Is There an Energy Paradox in Fuel Economy: The Role of Consumer Heterogeneity and Sorting Bias

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Introduction

- Due to concerns of local and global pollutants as well as energy security, the US government has worked to increase fuel economy.
- Many policies and economic models rely on the assumption that consumers understand the savings that occur when they buy higher MPG vehicles.
- Consumers may not be willing to pay more at the time of purchase for an equivalent reduction in future fuel cost.
- Known as "an energy paradox." Appears in many household purchases.
- If there is an energy paradox in fuel economy, a variety of policies, including CAFE standards, may be warranted (Fischer, Harrington and Parry, 2007).

Challenges

- Two main challenges:
  1. Unobserved product characteristics

Honda Civic
38 mpg

Accura (Honda)
NSX
18 mpg

  2. Heterogeneity and Sorting

Prius ?

Truck/SUV ?

Do these individuals sort across the product space?

Literature Review

- Studied in other durables. Jaffee and Stavins (1994), Hausman (1979).

- Accurate estimate needed for policy prescription.
  - Fischer, Harrington and Parry (2007) More than 30%, use gas tax.

- For fuel economy, large improvement on first problem:
  - Goldberg (1995) "No evidence that consumers are myopic. (Nested Logit)
  - Kilian and Sims (2006) 11-25% (Panel Data)
  - Allcott and Wozny (2009) 25% (Nested Logit)
  - Sallee, West and Fan (2010) 79% (Auction data)
  - Reviews by: Greene (2010), Helfand and Wolverton (2010)

Literature Review

- Studies have not yet addressed how consumer heterogeneity and sorting affect these numbers.
- Previous work in other areas has drawn attention to this issue.

- Deleire, Kahn, Timmins (2009) Roy Sorting, value of stat. life.
- Train (2003) Bias from logit models.

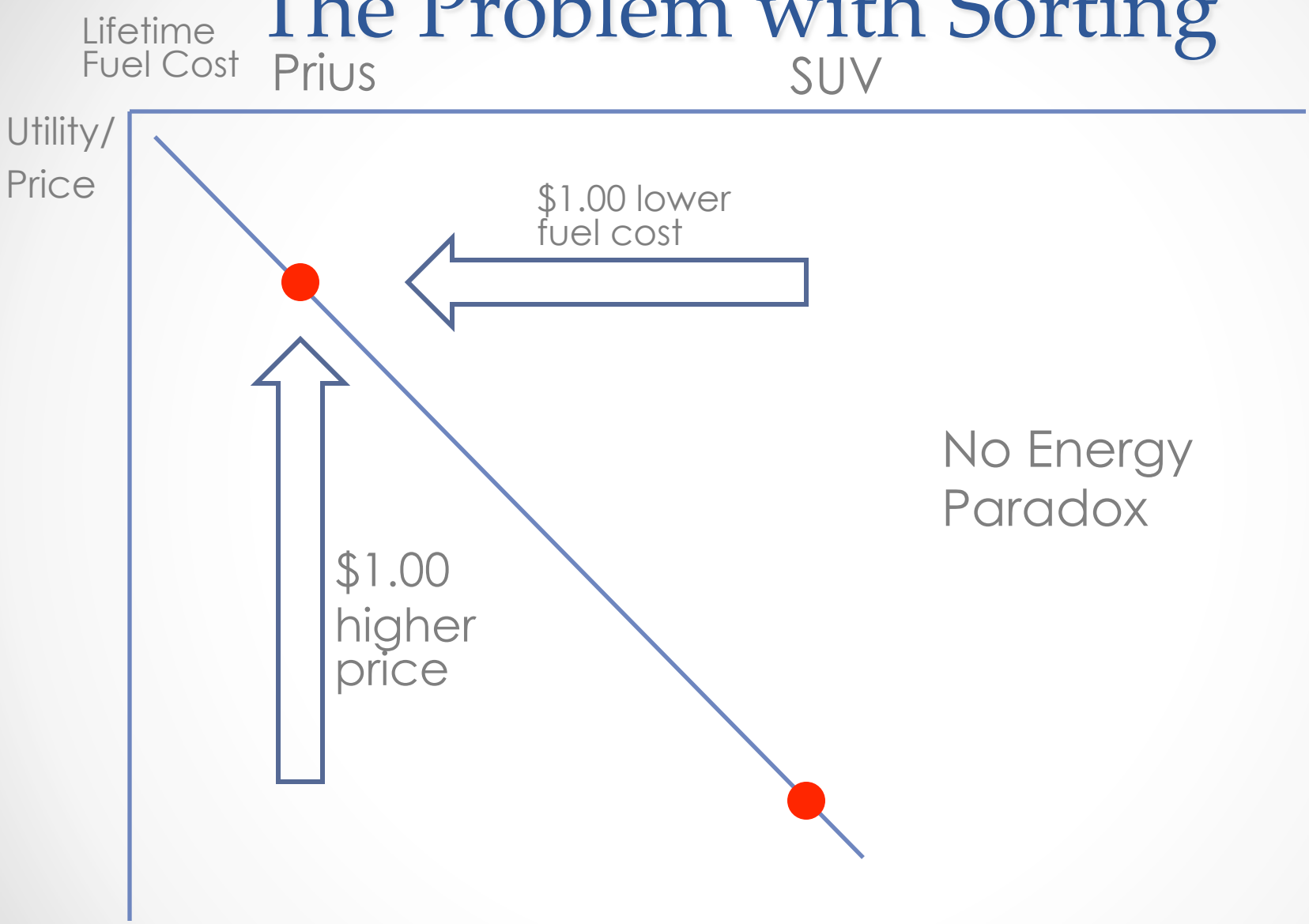
Contributions

- Show how estimating demand using a logit model without heterogeneity introduces bias in the estimate of the willingness-to-pay for reduced future fuel cost.
- This is true even when unobserved product characteristics are not a problem.
- The direction of this bias erroneously would suggest an energy paradox.
- This bias can be corrected for using a random coefficient logit model which captures heterogeneity.

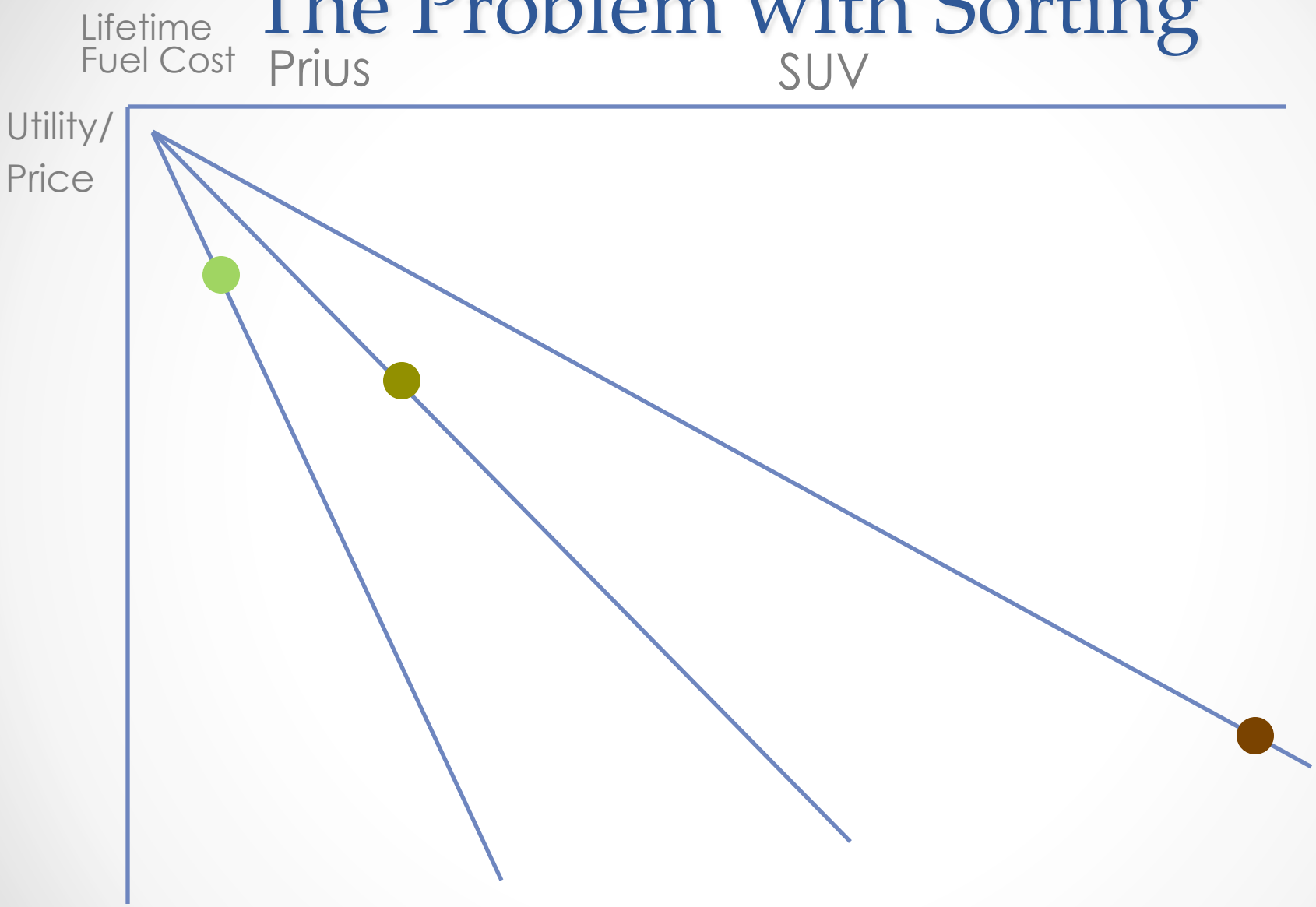
Heterogeneity

- Do consumers sort according to their marginal willingness-to-pay for reduced fuel cost?
- Problematic if car choice correlates with valuation of fuel cost.
- Any of the elements used to calculate the discounted future fuel cost can introduce heterogeneity:
  1. Future Gasoline Prices
  2. Discount Rates
  3. Yearly VMT distribution
  4. Vehicle lifetime

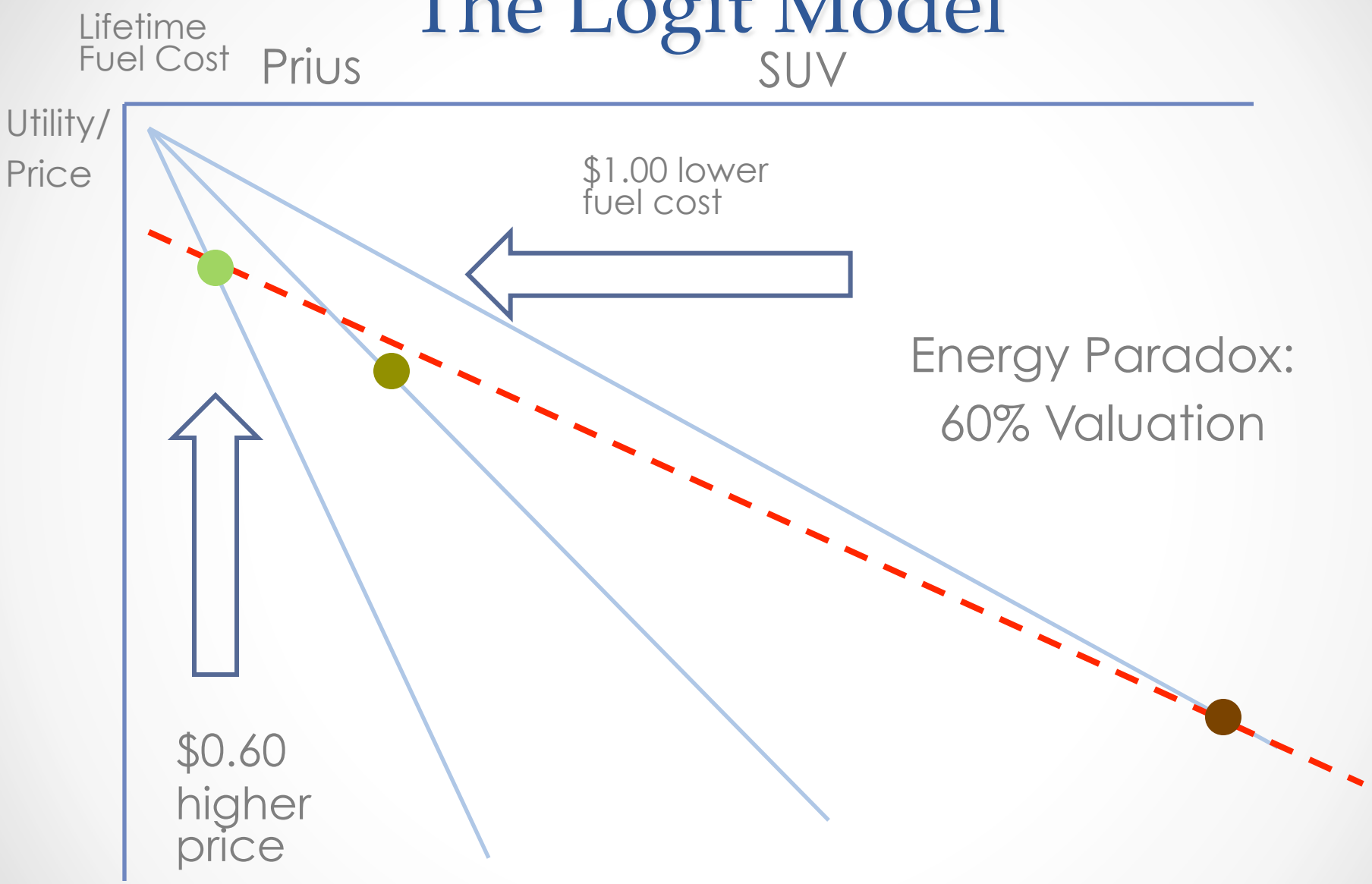
The Problem with Sorting



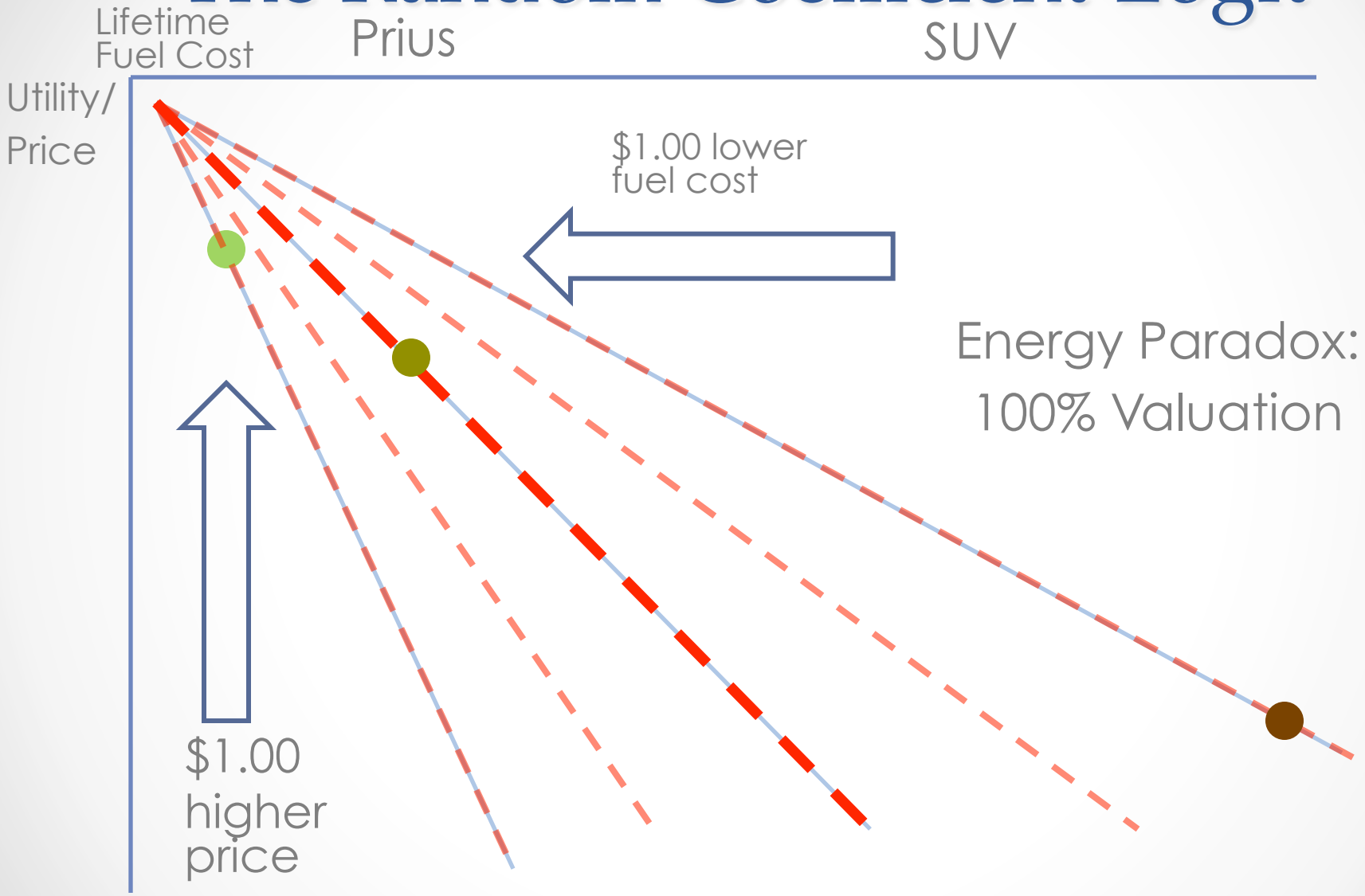
The Problem with Sorting



The Logit Model



The Random Coefficient Logit



Monte Carlo Simulation

- We use a Monte Carlo simulation.
- Benefit: Certainty of parameters to be recovered, no confounding influence of unobserved product characteristics.
- Limitation: Unclear what parameters to use in some instances, particularly how much heterogeneity to introduce.

Demand Specification

$$U_{ij} = \alpha_i p_j + \beta_i f c_{ij} + \gamma_i x_j + \epsilon_{ij}$$

where

$\epsilon_{ij} \sim$ Type I Extreme Value

$$\beta_i = \beta + \sigma * \nu_i$$
$$\nu_i \sim U(-0.5, 0.5)$$
$$\sigma = 4$$

Heterogeneous MWTP

$$\alpha = -2$$
$$\beta = -2$$

Implies no Energy Paradox

$$\gamma_{weight} = 4$$
$$\gamma_{horsepower} = 8$$

Demand Specification

$$fc_{ij} = \sum_{t=0}^{T} \delta^t * VMT_j * GasolinePrice_i / MPG_j$$

We choose δ to be 10%.

VMT and vehicle lifetime come from Lu (2006).

Gas price comes from average yearly gas price 2001-2006.

MPG from Wards.

$$\beta_i = \beta + \sigma * \nu_i$$

We vary σ between 4 in our main specification to 2 in a robustness check.

Using 4 implies MWTP lies between -4 and 0.

Using 2 implies MWTP lies between -3 and -1.

Anderson, Kellogg and Sallee (2010) find a dispersion of 60% on expected gas price.

This implies 95% of values lie between -3.2 and -0.8.

Dispersion on discount rate, expected MPG and expected VMT will increase this dispersion.

Supply Specification

Used to obtain equilibrium prices.

$$\pi^f = \sum_{j \in f} [p_j - mc_j] q_j(p, \theta)$$

Twenty-five products randomly drawn from Wards data.

Marginal cost from Berry, Kortum, and Pakes (1996).

Firms are used as observed but test results using a monopolistic market setting.

Estimation

Generate choices for 20,000 individuals for 6 years (2001-2006).

Cars repeat each year, gasoline price varies, car prices from supply model.

Estimate a multinomial logit and random coefficient multinomial logit model.

RCML model estimate with simulated maximum likelihood using Halton draws.

Results

Sigma = 4 (Wide dispersion on MWTP)

	True Parameter	Estimated Parameters			
		Logit	S.E.	Random Coefficient Logit	S.E.
Constant	1	0.60	0.05	1.05	0.07
Price	-2	-2.02	0.01	-2.00	0.01
Fuel Cost	-2	-1.43	0.03	-2.01	0.07
Weight	4	4.49	0.15	3.83	0.17
Horsepower	8	7.68	0.14	8.18	0.15
Sigma	4			4.18	0.26
Loglikehood		228,335		228,268	
Implied valuation for $1 drop in fuel cost		$ 0.71		$ 1.00	
Implied undervaluation		29%			

Statistically significant undervaluation on logit model.

Results

Sigma = 2

	True Parameter	Estimated Parameters				
		Logit	S.E.		Random Coefficient Logit	S.E.
Constant	1	0.93	0.05		1.08	0.06
Price	-2	-2.01	0.01		-2.01	0.01
Fuel Cost	-2	-1.82	0.03		-2.03	0.06
Weight	4	3.99	0.15		3.80	0.16
Horsepower	8	8.05	0.14		8.21	0.14
Sigma	2				2.31	0.31
Loglikehood		225,942			225,933	
Implied valuation for $1 drop in fuel cost		$ 0.90			$ 1.01	
Implied undervaluation		10%				

Robust to chosen distribution on fuel cost parameter, market power and product space.

Conclusion

Even when product characteristics can be perfectly controlled for, heterogeneity and sorting can lead to spurious undervaluation in fuel economy.

Using a Monte Carlo simulation we find that realistic parameter values can induce undervaluation similar to that observed in previous studies.

Next steps: Using observed data (NHTS survey) we will attempt to estimate the magnitude of the energy paradox using a RCML model.