t,make}$
- ▶ Where does this regression come from?

# Allcott & Wozny (2014) REStat

Explain Eq(2) requires a bit AW (2014), who studied VR for used car market

Transform demand estimation into a price regression

$$\ln s_{jt} - \ln s_{0t} = -\eta p_{jt} - \eta \gamma G_{jt} + \varphi_j + \nu_{jt} \quad (\text{AW-2})$$

$$p_{jt} = -\gamma G_{jt} - \frac{1}{\eta} (\ln s_{jt} - \ln s_{0t}) + \phi_j + \xi_{jt} \quad (\text{AW-3})$$

$$p_{jt} = -\gamma G_{jt} + \phi_j + \phi_t + \varepsilon_{jt} \quad (\text{AW-5})$$

- ▶ In Eq (AW-2), consider a demand estimation equation (following Berry (1994) or BLP (1995))
  - ▶  $\eta$  is the price coefficient for everything related to the cost of buying & using a vehicle
  - ▶  $G$  is the *NPV*, so  $\gamma$  represent valuation ratio
- ▶ Re-arrange Eq (AW-2) into Eq (AW-3) by moving price to LHS and  $G$  to RHS
  - ▶ A regression of  $p$  on  $NPV$  with product FE ( $\phi_j$ ) + an extra term ( $\ln s_{jt} - \ln s_{0t}$ )
  - ▶ Note 1:  $\ln s_{0t}$  can be completely absorbed by time FE
  - ▶ Note 2:  $\ln s_{jt}$  can be grouped into error term  
(It is not an omitted confounder as it is unlikely to be correlated with  $G_{jt}$  for used vehicles)
- ▶ Re-arrange into Eq (AW-5):  $\gamma$  represents valuation ratio if no sales effect
  - ▶ AW (2013) and other studies construct  $G_{jt}$  and use temporal variation in  $fp_t$
  - ▶ GHvB (2021) construct  $\Delta G_{jt}$  use within- $j$  temporal variation in  $mpg_{jt}$

# Results on (Almost) Valuation Ratio $\hat{\gamma}$

Effect of  $\Delta NPV = \$1$  on equilibrium price: **-\$0.17**

TABLE 6—THE VALUATION OF FUEL ECONOMY BASED ON THE EQUILIBRIUM PRICE CHANGE

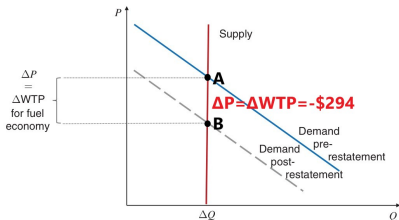
	$r = 1\%$		$r = 4\%$		$r = 7\%$		$r = 12\%$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\mathbf{1}(\Delta Lifetime Fuel Costs)_{jt}$ $\times \mathbf{1}(Affected Model)_j$	-0.14 (0.05)		<b>-0.17</b> (0.06)		-0.20 (0.07)		-0.25 (0.08)	
$\mathbf{1}(\Delta Lifetime Fuel Costs)_{jt}$ $\times \mathbf{1}(2011-2012 Affected Model)_j$		-0.33 (0.17)		-0.39 (0.20)		-0.46 (0.24)		-0.58 (0.30)
$\mathbf{1}(\Delta Lifetime Fuel Costs)_{jt}$ $\times \mathbf{1}(2013 Affected Model)_j$		-0.13 (0.05)		-0.16 (0.06)		-0.18 (0.07)		-0.23 (0.08)
Year-month $\times$ class fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-month $\times$ make fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VIN10 fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
DMA fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\mathbf{1}(Post Restatement)$ $\times$ DMA fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$R^2$	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Observations	1.52m	1.52m	1.52m	1.52m	1.52m	1.52m	1.52m	1.52m

- ▶ Baseline assumes discount rate  $r = 4\%$
- ▶ Consider sales effect,  $\gamma = 17\%$  is a lower bound

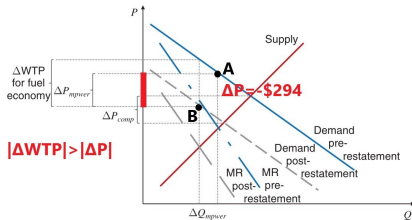
# $\hat{\gamma} = 17\%$ as a lower bound of valuation ratio

Recall: size of  $\Delta P$  is a lower bound of  $\Delta WTP$  as long as supply is normal

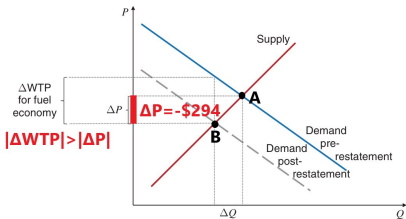
Panel A. Inelastic supply



Panel C. Market power and upward-sloping supply



Panel B. Upward-sloping supply



Panel D. Downward-sloping supply

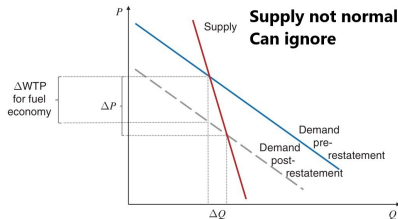


FIGURE 3. INTERPRETATION OF THE EQUILIBRIUM EFFECT

FIGURE 3. INTERPRETATION OF THE EQUILIBRIUM EFFECT (CONTINUED)

# Compute the range of VR ( $\hat{\gamma}$ ) if $\Delta Q\% \in [-5\%, 0\%]$

Compute  $\Delta WTP$  and then the VR

TABLE 7—INTERPRETATION OF EQUILIBRIUM CHANGE IN PRICES WITH RESPECT TO DIFFERENT SUPPLY CURVES

Quantity effect (%)	Willingness to Pay (\$) $\eta_D = -6$	Willingness to Pay (\$) $\eta_D = -4$
-5	498	600
-1	335	355
0	294	294
1	253	233
5	90	-12

**Let's not consider downward sloping supply**

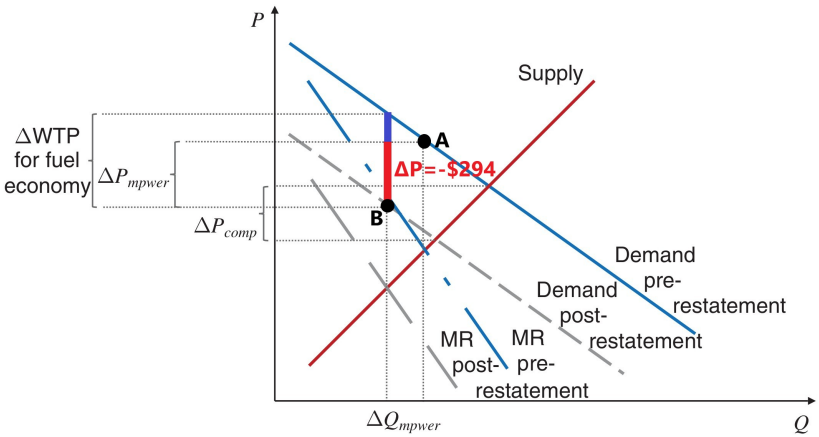
Notes: The table shows how a given equilibrium change in price translates into willingness to pay for fuel economy (under perfect competition).  $\eta_D$  refers to the price elasticity of demand that we use in our calculations. For all rows, we use an equilibrium change in transaction prices of \$294, following our primary results. These illustrative calculations are also based on an average preresatement price of \$24,500.

- ▶ When sales effect = 0,  $|\Delta WTP| = \$294$
- ▶ I will demonstrate the example when  $\Delta Q = -1\%$  and demand elasticity = -4
- ▶ We will show  $|\Delta WTP| = \$355$  and we will compute VR

# Compute the range of VR ( $\hat{\gamma}$ ) if $\Delta Q\% \in [-5\%, 0\%]$

Example: Suppose quantity effect is  $\Delta Q = -1\%$

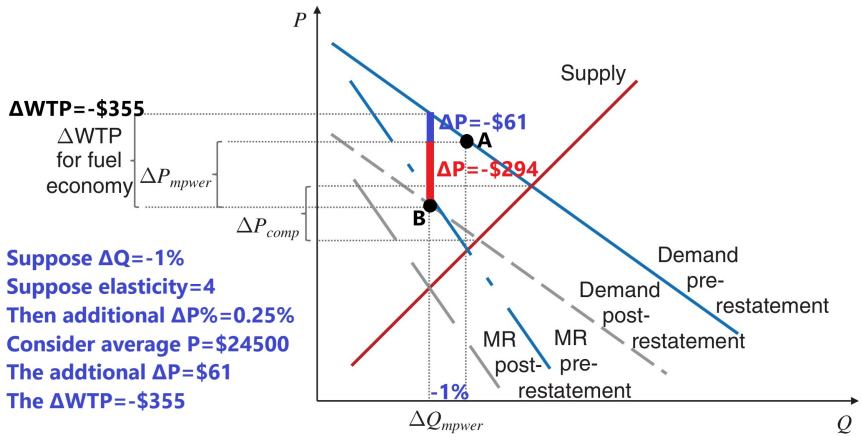
Panel C. Market power and upward-sloping supply



# Compute the range of VR ( $\hat{\gamma}$ ) if $\Delta Q\% \in [-5\%, 0\%]$

Example: Suppose quantity effect is  $\Delta Q = -1\%$

Panel C. Market power and upward-sloping supply

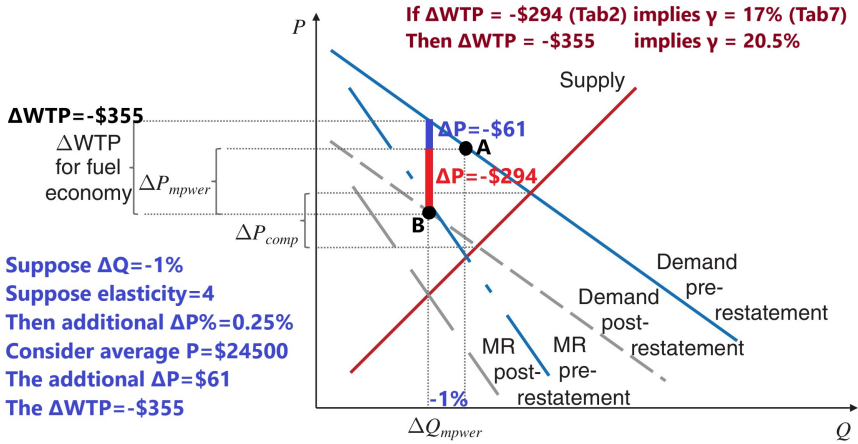


Suppose  $\Delta Q = -1\%$   
 Suppose elasticity = 4  
 Then additional  $\Delta P\% = 0.25\%$   
 Consider average  $P = \$24500$   
 The additional  $\Delta P = \$61$   
 The  $\Delta WTP = -\$355$

# Compute the range of VR ( $\hat{\gamma}$ ) if $\Delta Q\% \in [-5\%, 0\%]$

Example: Suppose quantity effect is  $\Delta Q = -1\%$

Panel C. Market power and upward-sloping supply



# VR ( $\hat{\gamma}$ ) Estimates (17%-44%)

A lot of undervaluation

TABLE 8—COMPARISON OF ESTIMATES WITH OTHER STUDIES

<i>Studies using exact valuation parameter</i>	<i>r</i>	<i>valuation parameter</i>
Sallee, West, and Fan (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]
<i>Studies using approximate valuation parameter</i>		
Busse, Knittel, and Zettelmeyer (2013a)	6%	1.33
Grigolon, Reynaert, and Verboven (2018)	6%	0.91
Leard, Linn, and Zhou (2017)	1.3%	0.54
Leard, Linn, and Springel (2019)	2.9–5.3%	0.06–0.76
Own estimate from restatement	6%	[0.40–1.01]
Own estimate from restatement	1.3%	[0.31–0.77]

*Notes:* For our own estimates, we report a range that highlights the heterogeneity of model years 2011–2012 versus 2013. The lower value of the range represents the valuation parameter for model years 2011–2012. The upper value corresponds to model year 2013.

# Student comments & questions

- ▶ One question I have after reading this paper is whether or not the estimated subjective discount rates truly reflect myopia alone or also account for search/information frictions or potential miscalculations of future fuel savings
- ▶ This is interesting part of the paper as the cars were physically unchanged, any price difference after the restatement must come purely from the label update, making the causal interpretation much more convincing than studies that rely on gasoline price swings.
- ▶ If late buyers never knew the ratings changed and simply took the new lower ratings at face value, the persistent undervaluation they exhibit may just reflect a pre-existing general tendency to undervalue fuel economy across all vehicles, the natural experiment may be capturing something broader than the causal effect of the restatement itself.
- ▶ I feel like it is very unlikely that late buyers didn't know about the restatement. With a large purchase, like a car, there is so much research being done before even looking at the cars on a lot.
- ▶ I think the authors can add whether consumers ignore fuel economy ratings altogether or simply struggle to convert MPG into lifetime dollar costs this may matter for policy designs.

# Outline

- ▶ Introduction ✓
- ▶ Example 1: Busse, Knittel, & Zettlemeyer (2013) AER ✓
- ▶ Example 2: Gillingham, Houde, & van Benthem (2021) AEJ:EP ✓
- ▶ Example 3: Sallee & Fan (2016) JPubE
- ▶ Example 4: Myers (2019) AEJ-EP
- ▶ Example 5: Myers (2020) JPubE
- ▶ Future directions

# Ex3. Sallee, West, & Fan (2016) JPubE

## Estimate VR using used car transactions

**Table 2**  
Effects of future fuel cost shocks on transaction prices.

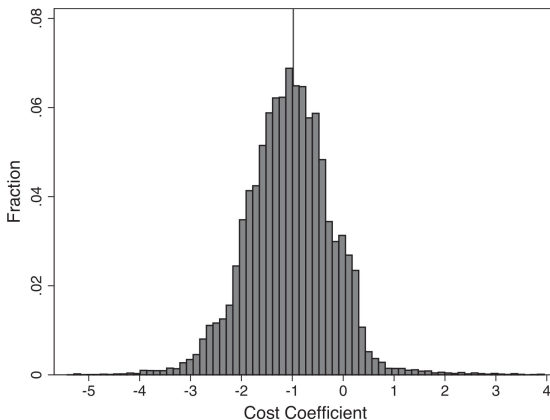
	(1)	(2)	(3)	(4)	(5)
Future fuel cost	-1.01 (0.04)	-1.01 (0.03)	-1.02 (0.10)	-1.01 (0.04)	-1.01 (0.04)
Number of observations	1,429,677	880,809	548,868	1,433,453	1,426,720
Number of unique VIN Stubs	9,498	5,712	3,786	9,723	9,352
Polynomial order	7	7	7	5	9
Class	All	Cars	Trucks	All	All
Minimum mileage	10,000	10,000	10,000	10,000	10,000
Maximum mileage	100,000	100,000	100,000	100,000	100,000

The dependent variable is the real transaction price. All specifications include month of sample by VIN stub fixed effects, a polynomial in odometer, a set of dummy variables for each 10,000 odometer bin, and a linear control for 1,000 odometer categories. Standard errors (in parentheses) are clustered on VIN stub. Sample includes vehicles sold by dealers. Future fuel cost calculations use a 5% discount rate.

- ▶ **RQ:** How do used car consumers value fuel cost savings?
- ▶ **Methodology:** Regress price on NPV (as in AW 2014, GHvB2021)
- ▶ Key variation in NPV: temporal shifts in fuel price
- ▶ Need to flexibly control for vintage (age) and odometer
- ▶ Key results: valuation ratio  $\hat{\gamma}$  around 1 - full valuation

# Ex3. Sallee, West, & Fan (2016) JPubE

Quite a bit heterogeneity in  $\hat{\gamma}$  around -1 if they estimate  $\gamma_j$



**Fig. 6.** Histogram of valuation coefficient for individual VIN stubs. Each data point is the cost coefficient from Eq. (4) estimated for a single VIN stub. The vertical line is the point estimate from the joint regression from the same specification, which is found in Table 2, column 1.

# Outline

- ▶ Introduction ✓
- ▶ Example 1: Busse, Knittel, & Zettlemeyer (2013) AER ✓
- ▶ Example 2: Gillingham, Houde, & van Benthem (2021) AEJ:EP ✓
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# Ex4. Myers (2019) AEJ-EP

## "Are home buyers inattentive? Evidence from Capitalization of Energy Cost"

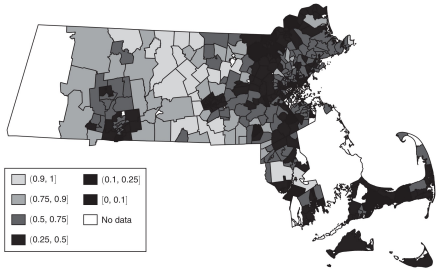


FIGURE 1. PROPORTION OF MASSACHUSETTS HOMES HEATED WITH OIL

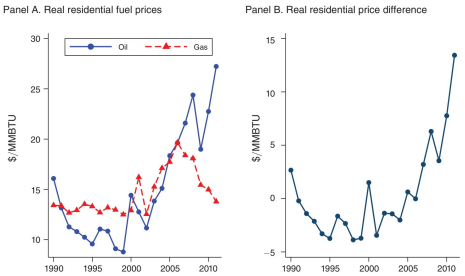


FIGURE 4. REAL RESIDENTIAL FUEL PRICES AND DIFFERENCE (2012 US DOLLARS)

- ▶ **RQ:** How does the variation in fuel prices (for heating) affect housing prices?
- ▶ **Methodology:** run a price regression for WTP, then compute the IDR  $r$
- ▶ For house  $j$  area  $a$  year  $t$ , run:  $H_{jat} = \gamma p_{jt} + \lambda_{at} + \theta_j + \varepsilon_{jat}$
- ▶ **Key variation:** spacial variation in heating source + temporal shift in relative heating price
- ▶ **Data:** CoreLogic

# Ex4. Myers (2019) AEJ-EP

IDR  $\hat{r}$  around 8-9%, pretty much full valuation

TABLE 2—ESTIMATION OF THE EFFECT OF RELATIVE FUEL PRICES ON RELATIVE TRANSACTION PRICES

	Sales price	Sales price	Sales price	Sales price	Sales price
Fuel price	-1,186.4 (198.8)	-1,002.4 (242.6)	-1,122.1 (115.1)	-1,074.7 (167.1)	-1,064.7 (131.7)
Oil-heat indicator	-1,5334.4 (1,066.5)	-8,165.6 (1,157.8)	1,311.1 (978.3)		
Year FE	Yes	Yes	No	Yes	No
Attribute controls	No	Yes	Yes	No	No
Geographic area $\times$ year FE	No	No	Yes	No	Yes
Unit FE	No	No	No	Yes	Yes
Observations	909,434	870,567	870,504	529,156	529,008
$R^2$	0.0854	0.461	0.675	0.860	0.884
Implied discount-rate infinite horizon	8.4%	9.1%	8.6%	9.4%	9.5%

Notes: Regressions are based on transaction and unit characteristic data for the state of Massachusetts from CoreLogic, years 1990–2011. Price is the average annual residential retail fuel price for oil or natural gas in dollars per MMBTU. All prices are inflated to 2012 dollars. Standard errors are two-way clustered at the house and geographic unit by year level and are in parentheses.

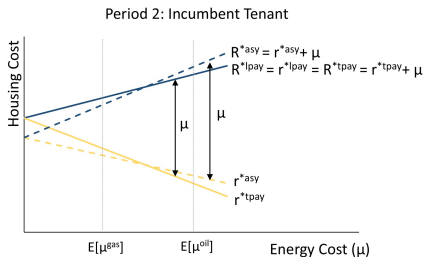
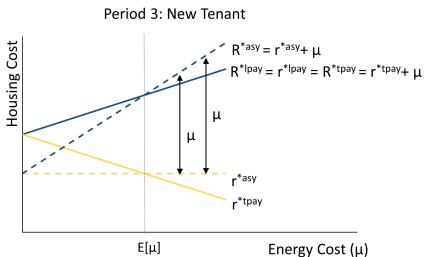
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# Ex4. Myers (2016) JPubE

Testable hypothesis: Consider the scenario when energy cost  $\mu$  goes up



- ▶  $R$  as post-energy-cost rent, and  $r$  as pre-energy-cost rent
- ▶ Test 1: Faster turning over probability for "tenant-pay" when heating price goes up (compare blue solid vs blue dash on LHS)
- ▶ Test 2: Greater rent when heating price goes up for "landlord-pay" (blue solid on LHS)  
Null effect for "tenant pay" (yellow dash on LHS)
- ▶ Test 3: Greater probability to switch from oil to nat gas for "landlord-pay" when heating price goes up

# Ex4. Myers (2016) JPubE

## Tests 1-2: Effect on turning over rate & rent

**Table 2**

Estimation of the effect of heating prices on the probability of turning over.

Dependent variable: turnover indicator	(OLS)	(OLS)	(OLS)	(2SLS)
Heating price	-0.00698* (0.00387)	-0.00398 (0.00415)	-0.00358 (0.00472)	-0.00915 (0.00756)
Heating price × tenant-pay indicator	0.0171*** (0.00627)	0.0194*** (0.00656)	0.0238*** (0.00731)	0.0263** (0.0121)
Oil indicator × tenant-pay indicator	-0.0103 (0.0211)	0.0127 (0.0288)	0.00686 (0.0301)	0.115 (0.387)
Oil indicator	-0.0497*** (0.0154)	-0.0421 (0.0275)	-0.0317 (0.0280)	-0.0187 (0.135)
Covariates	Yes	Yes	Yes	Yes
Tenant-pay indicator × year FE	Yes	Yes	Yes	Yes
Decade built indicator × year indicator	Yes	Yes	Yes	Yes
Unit FE	No	Yes	Yes	Yes
Covariate indicator × year indicator	No	No	Yes	Yes
N	13,269	12,557	12,557	12,536

Notes: The unit of observation is apartment unit × year. Heating price is the price per unit of heat (MMBTU) for home heating oil or natural gas averaged over the survey year ( $t$ ) and the previous year ( $t - 1$ ) in the Northeast Census region. The price per unit heat is the retail price divided by the average furnace efficiency (0.78 for oil and 0.82 for natural gas). For the 2SLS

**Table 3**

Estimation of the effect of heating prices on rent.

Dependent variable: monthly rent	(OLS)	(OLS)	(OLS)	(OLS)	(2SLS)	(2SLS)
(1) Heating price	3.276 (2.617)	5.188** (2.215)	4.895** (2.306)	4.957** (2.504)	13.02** (5.207)	15.02** (6.444)
(2) Heating price × tenant-pay indicator	-2.216 (4.260)	-5.364 (3.355)	-4.777 (3.454)	-6.968* (4.151)	-7.430 (8.904)	-7.917 (11.71)
tpuxoil	-15.49 (14.70)	-7.992 (12.35)	-9.223 (12.50)	-14.30 (13.64)	-429.4 (472.7)	-423.4 (413.7)
oil	68.75*** (9.722)	-22.92* (11.84)	-17.29 (11.83)	-17.80 (12.39)	257.0 (215.6)	266.2 (198.8)



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# What people are doing now?

## In the literature of EE gap

In addition to produce more rigorous estimates for WTP and quantifying EE gap, researchers study the following:

- ▶ Understand how specific elements in *NPV* are formed for consumers.  
Are some of them formed with bias? Which one? Why?  
Are some of them the source of inattention? Why one? How come?
- ▶ Policy implications: more information disclosure? financial literacy education?
- ▶ Heterogeneity and policy/incentive targeting  
e.g., Allcott, Knittel, & Taubinsky (2015) AER P&P "Tagging and Targetting of Energy Efficiency Subsidies"  
e.g., Jacobsen, Knittel, Sallee, & van Benthem (2020) JPE "Use Regression Stats to Analyze Imperfect Pricing Policies"  
e.g., Sallee (2019) NBER WP "Pigou Produce Losers"

# What people are doing now?

## In board literature of EE (not EE gap)

- ▶ Consumers' taste for EE for the electric vehicle (EV) market and barriers for EV adoption
- ▶ The effect of EE policies (regulations and subsidies)
- ▶ Attribute-based EE policies (to avoid strategic attribute tradeoffs)
- ▶ Firms' strategic gaming of faking/exaggerating energy efficiency (similar to VW scandal)  
e.g., Reynaert and Sallee (2021) AEJ:EP "Who Benefits When Firms Game Corrective Policies"
- ▶ Firms' strategic bunching behavior of offering specific energy efficiency
- ▶ Multi-product firms' strategic behavior of manipulating price and attributes to steer consumers towards products they want to sell
- ▶ Multi-product firms' strategic behavior of manipulating product offering (aka choice set) in energy efficiency to steer consumers towards products they want to sell