Chapter 8
More on Transportation

Lecture #18
HNRS 228
Energy and the Environment
Adapted from Ken Kurani, Tom Turrentine, Reid Heffner and Nic Lutsey, UC Davis and Walter McManus, U.Michigan

Remember Overview of Chapter 8
- Transportation
- Power and Energy
  - Batteries, flywheels, hybrids, hydrogen, alcohol
- Traffic safety
- The Automobile
- Mass Transportation

iClicker Question
A particular light bulb produces 8 J of thermal energy while producing 2 J of radiant energy, and this is its entire energy output during this time. How energy-efficient is this bulb [as a producer of light]?
A 50%
B 40%
C 80%
D 25%
E 20%

Efficiency = useful output / total input
= 2 / (2+8) = .2 = 20%

A 100 W light bulb has an energy efficiency of 5%. It is turned on for one minute. Its total energy output during this minute is
A 2000 J
B 5000 J
C 300 J
D 600 J
E It is impossible to determine because we don't know the power.

Power input = 100 W
Power output = 5% x 100 = 5 W
Total energy output = (Power output) x (Time)
= (5 W) x (60 seconds)
= 300 J

iClicker Question
What is the work output of a heat engine whose thermal energy input is 400 J and whose exhaust is 300 J?
A 100 J
B 200 J
C 300 J
D 400 J
E 700 J

Work output = Energy Input - Exhaust (or waste)
Work output = 400 - 300 = 100 J

iClicker Question
You have a heat engine whose thermal energy input is 400 J and whose exhaust is 300 J, what is the efficiency of this heat engine?
A 175%
B 75%
C 50%
D 33%
E 25%

Efficiency = work output / energy input
= 100 / 400
= 25%
During each cycle of its operation, a certain heat engine does 40 joules of work while exhausting 160 joules of thermal energy to the environment. The energy efficiency of this heat engine is

\[ \text{Energy efficiency} = \frac{\text{Work output}}{\text{Energy input}} = \frac{40 \text{ J}}{200 \text{ J}} = 20\% \]

Please do not forget that the energy input = work output + exhaust (because of the conservation of energy).

A 2000 N car travels 50 m along a level road, powered by a drive force of 1000 N. The work done by the drive force is

\[ W = F \times d = (1000 \text{ N}) \times (50 \text{ m}) = 50,000 \text{ J} \]

Consumers and Fuel Economy

The particular version of economic rationality that has served as the sole model of human behavior in the analysis and formation of transportation energy policy in the US is...

- ...too rare in the population to be the sole model...
- ...incapable of accounting for observed behaviors in the market for automobiles and fuels...
- ...and therefore needs to be improved or replaced.

But with what?

Specific "Illustrative" sample

A complex cross-section of personal, social, and geographical variables to explore the variety of decision making if not necessarily the distribution

- Pilot interviews (Interview design and testing)
- Students just graduating (relatively poor, but informed; Davis)
- Workers in state resource agencies (informed; Sacramento)
- Off-road enthusiasts (vehicle enthusiasts; fuel consuming hobby; Auburn)
- Farmers/ranchers (careful business people; rural areas)
- Computer hard/software engineers (global connected; quantitative skills; EV aware; Roseville, Folsom)
- Financial services (quantitative financial skills; Auburn, Sacramento)
- Military personnel (know the personal (non-fuel) costs of oil imports; Sacramento, Wheatland)
- Recreational industry (lifestyle driven; Sacramento, Truckee)
- Hybrid buyers (already bought a high mpg car; Santa Cruz, Davis)

What does HEV stand for?

- A High Efficiency Vehicle
- B Heavy Economy Vehicle
- C Hybrid Electric Vehicle
- D High-voltage Electric Vehicle
- E High Energy Vehicle
A Look at HEV Buyers (2004-6)

Why do people buy HEVs?
  • Cars as symbols
    - In modern consumer culture, products are important symbols.

• Symbolism in Vehicle Purchases
  "Symbolic meaning key to early HEV owners (Gjøen and Hård, 2002)
  "Compact HEVs buyers seek symbolic meaning (OEC, 2003; UCD, 2004)
  "1/3 of current HEV buyers purchase to "make a statement" (CNW, 2006)

What You Can Do NOW for Better MPG

• Things you can do to improve fuel efficiency
  - Kind of vehicle
  - Type of driving
  - Speed of driving
  - Oil used
  - Weights in vehicle
  - Inflation of tires
  - Tuning of engine

• http://willyoujoinus.com/usingenergywisely/mpgoptimizer/?gclid=CNLAS546q4aECF5a75Q8dauIK

UC Davis Study Methods

• Two rounds of interviews with HEV owners in northern California
  1. Honda Insight and Civic Hybrid, Toyota Prius (25)
  2. Honda Accord Hybrid, Toyota Highlander Hybrid and Camry Hybrid, Ford Escape Hybrid (20)
• Two-Hour, Semi-Structured Interviews in Home Setting
• Situate vehicle purchase in larger context of participants’ lives
  • Vehicle history, job and activities, social networks, personal views

A “neo-classical” definition of “rational”

“Each individual/participating in the society is motived by self-interest and acts in response to it.”
“...decision makers are assumed to be purposive individuals whose choices are consistent with their evaluations of their self-interest.”
“...it is assumed that these individuals’ choices could be predicted simply from a knowledge of their preferences and the relevant features of their alternatives.”

Starting from this definition, how might one answer this?

• When will a consumer buy a higher fuel economy hybrid instead of a lower fuel economy ICEV?

In Greek, when

\[
(P_{\text{hybrid/ICE}})_{t_0} \leq \sum_i (p_{pg}(\text{mpg}_{ICE}))^{-1}(D_{ICE,i,t}) - \\
\sum_i (p_{pg}(\text{mpg}_{hybrid}))^{-1}(D_{hybrid,i,t})
\]

In English, when an identifiable purchase price premium for the (assumed higher price) higher fuel economy hybrid vehicle is less than or equal to the sum of fuel cost savings generated by the hybrid vehicle over time (where for simplicity of presentation we ignore discounting that stream of benefits).

iClicker Question

• Which of the following does not increase fuel efficiency?
  - A Properly inflated tires
  - B Proper oil used
  - C Weight of cargo
  - D Driving faster
  - E Lighter weight vehicle
Many such analyses say...
Consumers Shouldn’t be Buying Hybrids

“Higher gasoline prices would be needed to make even the mild hybrid economically logical for a typical consumer.”
Argonne National Laboratory. (2001)

“On straight economics, these vehicles, make little sense at today’s prices…”

“Most Hybrid Vehicles not as Cost-Effective as they Seem, Reports Edmunds.com”
Edmunds.com. June 1, 2005

Also, Consumer Reports, National Research Council, Wall Street Journal...

iClicker Question

- How many years before a more efficient car pays for itself, before you would consider buying such a car at the higher initial expense?
- A 1 year
- B 2 years
- C 3 years
- D 4 years
- E 5 years or more

What do consumers say?

- Consumers do not have the most basic information.
  - Travel distances, summed distances, fuel prices, fuel costs, summed fuel costs, and certainly not the prices of vehicles they did not buy or future streams of any of these; few know the mpg of their vehicles.
  - Buyers of hybrid vehicles have not compared their hybrids to the vehicles analysts commonly assume.
  - Hybrids are often the only vehicle in the “choice set.”

Recall the equation:

\[
(P_{\text{Hybrid-ICE}})_{t} \leq \sum_{t} (p_{t})(mpg_{\text{ICE}})^{t}(D_{\text{ICE},i,t}) - \sum_{t} (p_{t})(mpg_{\text{Hybrid}})^{t}(D_{\text{Hybrid},i,t})
\]

A Framework for Thinking about People and their Vehicles

1. Symbols can cause Action
2. Action can be constructed from social interaction, that is, the transmission or exchange of symbols (communication)
3. People act to create, sustain, or change self-identity; Self-identity is constructed as a narrative
4. In modern consumer societies, consumption is tied to these identity narratives.
   a) Investment in consumption outputs
   b) Symbols and accessible attributes of alternatives
1. Symbols can cause car buyers to act
- Gasoline prices
- From Sequoia to Prius: from deliberative to impulsive
  - He’s no longer buying just a car
- Hybrids electric vehicles
- prompted purchases, one vehicle “choice sets,” and plot lines
- Vehicle Purchase incentives
  - Zero percent financing

2. Socially transmitted purchases
- Imitation: Actions of strong social referents may be repeated by others in their network
  “They can buy anything they want, and they bought a Prius.”
  “They would have investigated this car very carefully...Her husband’s an engineer ya’ know.”
- Supporting Group membership

3. Creating, sustaining identity narratives
- Actions are taken to create or support self-identity
  - Mustang, Mustang, Mustang, Mustang...
  - We’ll buy a boat...someday
- Actions are taken to avoid being someone
  - Why some people won’t compare a Corolla to a Prius
- Who am I?
  - Honda Civic, Chevy Silverado, BMW, Honda Accord Hybrid, etc.

4a. “Novel” Consumption Outputs
- The thing I like best about my Prius is that it shuts off when you stop. When I’m sitting in the line of cars at school, seeing all those other cars and giant SUVs idling, I wonder why everybody doesn’t [buy a Prius].”
- Reducing pollution at her grandchildren’s school
- Other novel consumption outputs
  - Investing in energy efficient driving
  - Investing in lower resource consumption, including driving less

4b. Symbols and accessible attributes of perceived alternatives
- Relevant measures of attributes
  - News of difference—a vehicle with non-incrementally higher fuel economy can symbolize goals other than dollar savings
  - High—doubling, tripling—MPG allows hybrid buyers to:
    - Lower resource consumption: “Live lighter”
    - Limit financial payments to oil producers
    - Represent themselves as a “smart consumer, saving money”

Some examples...
1. HEV-owning household’s “territory”
2. “Rational analytic” and “symbolic” time
3. Narratives and symbols in marketing
iClicker Question

What do you consider to be important in a hybrid electric vehicle?
- A High MPG
- B Low carbon emission
- C Use less gasoline
- D Like latest technology
- E Don’t see any difference

What are all the meanings heard?

Wave One HEV interviews

Denotations | Connotations
---|---
Preserve the Environment: | Ethics; Concern for Others; Community Orientation; Intelligence / Awareness
Oppose War: | Ethics
Manage Finances: | Maturity / Sensibility; Ethics; Intelligence / Awareness
Reduce support to Oil Producers: | Personal Independence; National Independence
Embrace New Technology: | Individuality; Advocate to Manufacturers

Policy Analysis and Design Conclusions

- Use more models of what it means to be a human being
- As regards automotive fuel economy, consumers don’t have even the basic building blocks of a “rational” choice
- Fuel economy policy: initiate and sustain a national conversation—discourse—about energy, energy efficiency, carbon-free energy, and global warming, automobility…
- Alternative fuels, electric-drive vehicles, car-use reduction, land use changes, and other strategies are subject to similar re-interpretation

Automotive Consumers and Fuel Economy Conclusions

- Non-incremental options allow and foster non-incremental thinking, i.e., creation of new symbols.
- Early hybrid buyers didn’t buy just (or even importantly) lower private fuel cost.
- They bought symbolic as well as real fuel cost savings
- They bought a piece of the future.
- They bought a less-consumptive lifestyle.
- They bought the car of a smart, tech-savvy consumer.
- They bought into a system to produce cleaner air, lower oil consumption, and less terror.
- They bought a better story about themselves.

“Expert” model of fuel efficiency and fuel economy

- Useful energy cost of the vehicle to fuel energy output (final and initial)
- Part 1: Engine Torque / Horsepower
- Torque
- Acceleration
- Top speed
- Weight / Size / Shape
- Passenger room
- Cargo room
- Safety (real or perceived)
- Other Onboard Energy
- Four-wheel drive, lighting, HVAC, Entertainment...
- Fuel Economy
- Fuel consumption / Range
- Legal: MPG...
Simple models of fuel efficiency/economy

1. Fuel efficiency = fuel economy
   - Classes and measures: Fuel efficiency defines classes or types of vehicles; fuel economy is "a number, a numeric measure of fuel use."
2. Fuel efficiency = how much gasoline the engine uses. (MPG)
   Fuel economy = money, sometimes per unit of mobile lifestyle.
3. Efficiency and economy are viewed to be related by an underlying distribution on quality.
   Economy/low quality    Efficiency/high quality

iClicker Question
- What does CAFÉ stand for?
  - A Combined Average Fuel Economy
  - B Corporate Average Fuel Economy
  - C Composite Average Fuel Economy
  - D Calculated Average Fuel Estimate
  - E Corporate Average Fuel Estimate

What is the correct inference?
- Even if consumers accurately answer the question on the left, we risk making incorrect inferences about the real world.
- One of the conclusions of the UC Davis fuel economy study is that it is unlikely that any more than a decreasingly small minority of consumers...
  - Understand the question,
  - Have ever asked themselves the question before
  - Have ever applied this logic to any vehicle purchase

The Use of Automobiles

America's Road Network

US Suburban Population and Vehicles Grew Together, 1900 to 2000
U.Michigan used a future-market simulation to estimate the impacts of higher industry-wide fuel economy requirements. Both supply and demand are affected.

- **Baseline "Middle" Market Scenario**
- **Fuel Economy Improvement Scenarios**
  - 30% (CAFE 2020 or Pavley 2016)
  - Corporate Average Fuel Economy
  - 40%
  - 50%
- **Consumer Demand for Vehicles with Higher Fuel Economy**
- **Cost of Supplying Vehicles with Higher Fuel Economy**
- **Sensitivity Analysis**
  - Uncertain Factors
  - Tornado Diagrams
- **Findings**

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U.Mich began their analysis with a scenario that represented a mid-range outlook for the market in the near future.

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### Sales by Automaker & Segment, Future-Market Mid-Range Scenario

<table>
<thead>
<tr>
<th>Segment</th>
<th>Chrysler</th>
<th>Ford</th>
<th>GM</th>
<th>Honda</th>
<th>Nissan</th>
<th>Toyota</th>
<th>Others</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Luxury Car</strong></td>
<td>84</td>
<td>314</td>
<td>793</td>
<td>916</td>
<td>103</td>
<td>740</td>
<td>806</td>
<td>3,678</td>
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<tr>
<td><strong>Small Car</strong></td>
<td>131</td>
<td>154</td>
<td>495</td>
<td>494</td>
<td>133</td>
<td>723</td>
<td>740</td>
<td>3,329</td>
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<tr>
<td><strong>Midsize Car</strong></td>
<td>235</td>
<td>403</td>
<td>711</td>
<td>513</td>
<td>272</td>
<td>703</td>
<td>894</td>
<td>3,739</td>
</tr>
<tr>
<td><strong>Small CUV</strong></td>
<td>102</td>
<td>344</td>
<td>400</td>
<td>200</td>
<td>83</td>
<td>307</td>
<td>137</td>
<td>1,563</td>
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<tr>
<td><strong>Large Van</strong></td>
<td>296</td>
<td>141</td>
<td>134</td>
<td>127</td>
<td>106</td>
<td>45</td>
<td>570</td>
<td>1,791</td>
</tr>
<tr>
<td><strong>Large Pickup</strong></td>
<td>490</td>
<td>612</td>
<td>654</td>
<td>0</td>
<td>114</td>
<td>0</td>
<td>0</td>
<td>1,791</td>
</tr>
<tr>
<td><strong>Small Pickup</strong></td>
<td>295</td>
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<td>65</td>
<td>21</td>
<td>94</td>
<td>137</td>
<td>0</td>
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<tr>
<td><strong>Large Luxury SUV</strong></td>
<td>102</td>
<td>31</td>
<td>26</td>
<td>0</td>
<td>0</td>
<td>51</td>
<td>127</td>
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<td><strong>Large SUV</strong></td>
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<tr>
<td><strong>Midsize Luxury SUV</strong></td>
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<tr>
<td><strong>Midsize SUV</strong></td>
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<td><strong>Large Luxury SUV</strong></td>
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<tr>
<td><strong>Large Van</strong></td>
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<td>0</td>
<td>0</td>
<td>349</td>
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</tbody>
</table>

Source: The Planning Edge, April 2009

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iClicker Question

- In the aforementioned model scenario, what do you think WTP may stand for?
  - A Weight Transfer Payload
  - B Willingness To Participate
  - C Willingness To Pay
  - D Weight To Participate
  - E Wait To Pay

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An industry-wide increase in vehicle fuel economy has impacts on OEMs' and dealerships' product costs, on product prices, and on consumers' willingness to pay for vehicles—leading to changes in profits.

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U.Mich used information from J.D. Power and Associates' Power Information Network (PIN) to define Retail Price, Gross Profit, and Direct and Indirect Costs at the level of the combined enterprise of an automaker and its dealerships.

- **Vehicle Price Less Customer Cash Rebate**
- **Customer Cash Rebate**
- **Dealer-Installed Options Price**
- **Dealer's Price**
- **Factory-Configured Vehicle F.O.B.**
- **OEM's Variable Vehicle Cost**
- **Customer Cash Rebate**
- **OEM's Gross Profit**
Evidence that automakers underestimate the value of fuel economy to consumers lead UMich to reject the assumption that fuel economy is optimized in the baseline scenario.

Fuel Economy Improvement:
Supply Price and Consumer Willingness to Pay

The improvement in fuel economy raises both the vehicle marginal cost and the vehicle marginal revenue curves, and vehicle unit sales could rise or fall, depending on which marginal curve shifts more. (If UMich had assumed that the baseline fuel economy were optimized, then unit sales could only fall.)

UMich estimated the detailed impacts on the industry of three levels of improvement in industry-wide fuel economy: 30%, 40%, and 50%. Industry total gross profit increases relative to the base case in all three scenarios; Detroit 3 gross profits increase roughly $3 billion (8%) relative to the base case in all three scenarios.

In the auto industry model of fuel economy, costs, demand, and gross profits UMich identified 11 future-market factors that cannot be predicted with certainty. Analysts such have widely different prior beliefs that most empirical evidence is unpersuasive. UMich approach was to do a sensitivity analysis for these factors in each of the three scenarios.

Sensitivity Analysis: Influence Factors Subject to Uncertainty

In the auto industry model of fuel economy, costs, demand, and gross profits UMich identified 11 future-market factors that cannot be predicted with certainty. Analysts such have widely different prior beliefs that most empirical evidence is unpersuasive. UMich approach was to do a sensitivity analysis for these factors in each of the three scenarios.

“Tornado” plot for 30% improvement

“Tornado” plot for 40% improvement
### "Tornado" plot for 50% improvement

<table>
<thead>
<tr>
<th>Sensit 1.42</th>
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<tbody>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>Variable 1</td>
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<td>Variable 2</td>
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<td>Variable 3</td>
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<td>Variable 8</td>
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<td>Variable 9</td>
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<td>Variable 10</td>
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</table>

The tornado plot shows the sensitivity of the model output to changes in individual input variables. The length of each bar represents the magnitude of the impact on the model output.