The Market for Fuel Economy: How Does it Work?

Dr. David L. Greene
Oak Ridge National Laboratory

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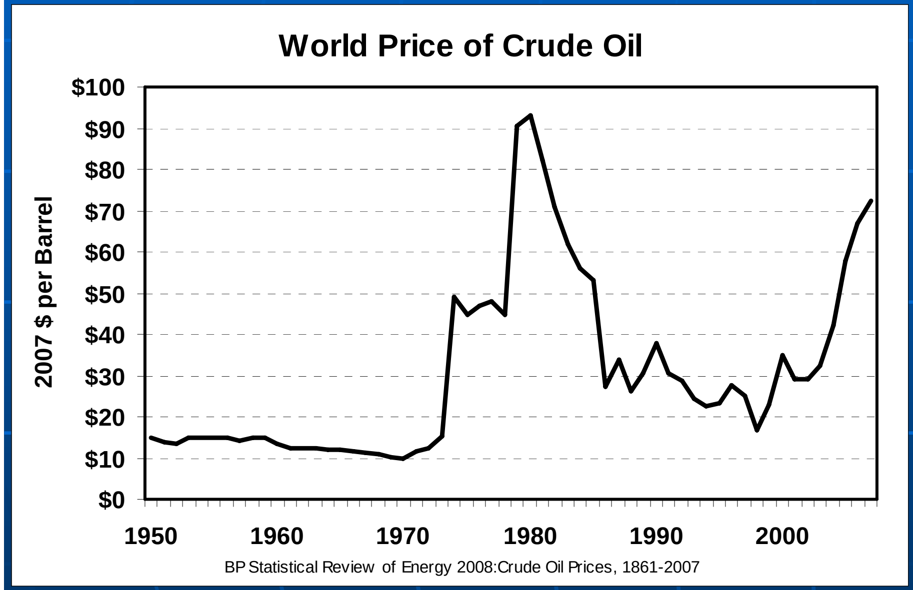
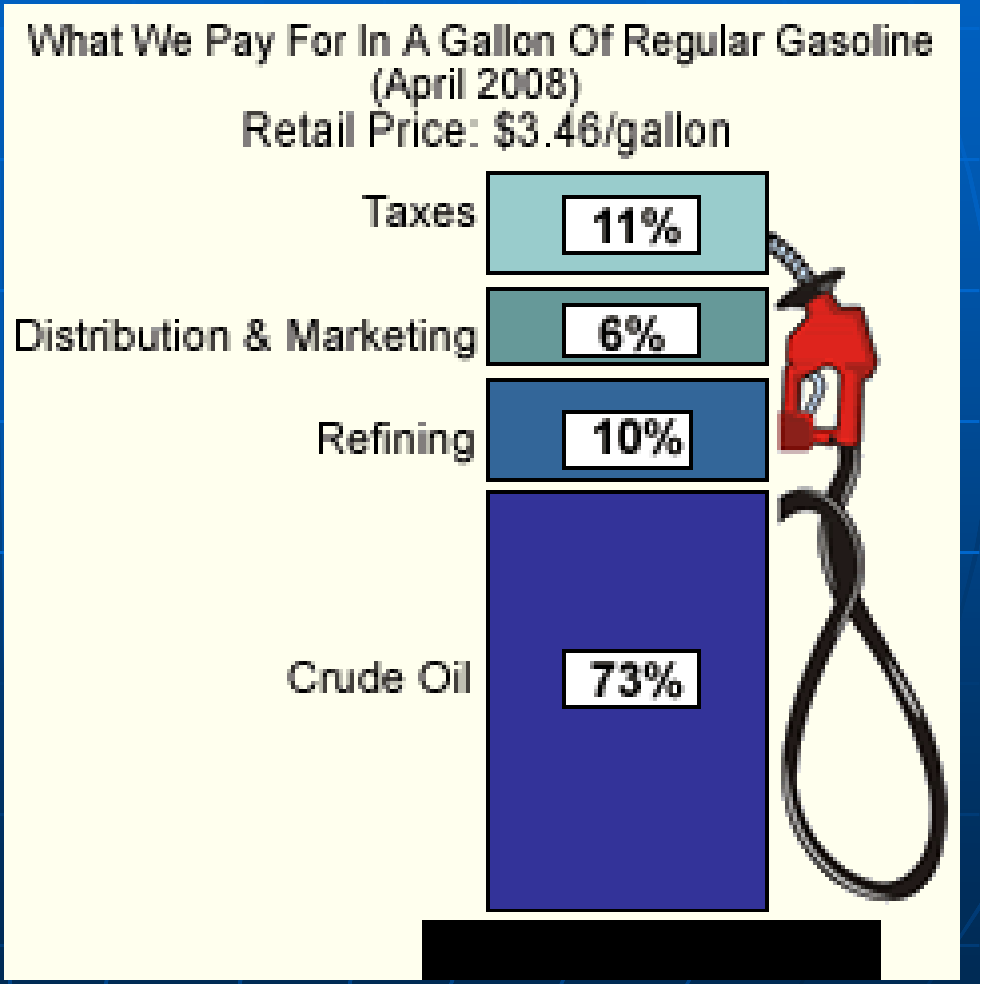
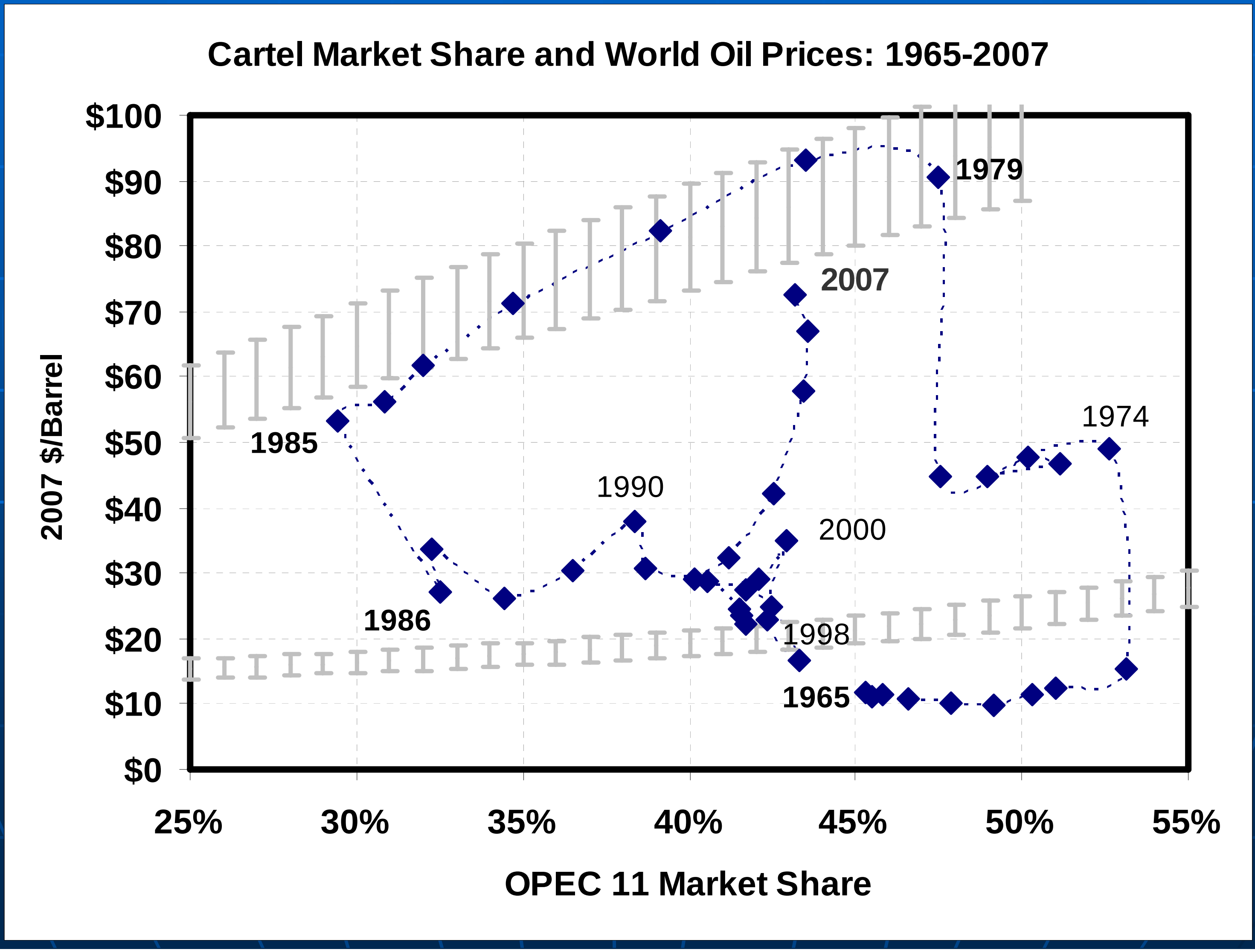
Most of the current cost of gasoline is the cost of crude oil (divide $/bbl by 42).



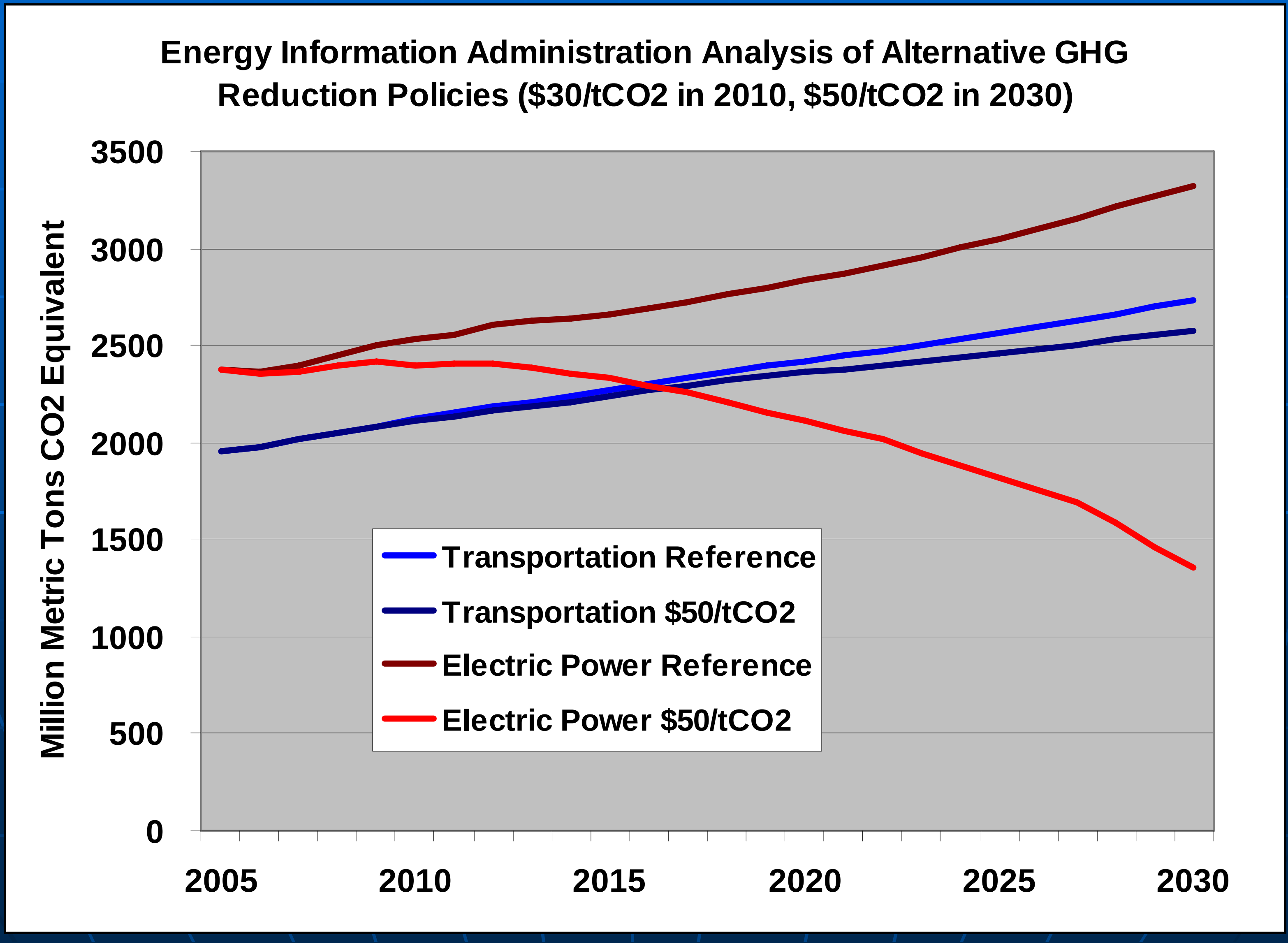



Cartel Market Share and World Oil Prices: 1965-2007
2007 $/Barrel
$100
$90
$80
$70
$60
$50
$40
$30
$20
$10
$0
1979
2007
1974
1985
1990
2000
1986
1998
1965
25%
30%
35%
40%
45%
50%
55%
OPEC 11 Market Share

Let’s get real.

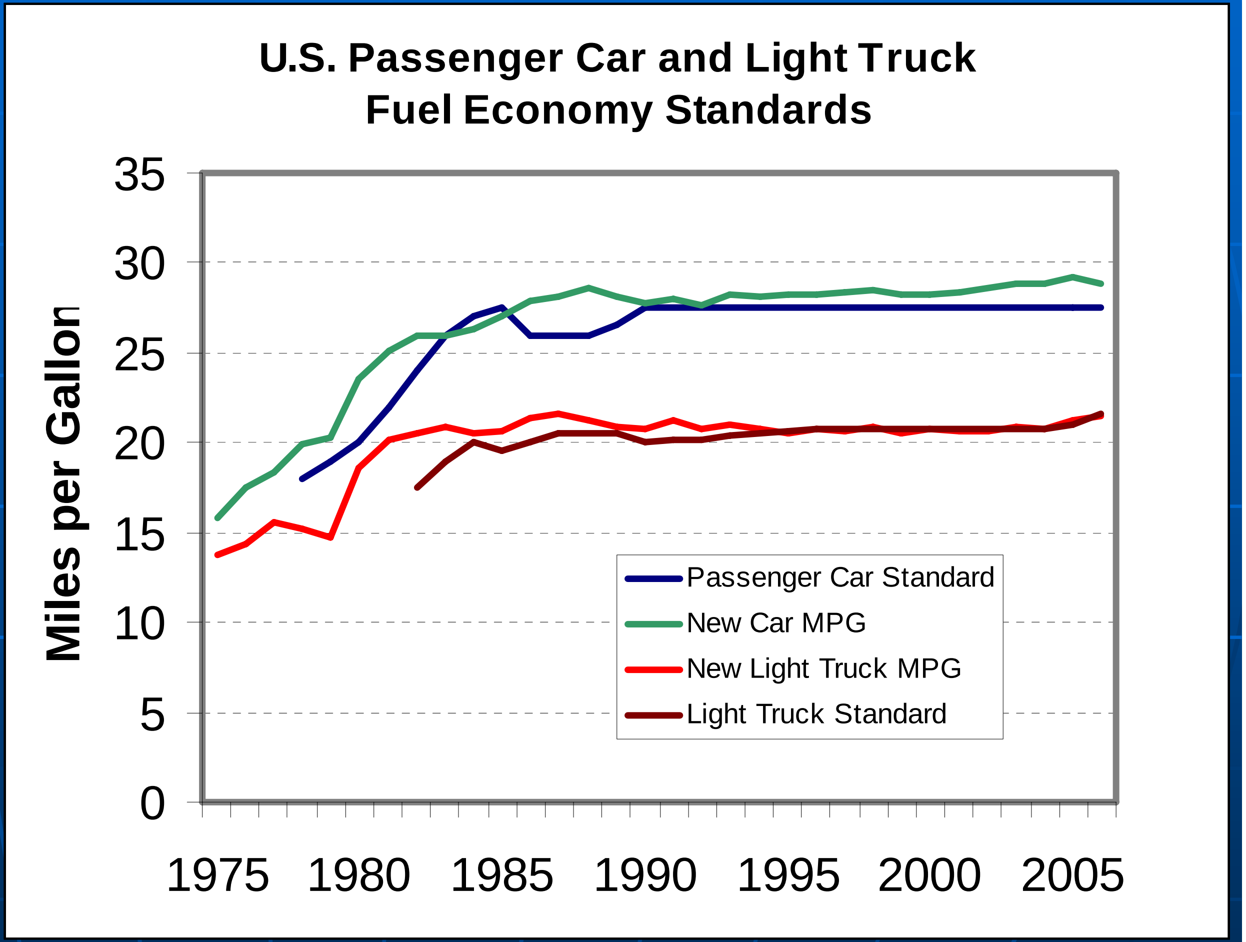
- Policy analysis should be based on how policies will work in the real world not in a perfect (market) world.
- Costs and benefits of alternative policies depend on how markets actually function.
- This is a woefully neglected area for economic research in general and for energy policy in particular.

Transportation is widely viewed as the toughest sector for greenhouse gas mitigation. (EIA, 2006).

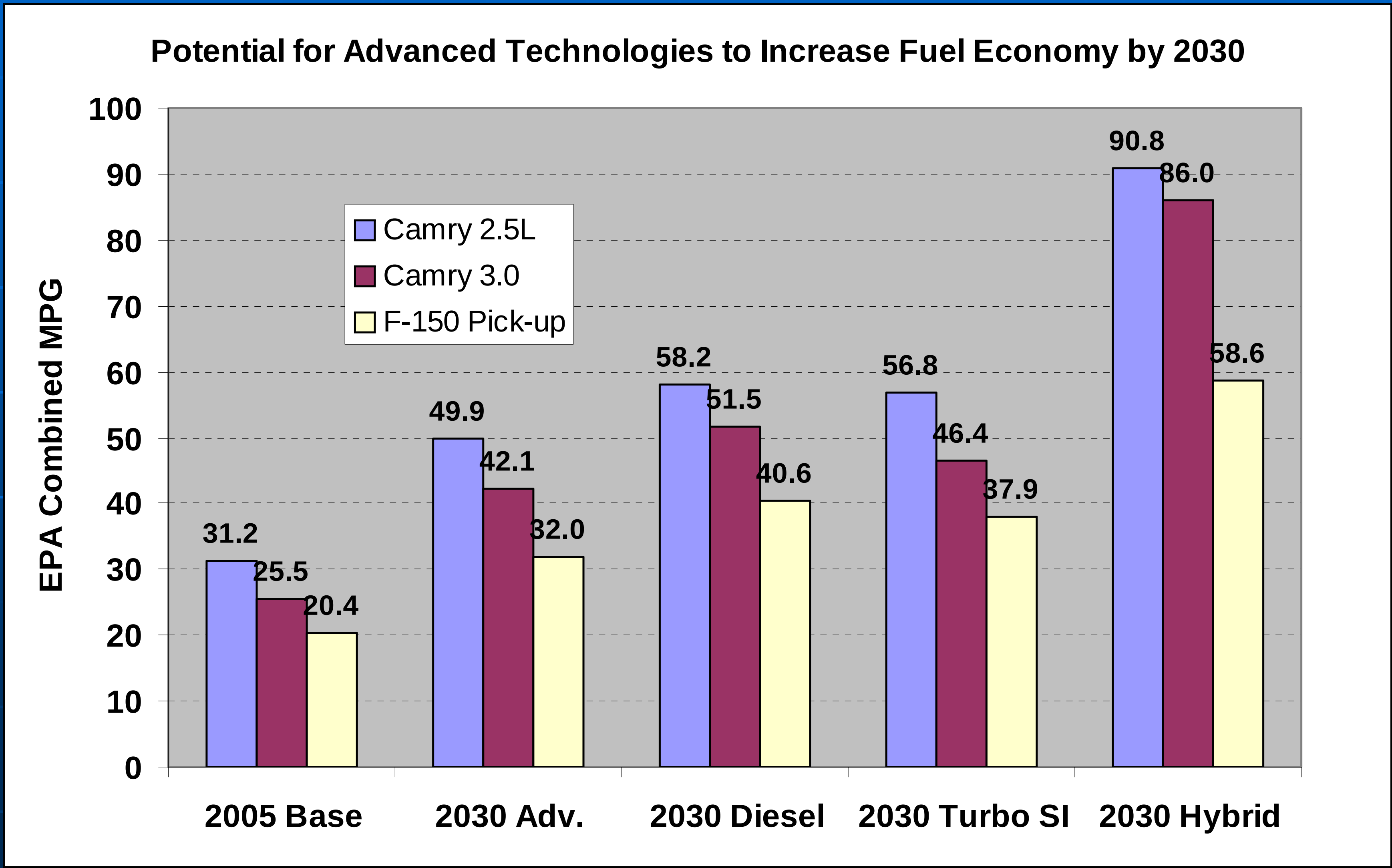


How can this be?

- 1975 EPACT standards led to a **doubling** of passenger car fuel economy.
- 2007 EISA calls for a **40% increase** in light-duty vehicle fuel economy to 35 mpg by 2020.
- Objective studies (e.g., NAS 2002) keep finding room for cost-effective fuel economy improvement.



A 2007 MIT study predicts MPG gains of 80-85% for model year 2030 vehicles via continuous improvement of conventional technology at a rate of 2-2.5%/year.



Source: Kasseris & Heywood, SAE Technical Paper 2007-01-1605, April, 2007.

Let's start with the structure of the economic determination of fuel economy.

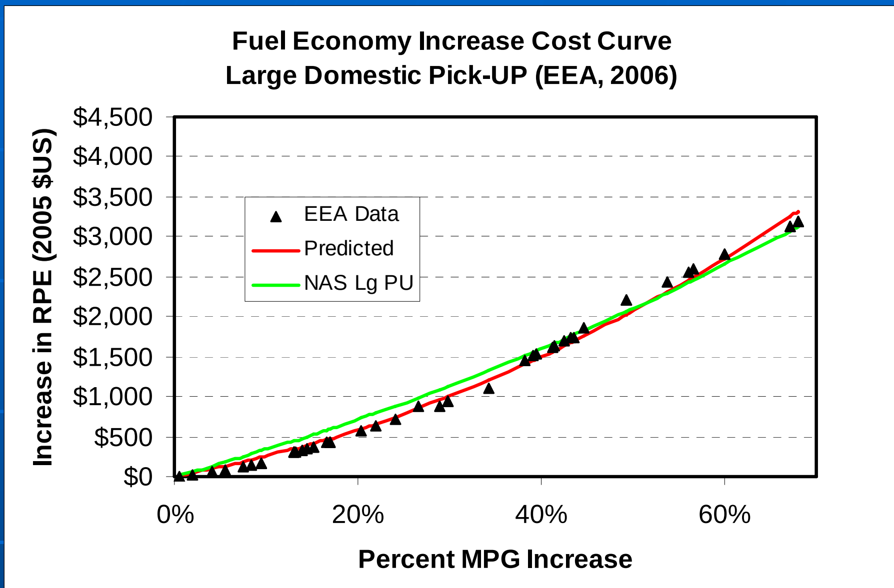
- Consumer chooses among available range of vehicles.
  - Fuel economy decreases with vehicle size, performance, accessories.
  - Fuel economy = cheap, small, weak.
- Manufacturer (as consumers' agent) determines design and technological content.
  - Fuel economy increases with more expensive, advanced technology.
  - Fuel economy = higher first cost, lower operating costs.

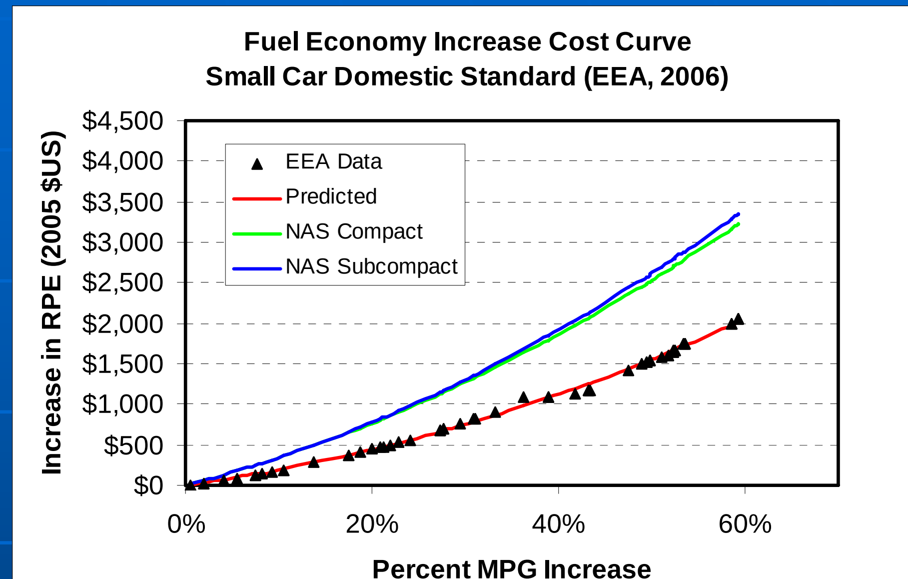
Technology/Cost analysis produces a list of technologies, ranked by cost-effectiveness and accounting for synergies and current market share. (EEA 2006).

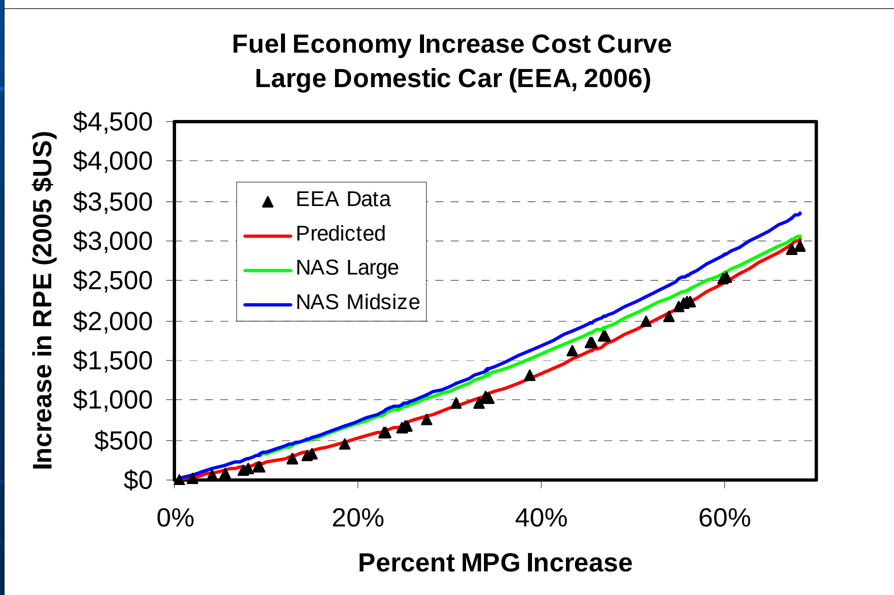
TECHNOLOGY TYPE	Short Term (2006-2012) Cumulative GHG Benefit [%]	Short Term (2006-2012) Cumulative RPE [US$]	Medium Term (2013-2018) Cumulative GHG Benefit [%]	Medium Term (2013-2018) Cumulative RPE [US$]	Long Term (2019-2025) Cumulative GHG Benefit [%]	Long Term (2019-2025) Cumulative RPE [US$]
Early Torque Converter Lockup	0.50	5	0.50	5	0.50	5
Rolling Resistance Reduction by 10%	1.99	25	1.99	25	1.99	25
Drag Reduction by 10%	3.95	53	3.95	53	3.95	53
Rolling Resistance Reduction by 20%	3.95	53	5.30	85	5.30	85
Drage Reduction by 20%	3.95	53	7.00	127	7.00	127
Aggressive Shift Logic	4.17	58	7.21	132	7.21	132
Improved Lube Oil						
Engine Friction Reduction by 8% I4						
Stoichiometric GDI I4						
Weight Reduction by 5%						
Engine Friction Reduction by 15% I4						
DOHC VVT (Intake) I4						
VVT (Intake plus Exhaust) DOHC I4						
Engine Friction Reduction by 8% V6						
Alternator Improvements						
VVL Discrete OHV-2v V6						
Stoichiometric GDI V6						
VVL Discrete OHC-4v I4						
Engine Friction Reduction by 8% V8						
Engine Friction Reduction by 15% V6						
VVLT Intake Continuous DOHC I4						
Engine Off at Idle(Manual Transmission)						
VVL Discrete OHV-2v V8						
Engine Friction Reduction by 15% V8						
Electric Power Steering						
Five Speed Automatic Transmissions						
Six Speed Automatic Transmissions						
Seven Speed Automatic Transmissions						
Continuously Variable Transmissions (Engines <						
4/5 Valves I4						
Camless Valve Actuation I4						
Stoichiometric GDI V8						
Weight Reduction by 10%						
Turbocharging & GDI with Engine Downsize V6						
DOHC VVT (Intake) V6						
DOHC VVT (Intake) V8						
VVT (Intake plus Exhaust) DOHC V6						
VVT (Intake plus Exhaust) DOHC V8						
VVL Discrete OHC-4v V6						
VVLT Intake Continuous DOHC V6						
Continuously Variable Transmissions (Engines >						
Turbocharging & GDI with Engine Downsize V8						
4/5 Valves V6						
VVL Discrete OHC-4v V8						
VVLT Intake Continuous DOHC V8						
Cylinder Deactivation V6 with Noise Cancellation						
Cylinder Deactivation V8 & Cont. VVLT						
Camless Valve Actuation V6 Incl. Cyl Deact.						
Camless Valve Actuation V8 Incl. Cyl Deact.	20.10	1104	37.43	2553	37.64	2590
Engine Off at Idle (Auto. Transmission & AC)	20.10	1104	40.11	2901	40.31	2939
Weight Reduction by 15%	20.10	1104	40.11	2901	41.92	3596
Electric Water Pump	20.10	1104	40.41	2951	42.21	3646
Homogeneous Combustion Compression Ignition (HCCI) I4	20.10	1104	40.41	2951	42.21	3646
Homogeneous Combustion Compression Ignition (HCCI) V6	20.10	1104	40.41	2951	42.30	3772

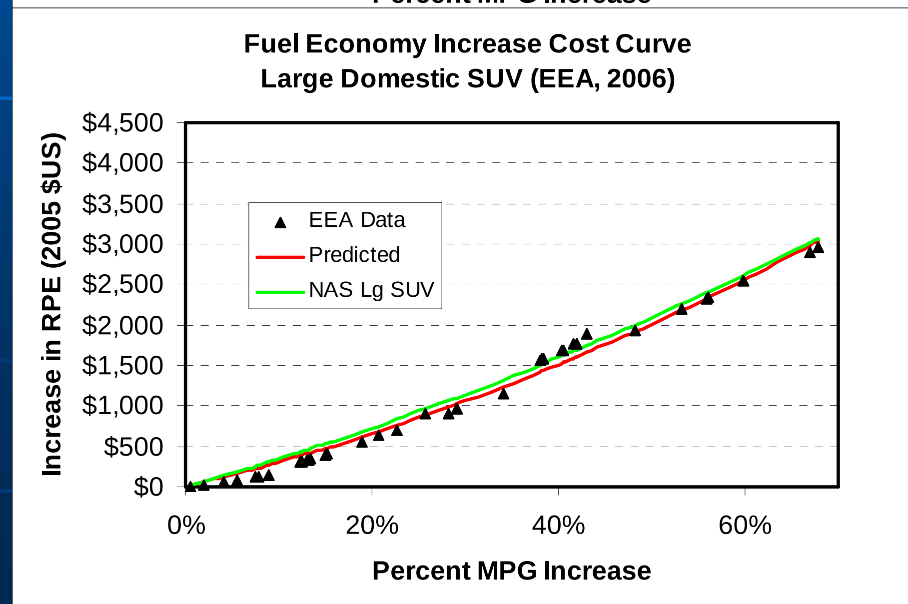
Technology	Medium Term Potential Cumulative % FC Red.	Medium Term Potential Cumulative Cost	Medium Term Potential Cumulative % FE Incr.
Early Torque Converter Lock-up	0.50%	$5	0.503%
Rolling Resistance Reduction by 10%	1.99%	$25	2.030%
Drag Reduction by 10%	3.95%	$53	4.112%
Rolling Resistance Reduction by 20%	5.30%	$85	5.597%
Drag Reduction by 20%	7.00%	$127	7.527%
Aggressive Shift Logic	7.58%	$139	8.202%
Improved Lube Oil	8.50%	$159	9.290%
Engine Friction Reduction by 8% I4	9.52%	$189	10.522%
Stoichiometric GDI I4	12.13%	$278	13.804%
Weight Reduction by 5%	14.85%	$369	17.440%
Engine Friction Reduction by 15% I4	15.79%	$409	18.751%
DOHC VVT (Intake) I4	16.70%	$447	20.048%
VVT (Intake plus Exhaust) DOHC I4	17.25%	$467	20.846%
Engine Friction Reduction by 8% V6	17.55%	$479	21.286%
Alternator Improvements	17.96%	$496	21.892%
VVL Discrete OHV-2v V6	18.63%	$528	22.895%
Stoichiometric GDI V6	19.39%	$565	24.054%
VVL Discrete OHV-4v I4	21.42%	$676	27.259%

Interestingly, the points ordered by cost-effectiveness often trace a quadratic cost curve.
(Compare 2006 study by EEA with 2002 NAS results)









As the car buyer's agent, manufacturers decide whether to:

- Decline to adopt fuel economy technology
- Adopt and use to increase MPG
- Adopt but use for other attributes
  - most importantly, horsepower, size
- Some of both
- Ideally, MC = MU = MWTP

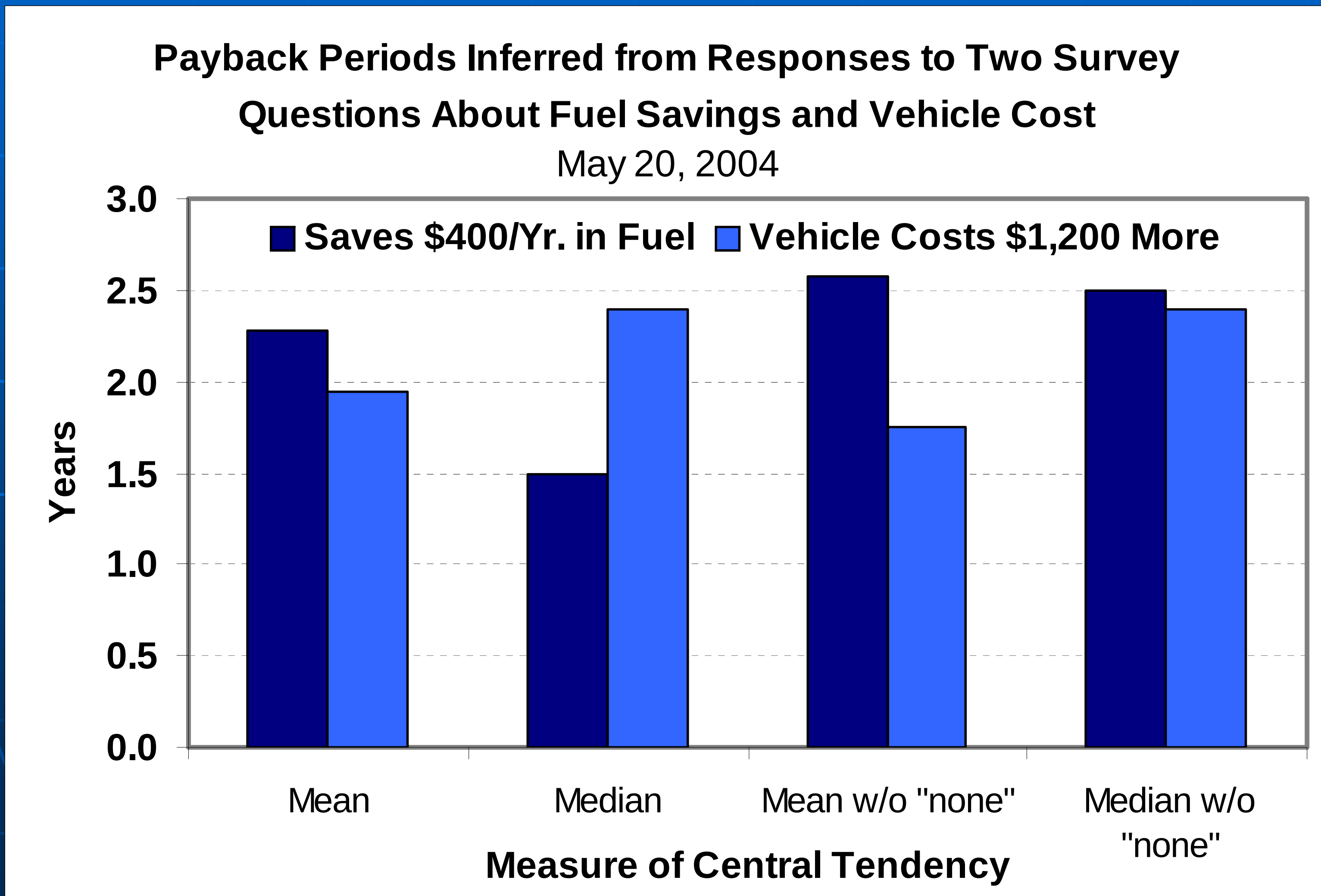
How does the market for fuel economy really work?

- Rational economic model
  - Max(PV fuel savings – initial cost)
- Payback periods
  - Manufacturers use this language
- None of the above
  - Best available consumer research indicates this is the right choice (one study, Turrentine & Kurani, *Energy Policy*, 2007).
- So what's going on?

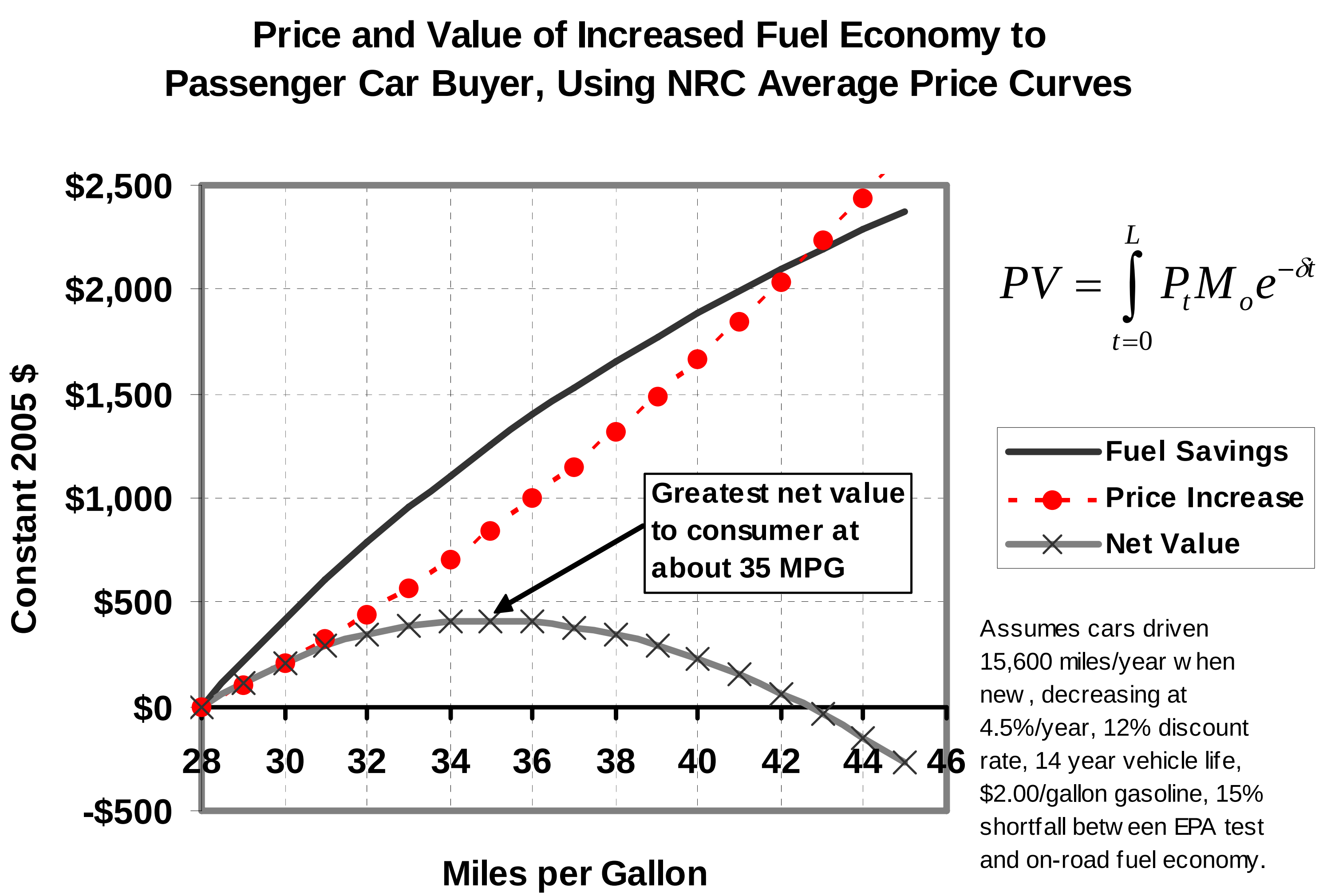
In surveys and focus groups consumers have shown little interest in MPG.

- UC Davis market research co-sponsored by ORNL's fueleconomy.gov – (Turrentine & Kurani, *Energy Policy* 2007)
  - In-depth interviews of 60 California households' vehicle acquisition histories found ***no evidence*** of "economically rational" decision-making about fuel economy.
  - Out of 60 households (125 vehicle transactions) 9 stated that they compared the fuel economy of vehicles in making their choice.
  - None had made any kind of quantitative assessment of the value of fuel savings.
- May 2007 DOE/NREL Opinion Research Corp. national random sample survey.
  - 39% did not consider fuel economy at all in their last vehicle purchase.
  - Only 14% mentioned considering MPG in economic terms (e.g., compare annual fuel costs, estimate $ value of fuel savings).

Asked about fuel economy payback, consumers respond with short payback periods. But few actually think about gas mileage in financial terms as Turrentine & Kurani's study demonstrated. What are they saying?



Rational economic model: NAS estimates imply that a 25% increase in MPG would be optimal (& cost-efficient).



$$PV = \int_{t=0}^{L} P_t M_o e^{-\delta t} \left(\frac{1}{E_o} - \frac{1}{E_1} \right) e^{-rt} dt$$

Assumes cars driven 15,600 miles/year when new, decreasing at 4.5%/year, 12% discount rate, 14 year vehicle life, $2.00/gallon gasoline, 15% shortfall between EPA test and on-road fuel economy.

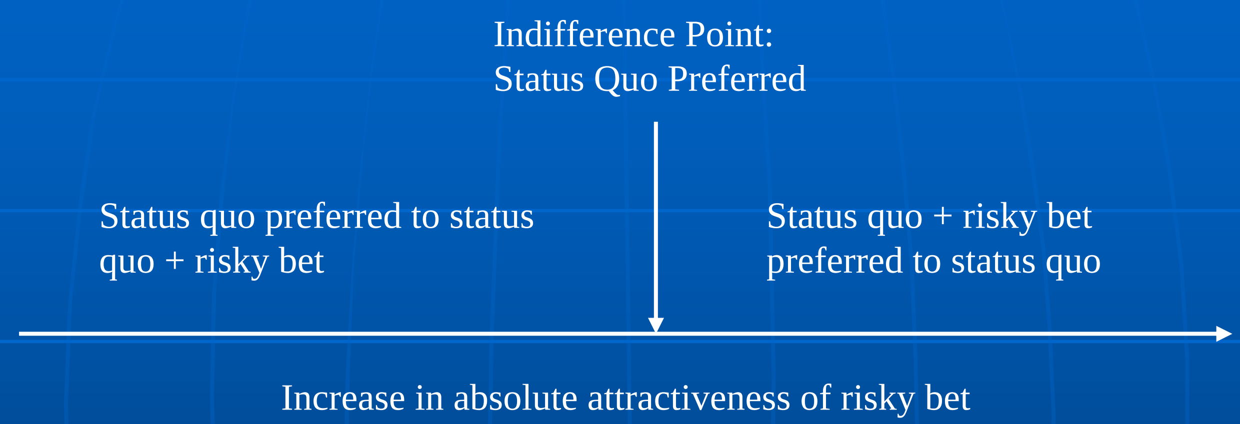
But in reality, uncertainty makes higher fuel economy a ***risky bet***.

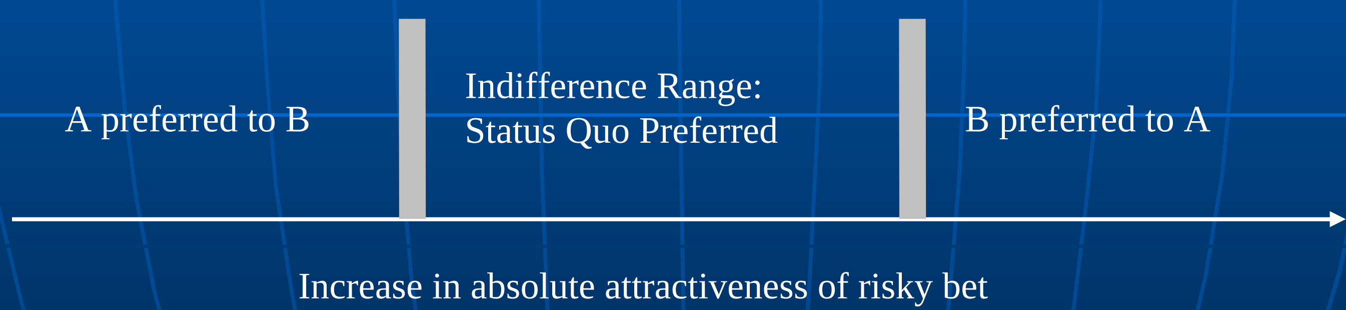
- Sure, there’s a fuel economy label but what MPG will ***I*** get?
- What will gasoline cost?
- How much driving will I do?
- How long will my car last?
- (How long will *I* last?)
- What will I have to give up to get better fuel economy? (How much will it cost?)

AND, consumers are, as a general rule, LOSS AVERSE.

- Will decline a bet with even odds of winning $110 or losing $100.
- Gal (2006) shows that loss aversion can be derived from two simple postulates:
  - Consumers require a motive to act
  - Consumers have imprecise (fuzzy) preferences

Consumers with fuzzy preferences will be indifferent over a potential payoff range.





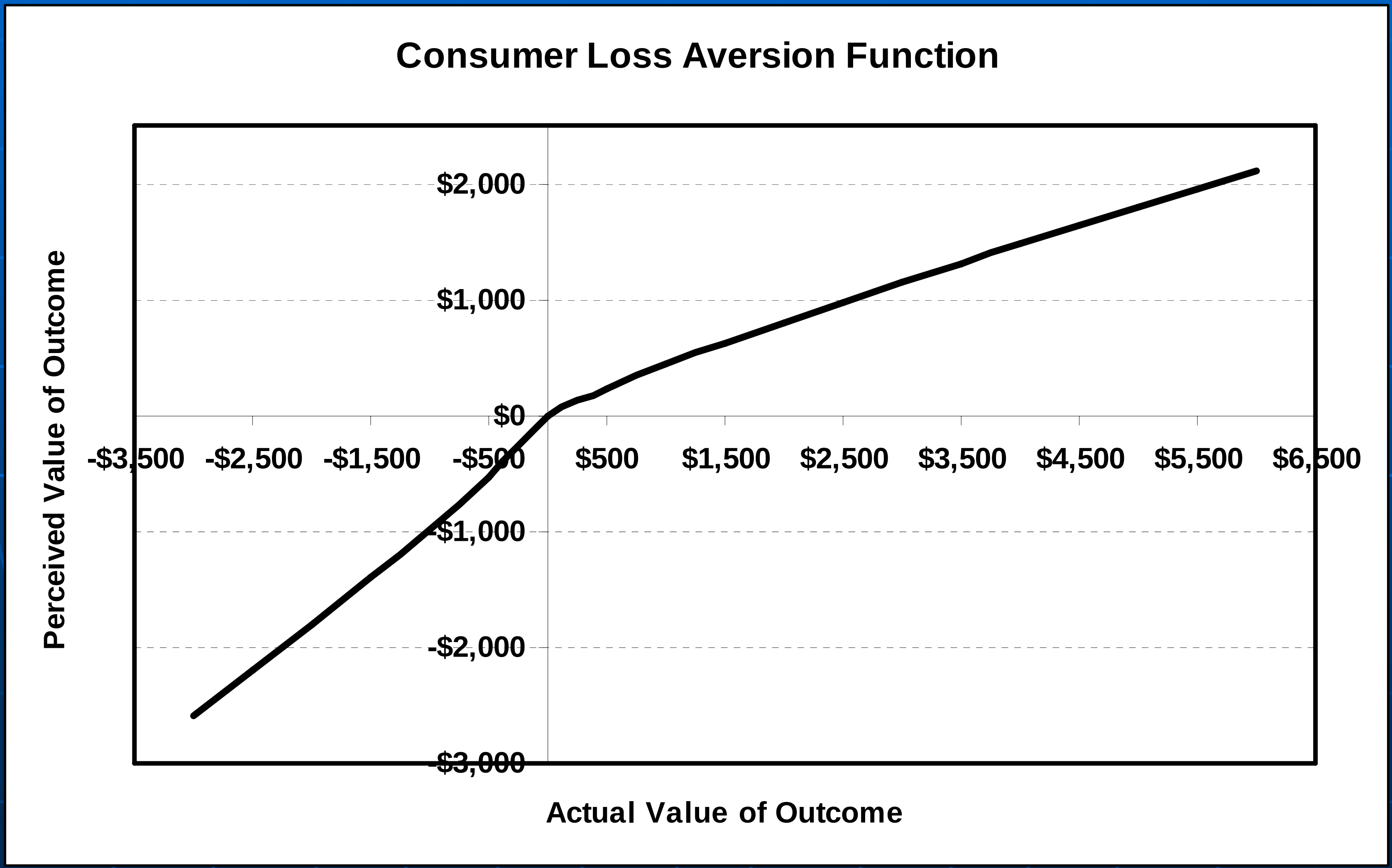
Preferences about the future are inherently fuzzy.

Numerous studies and experiments (& Nobel Prize in Economics) have confirmed the loss aversion principle. Kahneman and Tversky (1992) have fitted the following loss aversion function to empirical data.

$$u(x) = \begin{cases} x^{\alpha} & \text{if } x \geq 0 \\ -\lambda(-x)^{\beta} & \text{if } x < 0 \end{cases}$$

$$\lambda = 2.25 \qquad \alpha = \beta = 0.88$$

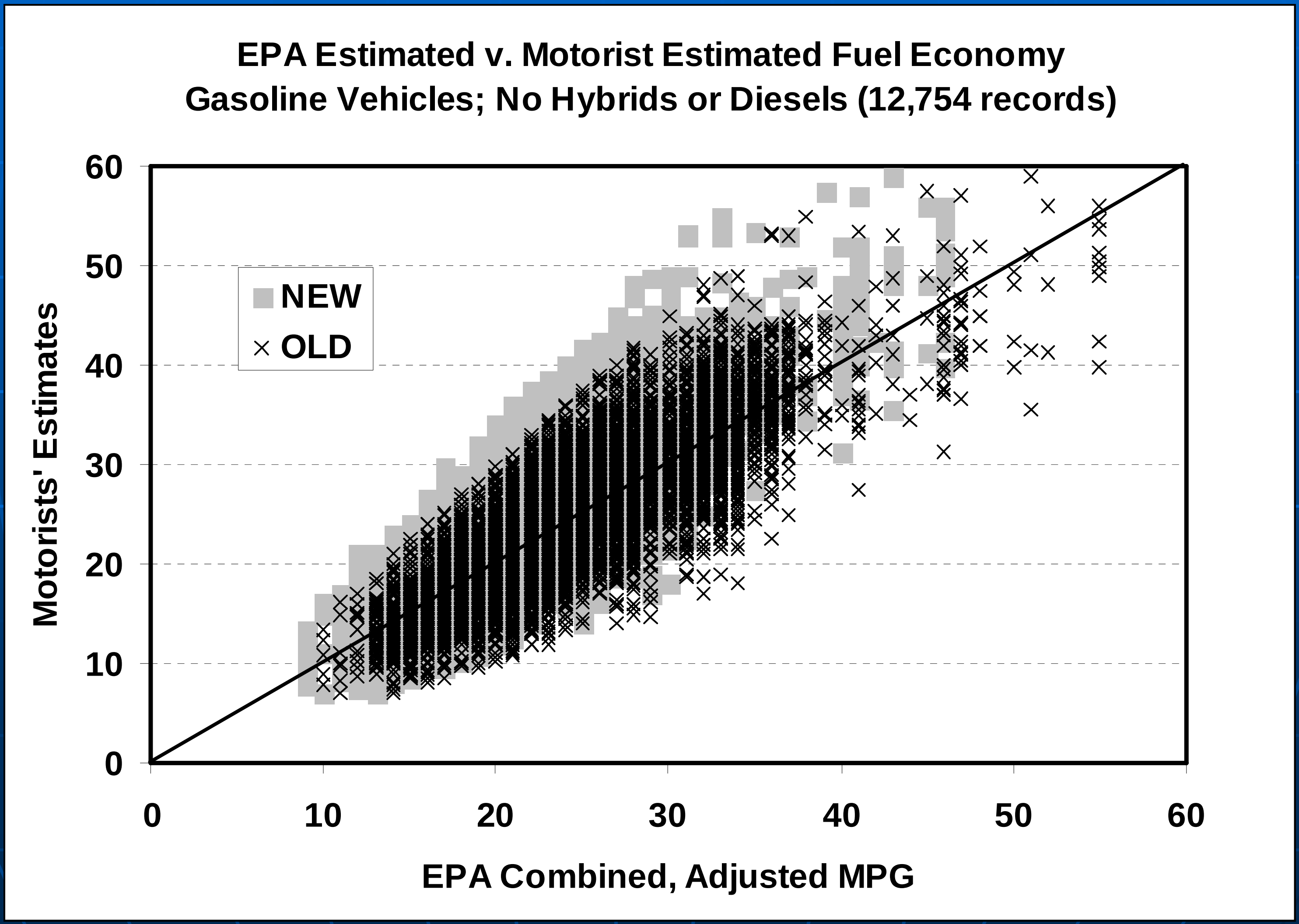
The loss-aversion function magnifies losses relative to gains.



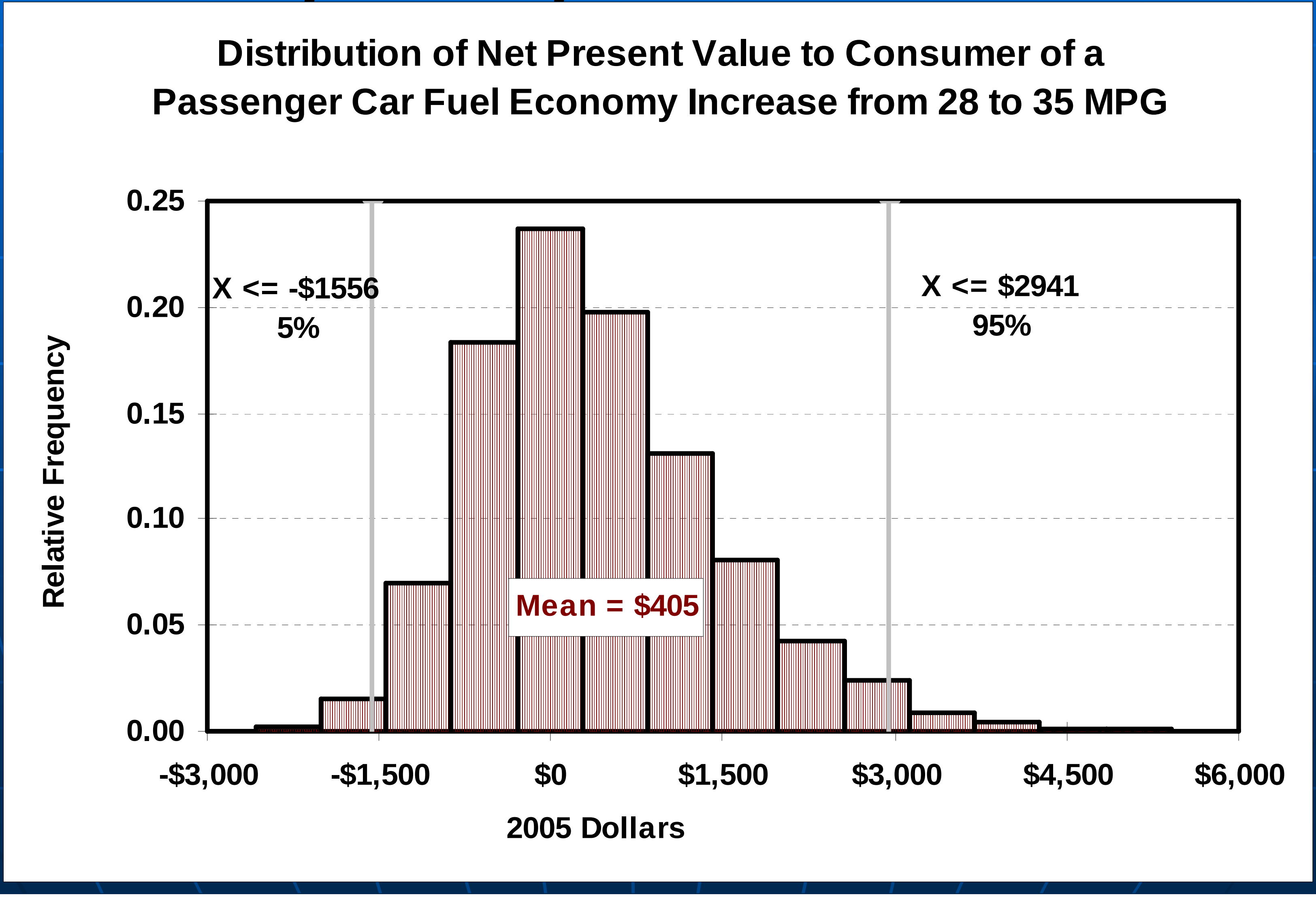
What if we try a plausible quantification of uncertainty to define the buyer's risky bet.

- **Fuel economy**: www.fueleconomy.gov "Your MPG" database: +/-7MPG = 95% C.I.
- **Cost**: NAS (2002) High/Ave./Low cost curves
- **Vehicle lifetime**: ORNL TEDB scrappage curves
- **Vehicle use**: +/- 10% of NHTS average
- **Fuel price**: EIA AEO 2007 Hi/Ref/Low Oil Price Cases (***not nearly enough uncertainty!***)
- Rates of decline in vehicle use, return on investment, are constant, NAS assumptions.

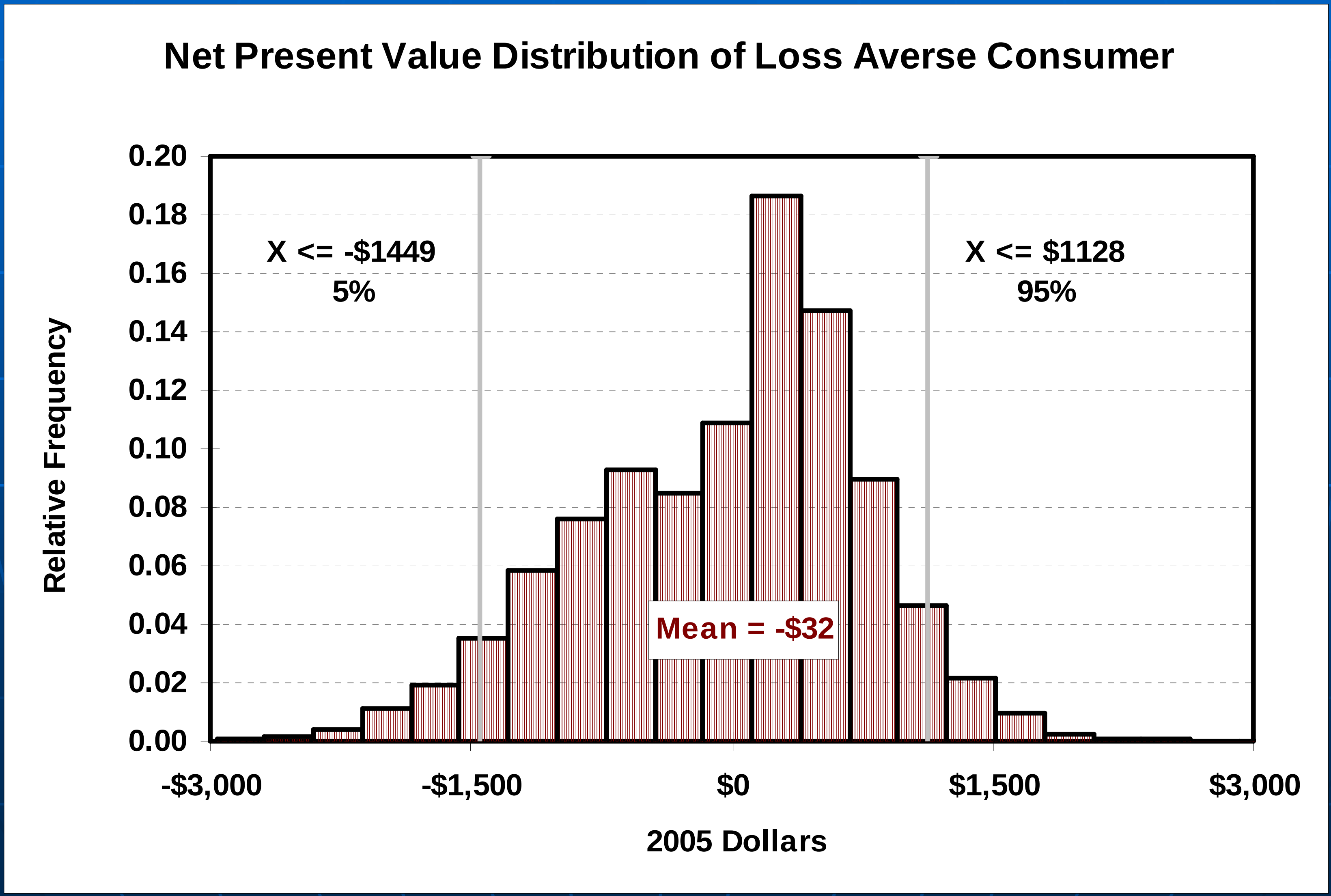
Based on MPG estimates submitted by 15,000 motorists, 2 std. dev. around the EPA's (old) estimate is +/- 7.4 MPG. (Correlated?)



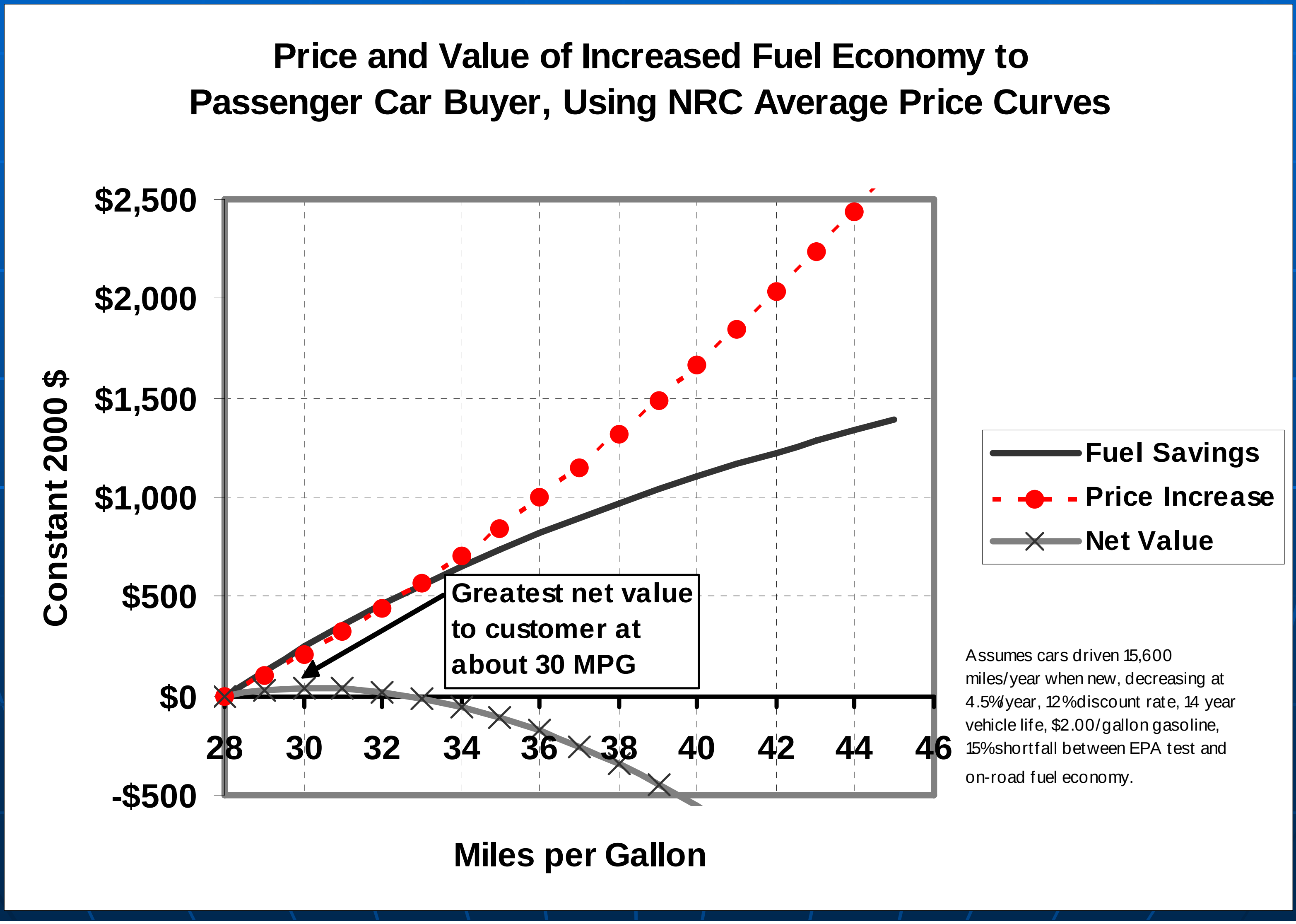
A simulation reflecting these uncertain factors indicates that the fuel economy bet has an ***expected present value*** of $405.



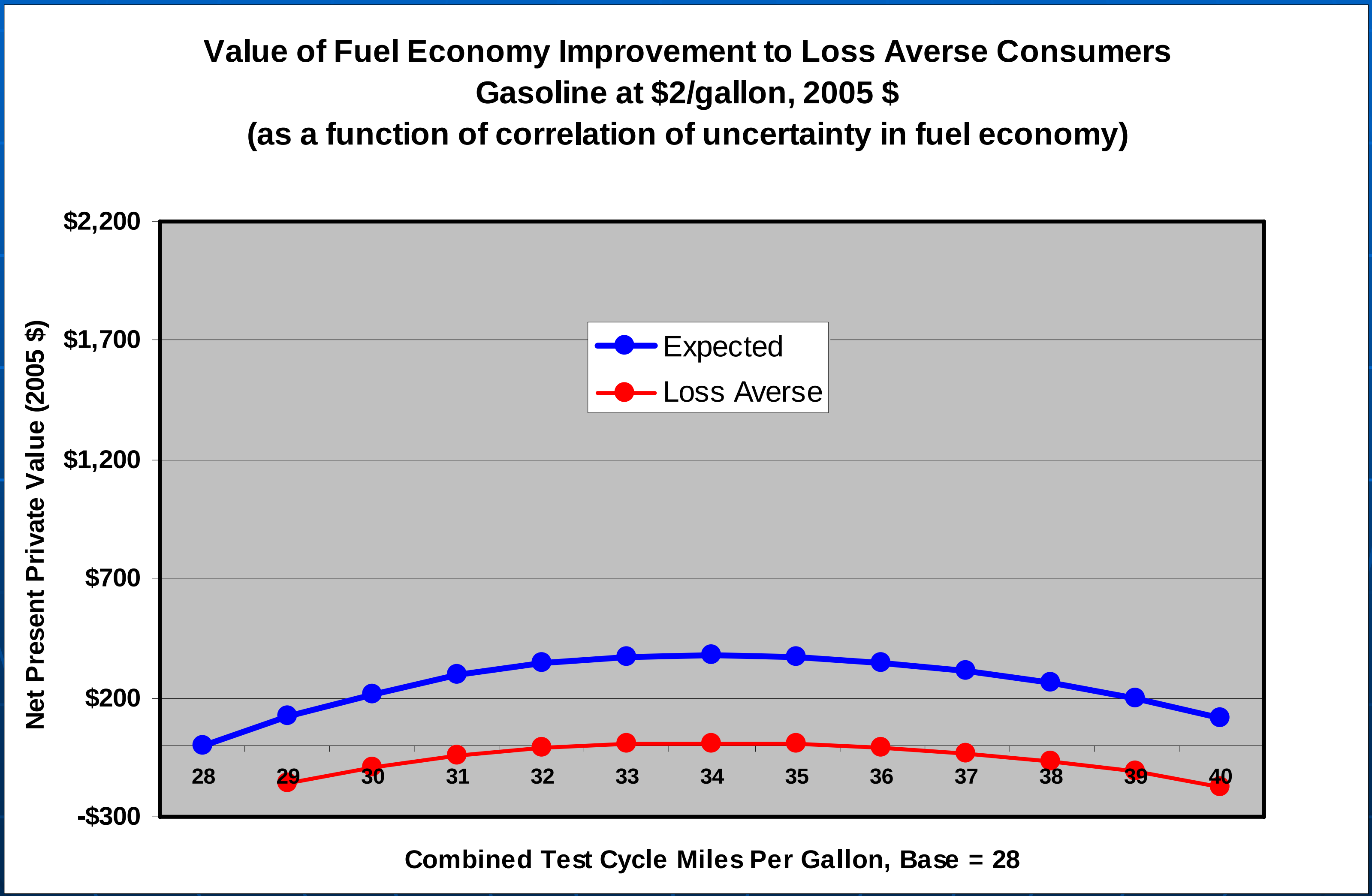
Applying Kahneman and Tversky's typical consumer **loss aversion** function changes the value of the fuel economy bet to -$32.



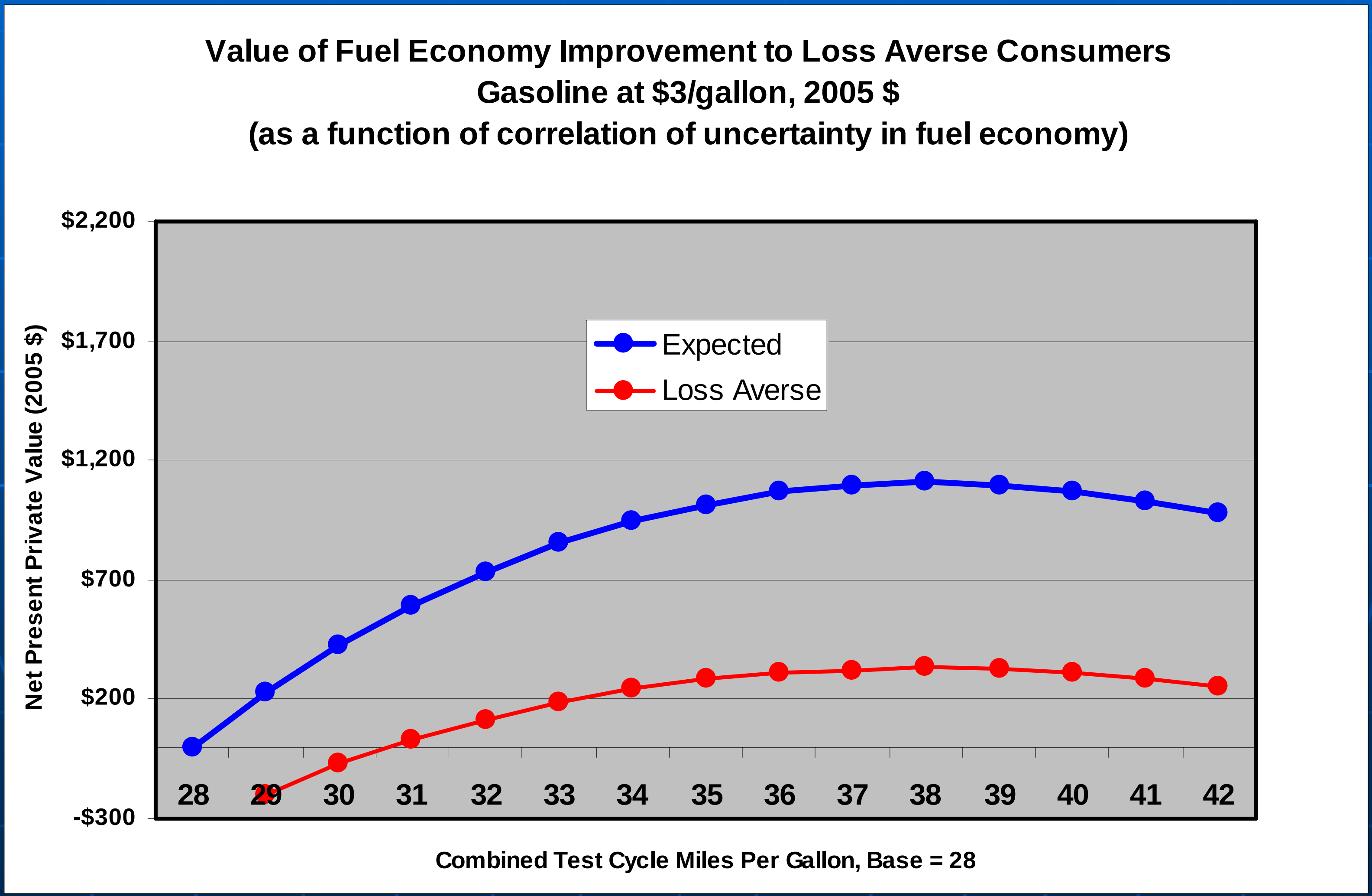
Maybe what consumers are really telling us when they cite short payback periods is that they are uncertain about net benefits and loss-averse.



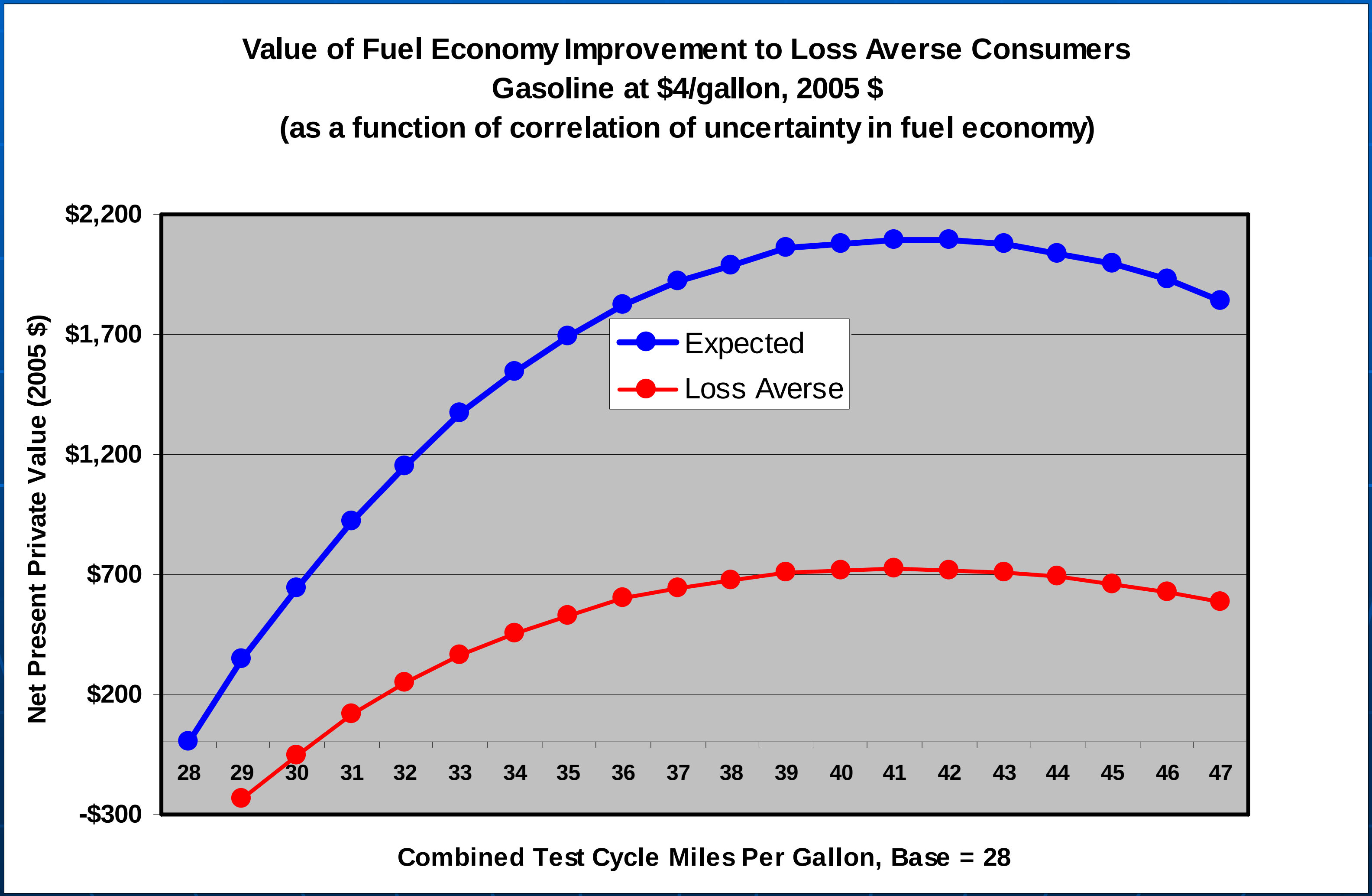
At $2/gallon, fuel economy improvements are of little or no interest to loss-averse consumers.



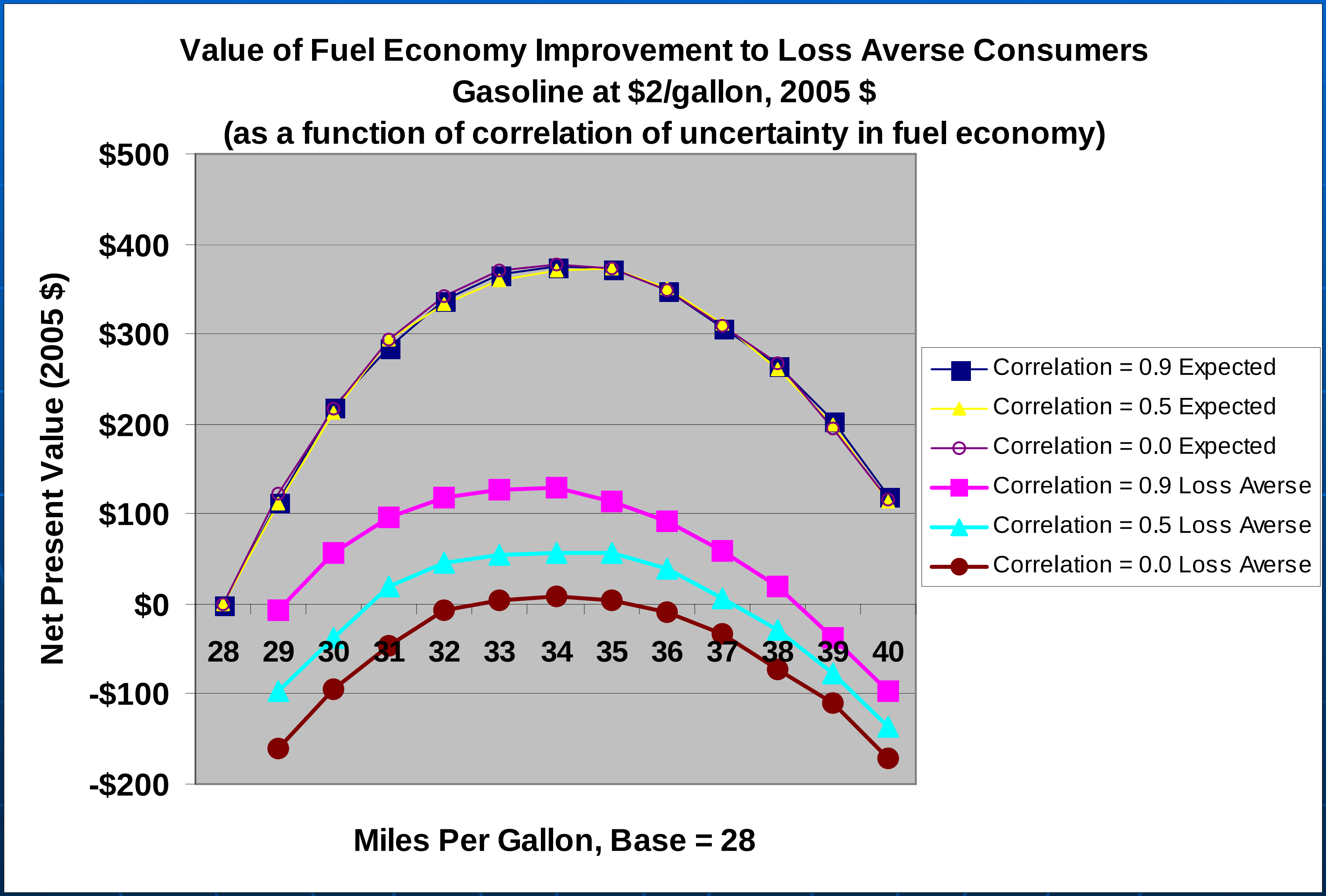
At $3/gallon, fuel economy improvements appear to have modest value and the loss-averse optimal level is close to the optimal expected value.



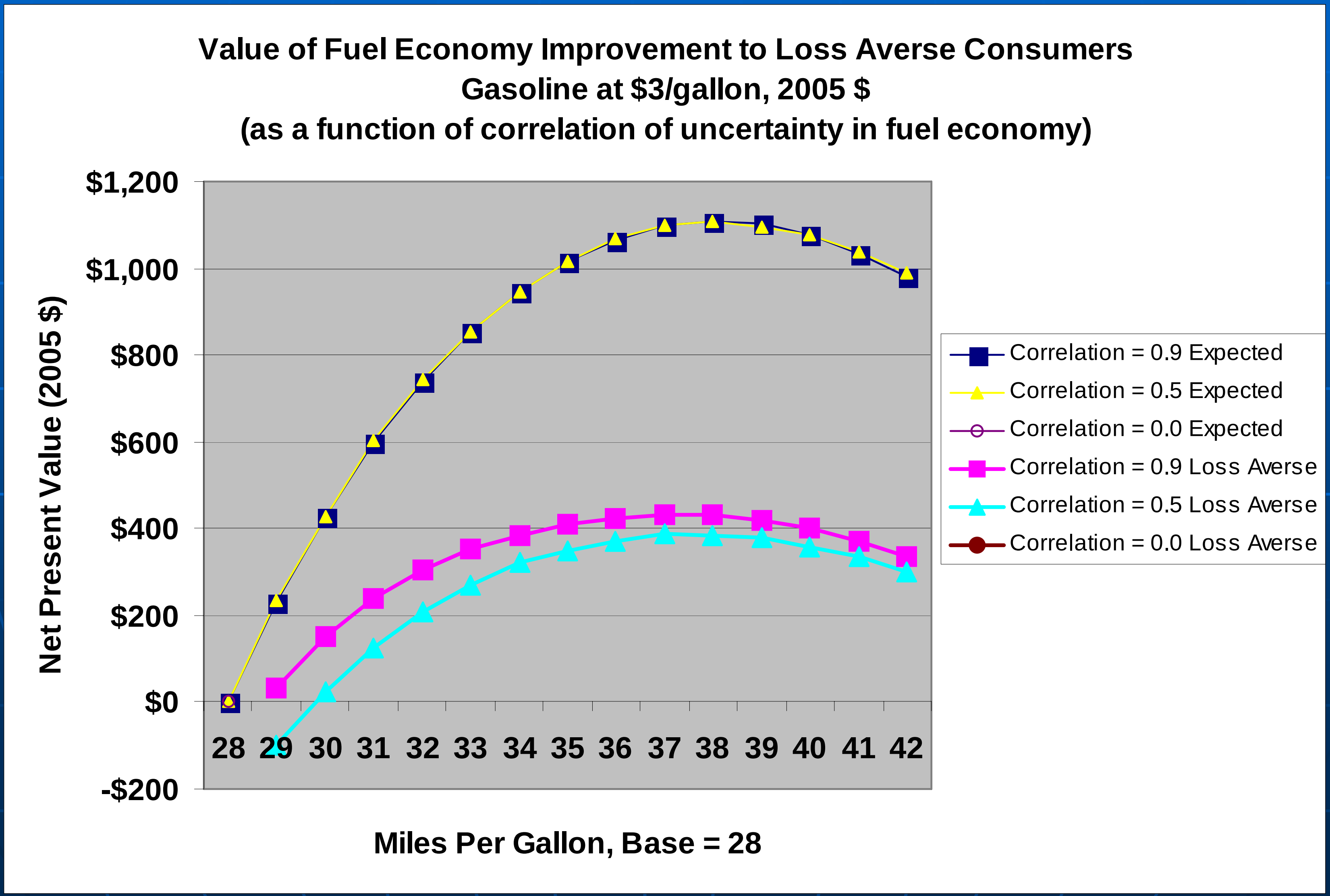
At $4/gallon, even loss-averse consumers attach significant value to increased fuel economy.



How important is the assumption of independence of the uncertain variables, especially MPG?



Of course, the price of gasoline matters! Yet fuel savings will still be undervalued.



Is this a “market failure”?

The implications of this theory are profound.

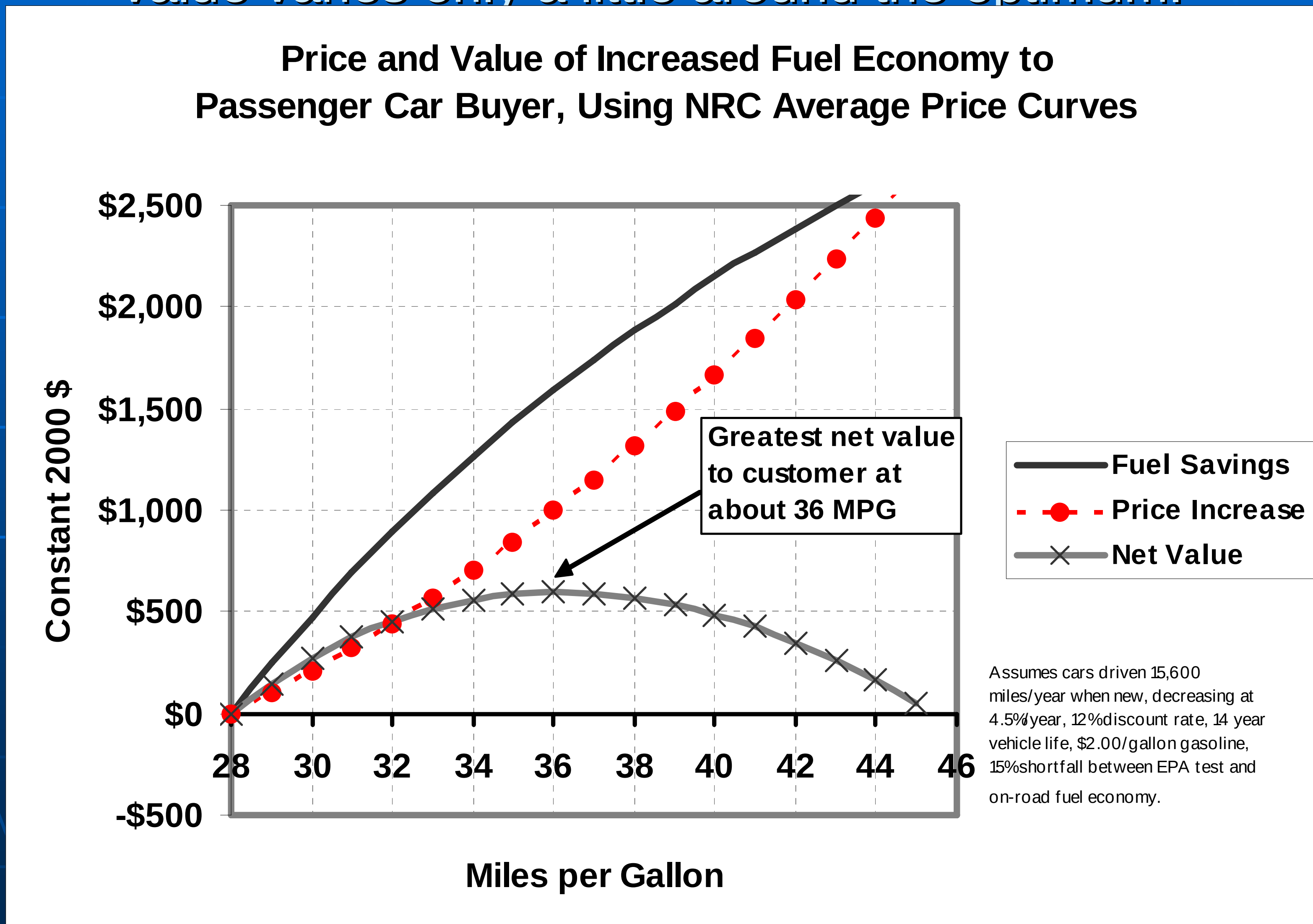
- Consumers are not irrational, manufacturers are not anti-social.
- **It's just that there's no there, there.**
- Governments (US, EU, Japan, China, Korea, Australia, etc.) are not irrational to adopt fuel economy standards.
- All market decisions about the energy efficiency of consumer durable goods share this structure.
  - Future energy savings (and cost, too) uncertain
  - Net value = PV savings – Cost, which increases ratio of noise/signal
  - Manufacturers are agents acting appropriately
  - Consumers are loss averse
- Not only market levels of efficiency will be too low but market will under-invest in efficiency R&D
- But energy efficiency is key to GHG mitigation and achieving oil independence.
- Policies must recognize this "market failure".

THANK YOU.

How do we know?

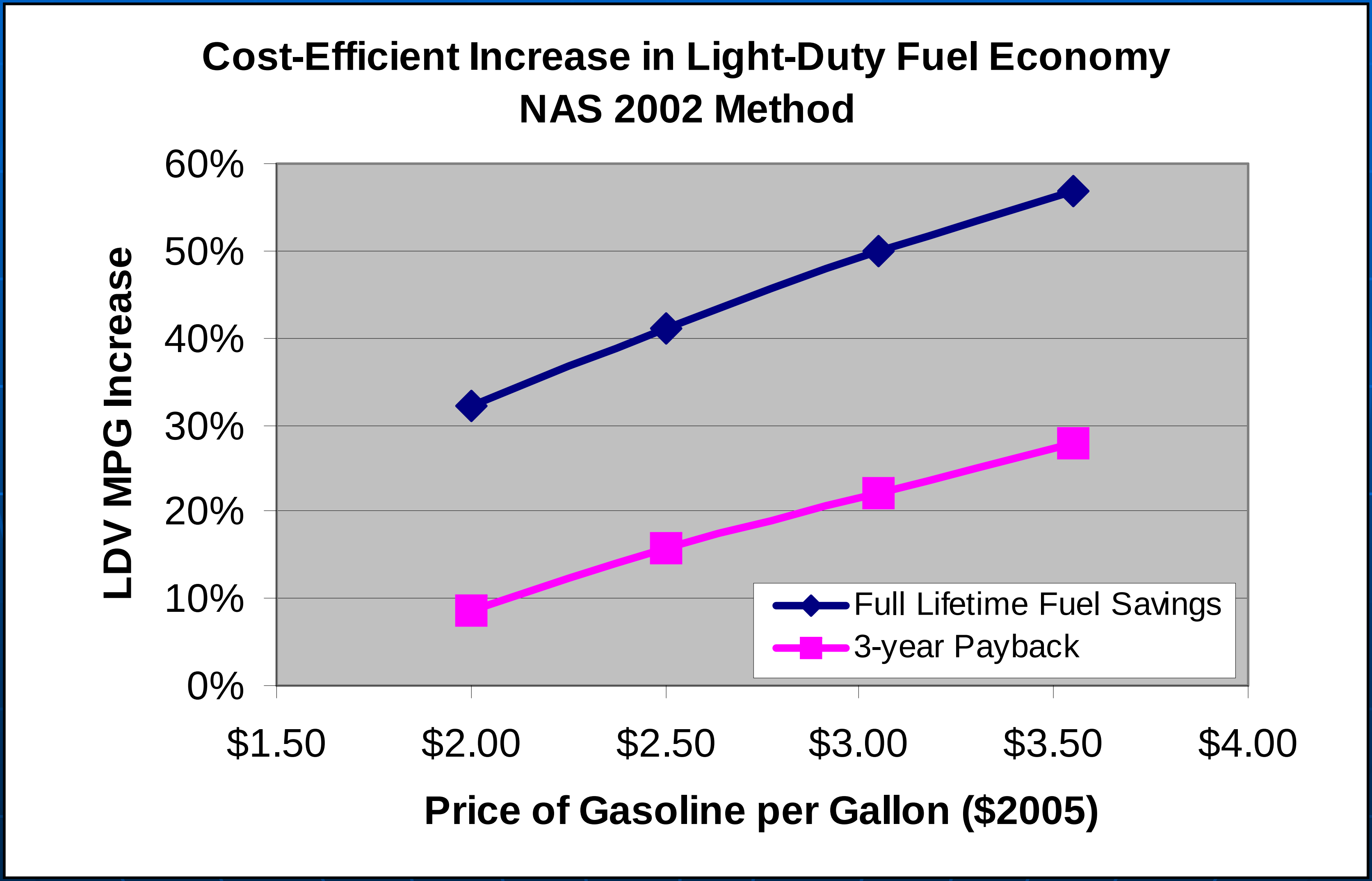
- Engineering-Economic analysis of what can be achieved by proven technologies.
- Proven: in-use in some mass-produced vehicle (market ready).
- No change in vehicle size or acceleration performance.
- Cost efficient: marginal cost to consumer = expected marginal present value of fuel savings to consumer.

The NAS "cost-efficient" method sets MC = MV, maximizing expected net value to the car buyer. Net value varies only a little around the optimum.

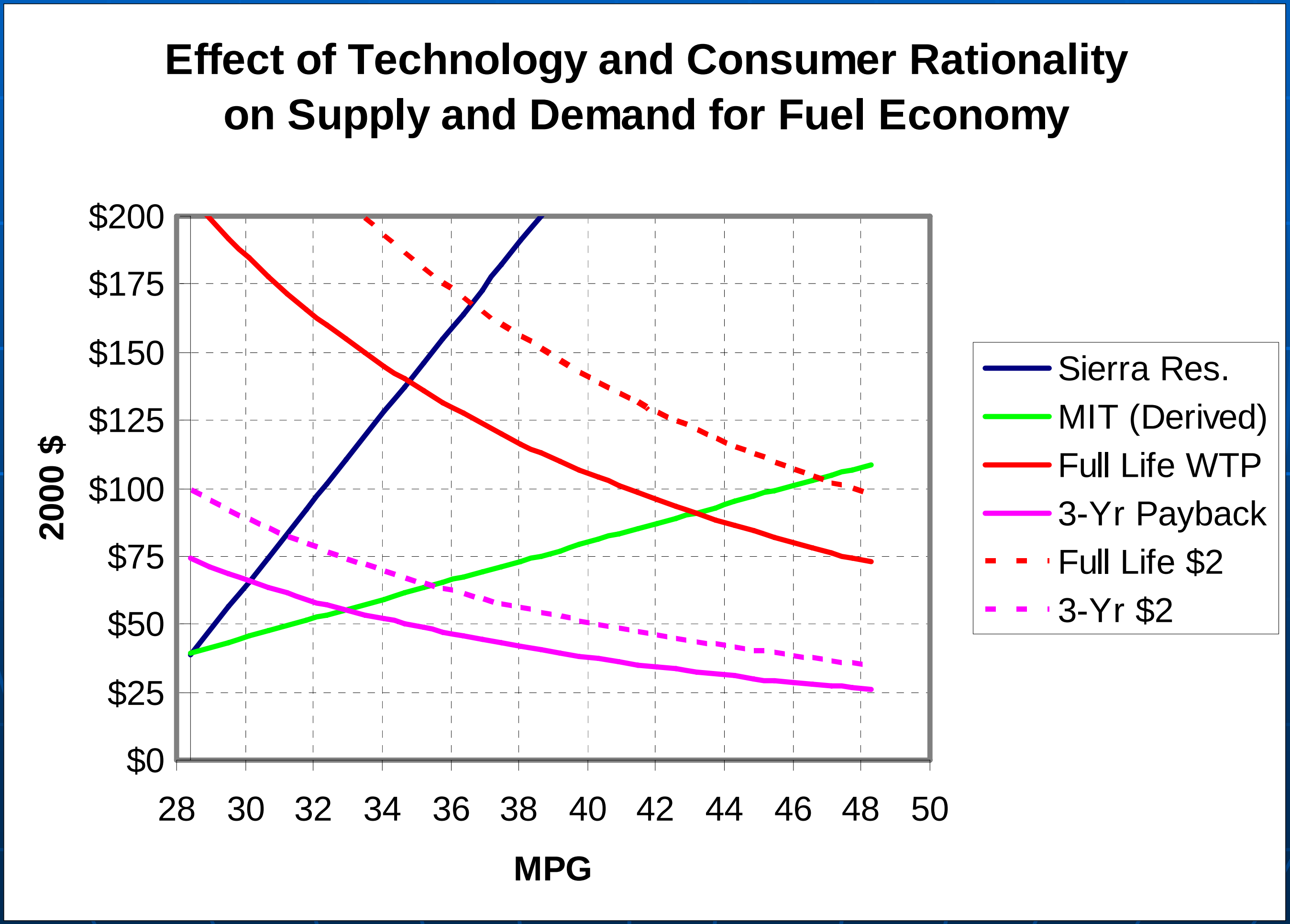


Source: Calculated from data in NAS, 2002.

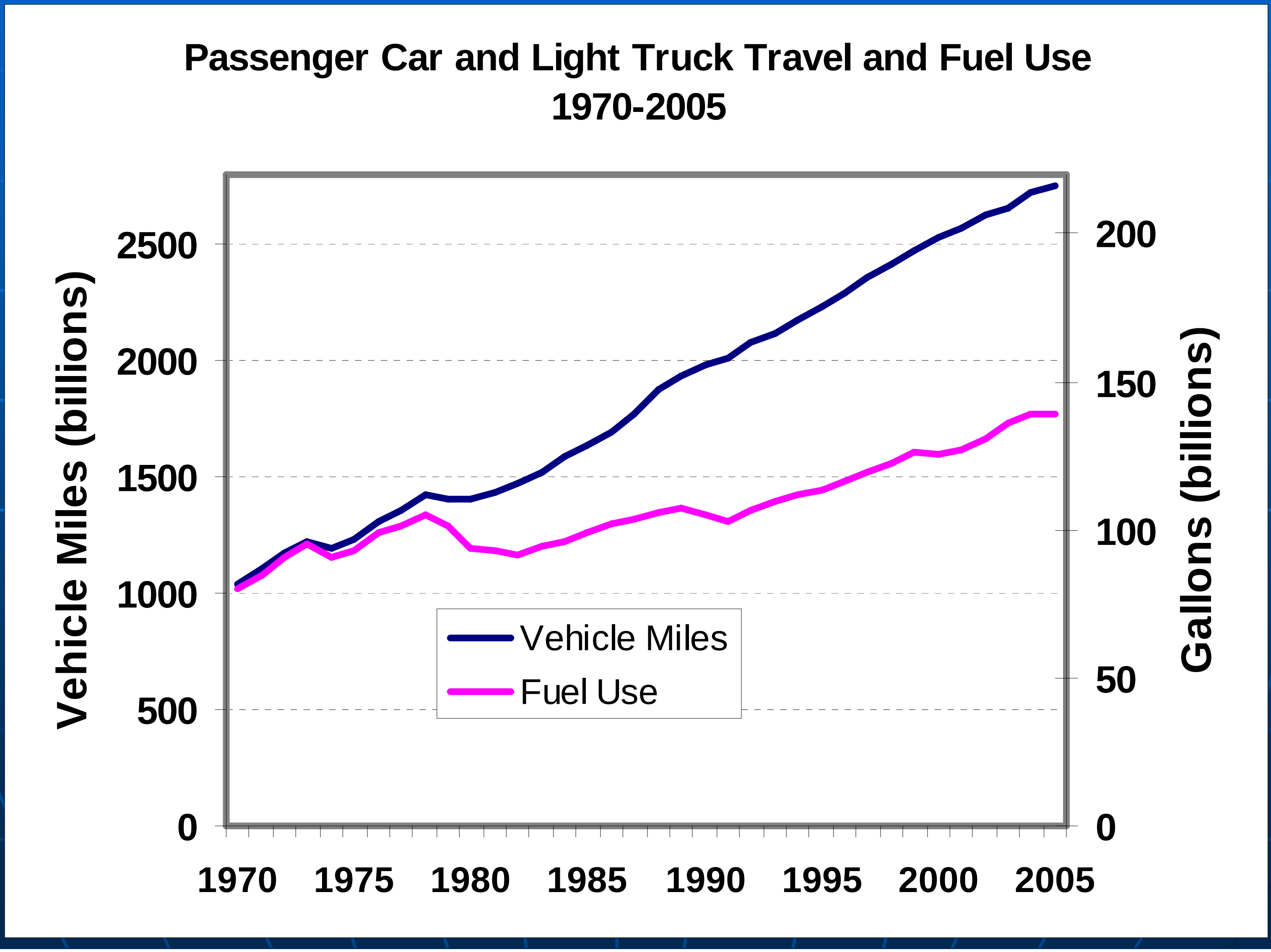
Depending on the price of fuel, increasing LDV fuel economy by 30% to 50% would be "cost efficient" at gasoline prices from $2 to $3 per gallon.



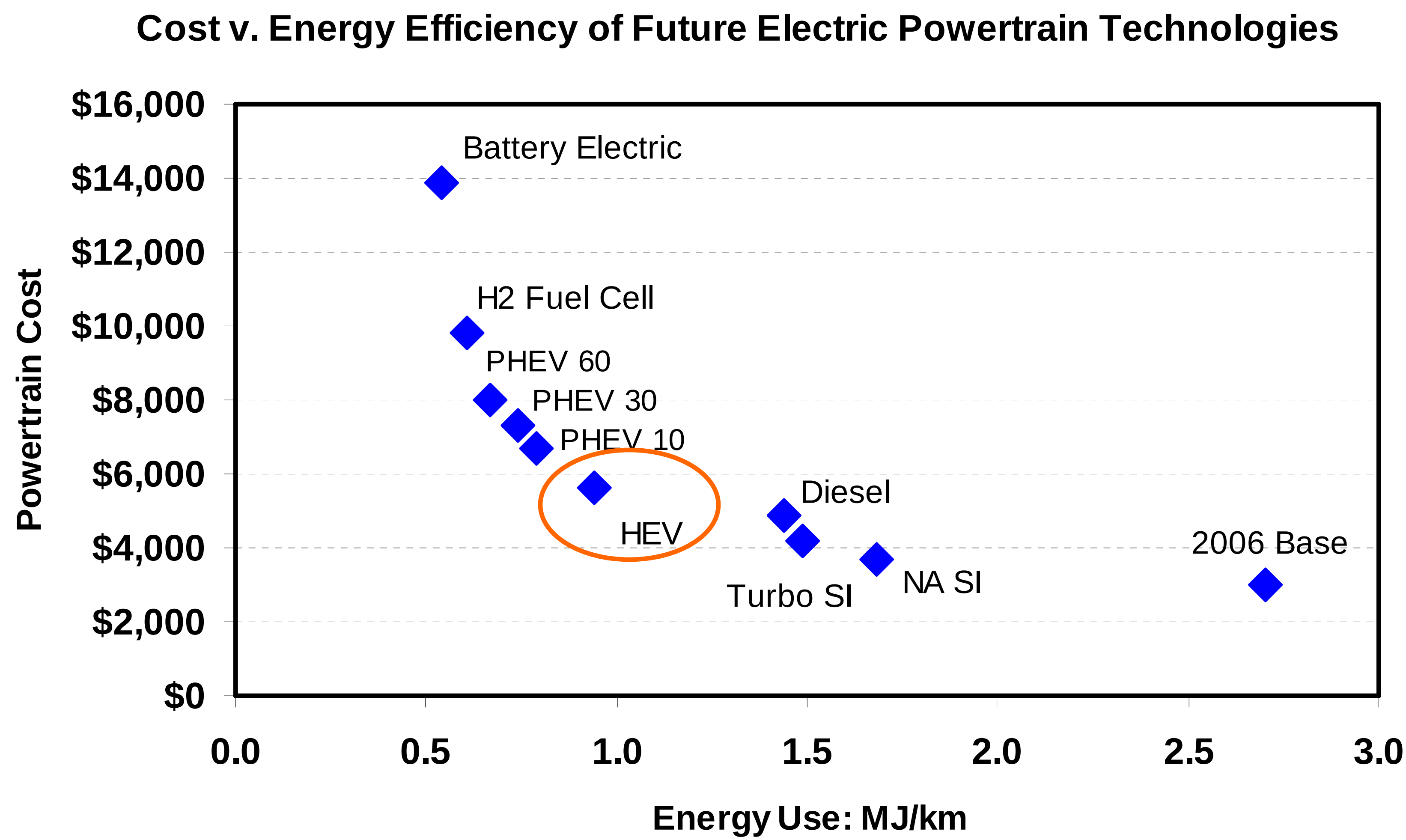
The marginal value of fuel savings is the consumer's demand curve for increased MPG. The derivative of the quadratic cost curve is the manufacturer's supply curve.



Fuel economy standards have worked well, and today save motorists about 70 billion gallons per year.



MIT also analyzed the technical potential & cost for electric drive to raise energy efficiency by 2030.



Source: Kromer & Heywood, LFEE 2007-02 RP, May, 2007.