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Car buyers and fuel economy?

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Abstract

This research is designed to help researchers and policy makers ground their work in the reality of how US consumers are thinking and behaving with respect to automotive fuel economy. Our data are from semi-structured interviews with 57 households across nine lifestyle "sectors." We found no household that analyzed their fuel costs in a systematic way in their automobile or gasoline purchases. Almost none of these households track gasoline costs over time or consider them explicitly in household budgets. These households may know the cost of their last tank of gasoline and the unit price of gasoline on that day, but this accurate information is rapidly forgotten and replaced by typical information. One effect of this lack of knowledge and information is that when consumers buy a vehicle, they do not have the basic building blocks of knowledge assumed by the model of economically rational decision-making, and they make large errors estimating gasoline costs and savings over time.

Moreover, we find that consumer value for fuel economy is not only about private cost savings. Fuel economy can be a symbolic value as well, for example among drivers who view resource conservation or thrift as important values to communicate. Consumers also assign non-monetary meaning to fuel prices, for example seeing rising prices as evidence of conspiracy. This research suggests that consumer responses to fuel economy technology and changes in fuel prices are more complex than economic assumptions suggest.

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Keywords: Fuel economy; Fuel efficiency; Automobiles; Car buyers

1. Introduction

1.1. It's a gut feeling

B., the male head of household, starts by saying, "$2000…I'm so wanting a spreadsheet right now." He laughs.

M., the female head of household, makes a joke about a colleague writing the spreadsheet program. They both laugh.

Then M. says, "$4000…it's a gut feeling."

B., "I was trying to calculate it [in my head], but I didn't carry it through very far."

M., "We probably drive each car about 7000 or 6000 miles every year."

She then suggests they might save 1000 gallons per year [for one car]; B. thinks this might be too much.

B. summarizes their initial responses, saying "$2000 to $4000."

Then, in unison, M. and B. say, "Call it $3000."

M. and B. are responding to our inquiry about their willingness to pay for a 1.5 times improvement in the fuel economy of an SUV they have designed during their interview—we have proposed to increase its fuel economy from 11 to 17 miles per gallon (MPG). They both work as financial service professionals. They appear to negotiate a lot with each other, having done so throughout the interview. Prompted by a desire to buy a vacation home, they have been reviewing their expenses to determine how much they can afford. They eventually offered a single number as their answer—$3000—but their dialog illustrates they do not think about their vehicle purchases in this way.

If a household in which both household heads are financial professionals has trouble providing realistic answer to a willingness to pay question in our extensive

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interview, how valid could their response be to the same question during a phone survey? How could we expect less capable households to answer such a question? Does it make any sense to even ask such questions?

1.2. Expert views on efficiency and fuel economy

There are at least three ideas behind most experts' thinking about efficiency and fuel economy. The first is a physical model: energy out of the crankshaft of an engine can be apportioned to a variety of end-uses. This model is summarized in Fig. 1. Increases in efficiency can be apportioned to more power, moving a larger or less aerodynamic vehicle, facilitating other on-board energy use, and increasing fuel economy. Fuel economy is codified as miles per gallon (under specified test conditions). This physical model imposes a design envelope on choices offered to consumers—the more energy apportioned to one use, the less is available to others.

The second idea is basic economics: maximum profit occurs when automakers offer consumers their most highly valued distribution of the possible end-uses of the energy produced by a vehicle's engine. In practice and regardless of any abstractions such as units of "utility" or "happiness," the value of these end-uses is typically measured in dollars, e.g., willingness-to-pay. In this view, the value of fuel economy is measured in cents per mile (of fuel savings).

Unfortunately, this idea has lead to the confusion of the measure for the thing being measured, i.e., that the only value to consumers of fuel economy is private monetary savings. Saving money is related to household income and budgets. As the price of gasoline goes up, consumers may, according to their incomes, buy more fuel economical vehicles or take other actions to stay within income and credit limits.

A third idea is that consumers, for the most part, value power, size, energy-consuming options and accessories (and according to a widely cited anecdote, cup holders) more than they do fuel economy, at least as long as fuel costs are low and incomes are high.

How do these three ideas relate to how consumers actually think about fuel economy? How do we reconcile M. and B.'s story, and those of the 56 other households we interviewed with these "expert" ideas? These households' personal histories with automobiles will prove to be crucial.

1.3. A short history of fuel prices, fuel efficiency, and fuel economy

For most of the past 90 years the real cost of gasoline declined. Notable exceptions include the Great Depression, the two "oil crises" of the 1970s and early 1980s, and recent years. This history is summarized in Fig. 2. For most of our households, their personal history with this trend dates back no further than the 1960s. Even people as old as 40 had no direct consumer experience with prolonged rising gasoline prices until the last few months of our study period (in 2004).

Over this time manufacturers delivered roomier, stronger, and faster vehicles, as well as more amenities such as automatic transmissions, all-wheel drive, air conditioning, and entertainment systems. What was the effect on fuel economy? Systematic data on fuel economy for the US fleet of light-duty vehicles is available starting in the mid-1970s.

Since then, only during the oil crisis of the 1970s and early 1980s and following the deployment of corporate average fuel economy (CAFE) standards did average fuel economy increase. This trend is illustrated in the Fig. 3, which shows a simple index of weight, power, and fuel economy plotted against fuel economy, and traced over time.

Once oil shocks were over, CAFE standards ceased to increase, and gasoline prices dropped, then automakers quickly shifted back to increased power and size while fuel economy improvements stopped. Fig. 3 understates this

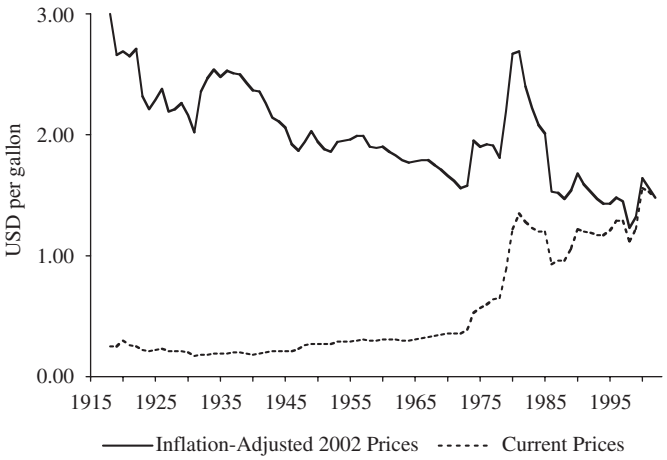

Fig. 2. Current and 2002 inflation-adjusted US prices for gasoline from 1918 to 2002. (American Petroleum Institute, 2002)

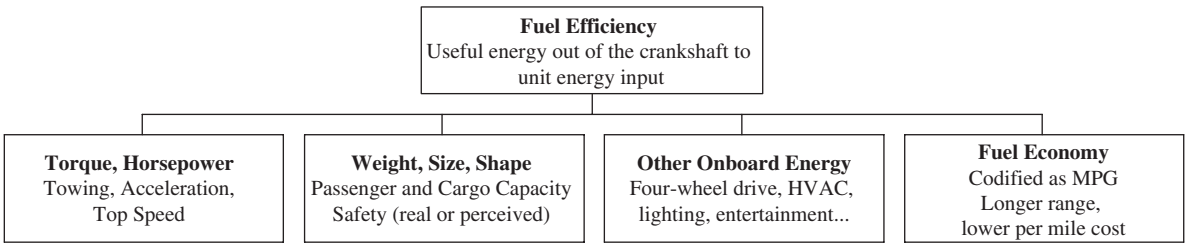

Fig. 1. Physical model of fuel efficiency–fuel economy relationship.

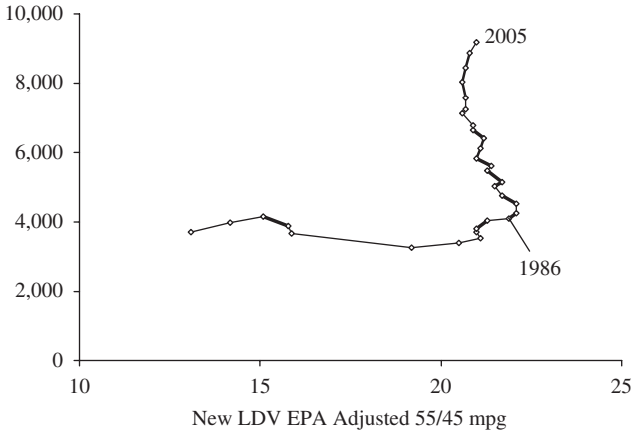

Fig. 3. Trends in new US LDV weight, power, and fuel economy, 1975 to 2005. (US Environmental Protection Agency, 2004)

effect since it does not include increasing numbers of SUVs and pickup trucks so large they are medium-duty, not light-duty, trucks. Automakers believed car owners wanted more power and bigger vehicles, and exploited the lower CAFE standard for light-duty trucks (and the absence of any standard for medium-duty trucks) to use truck platforms to provided consumers with minivans, SUVs and larger pick-up trucks.

Fig. 3 depicts two distinct periods in recent automotive history. Following the model of expert thinking presented earlier, the first episode is read as an aberration caused by temporary spikes in fuel price (and actual supply disruptions) and regulations, while the second marks a return to "true" consumer preferences. Our contentions are that (1) neither period can be dismissed as unrepresentative of what consumers want and (2) in all periods, consumers choose from what is offered to them.

Individual consumers may experience these historical periods of average improvements in power, size, and fuel economy quite differently than illustrated in Fig. 3. The most salient experience consumers bring to a new vehicle purchase is their past experience with their own vehicles, not improvements to vehicles in general. At any new vehicle transaction, their most recent vehicles are typically 2–7 years older than new vehicles being offered. Every time a household shops for a new vehicle they may find most new vehicles provide more power, size, and amenities—with similar fuel economy—than their past vehicles. People may experience new automobile purchases not so much as trade-offs between new vehicle options, but mostly trading-up compared to their past vehicles. This would be true especially if the findings discussed in this paper regarding consumers are right, that they do little calculated decision-making, relying most on what information is immediately available.

1.4. Transportation energy research and the rational car buyer

Transportation energy research extends the above model of expert beliefs about consumers and fuel economy a few steps further, applying more esoteric economic ideas about consumer decisions such as payback periods and net present value calculations. While many analysts admit that something is wrong with rational choice, they still create models and debate fuel economy policy as if drivers keep records on vehicle and gasoline costs, estimate their purchase costs and future ownership and operating costs, and discount future cost and benefit streams, as from higher fuel economy. Consumers are assumed to consider the cost of gasoline and fuel economy both in their travel and vehicle choices, and to consider such costs over time.

Studies based on this model have addressed, for examples, household response to higher gasoline prices (Espey and Nair, 2005; Kayser, 2000; Pitts et al., 1981; Puller and Greening, 1999), aggregate economic impacts of inaccurate EPA mileage estimates including impacts on consumer surplus (Senauer et al., 1984), competing effects such as gasoline cost savings versus safety (Yun, 2002), and the range of implicit inter-temporal discount rates in consumer decisions, (Calfee, 1985; Greene, 1983; Train, 1985; Verboven, 1999).

Based on this extended ideal model of consumer response to fuel costs, automobile makers and regulators debate how much more consumers would be willing to pay for vehicles with improved fuel economy, and over what period of time consumers will want their "investment" in fuel economy returned. Automotive manufacturers oppose higher CAFE standards, arguing that automobile buyers want to get back their money on new fuel economy technology sooner than the relative increases in vehicle prices and fuel economy will allow. In one review of national survey data, Steiner (2003) reported that on average consumers said they would want back an "investment" in higher fuel economy in 2.9 years, despite the fact they also said they expect to own vehicles, on average, for more than 5 years.

What could be wrong with this model? Imagine for a moment that at least some consumers do not value future gasoline savings entirely as dollars saved, but also out of a commitment to lower resource consumption, a belief in a link between efficiency and greenhouse gas emissions, or any of a variety of reasons other than private financial savings on fuel costs.

Further, past interviews we have conducted with automobile buyers lead us to think that the rational actor model is not an accurate or useful view of how consumers think about fuel economy and automotive fuel costs. A multi-year project on markets for alternative fueled vehicles in the 1990s left us with the impression that automobile owners did not have any idea how much they spend on fuel and often did not know the fuel economy of their vehicles (Kurani et al., 1994; Turrentine et al., 1992). Research on diesel vehicle buyers lead us to believe that consumers use retail fuel prices to gauge their satisfaction with their vehicle purchase, but did not record fuel costs over time (Kurani and Sperling, 1988). CNG buyers we studied in New Zealand did not calculate fuel costs, but

similarly used relative natural gas and gasoline prices (a difference subject to government policy) to gauge satisfaction with their vehicle conversion (Kurani, 1992).

But these results are more than 10 years old. Have consumers changed? Have rising gasoline prices in the past few years produced more rational consideration by consumers?

1.5. Hybrid electric vehicles (HEVs) and the extended model of the rational consumer

These expert ideas about fuel economy we outline also frame a newer debate around the future sales of high fuel-economy HEVs. Strong sales to date of HEVs have surprised many analysts and automakers. HEVs can cost more to buy than conventional vehicles, and some consumers wait months for delivery. On the other hand, resale value of HEVs (as a percentage of purchase price) is among the highest of any vehicle and sales of Toyota's Prius are reaching 100,000 units per year in the US.

Still not convinced, reports in the news and popular press continue to question the "rationality" of HEV buyers. Writing to consumers the Wall Street Journal (White, 2005) and the automotive market research firm Edmunds.com (2005) have recently published analyses of private financial costs that indicate HEV buyers are not being smart—*if buyers of HEVs are trying to save money through fuel cost savings*.

A number of energy analysts are afraid that hybrid technology, like fuel injection and many other technologies, will be put in service of increasing power, larger vehicles, or conveniences and accessories, instead of increased fuel economy. Carmakers have focused in the last 2 years on applying hybrid technology to larger and more powerful vehicle lines creating "performance HEVs" and hybrid SUVs. Are they signaling a belief that the success of "economy HEVs" is limited and ephemeral?

2. Developing a wider view of consumer behavior with respect to fuel economy

We do not argue with the belief that all things equal, under conditions of declining real gasoline prices many consumers have wanted more power and room in their vehicles. But the value of fuel economy, relative to power and room, is also not a simple matter of household economics and gasoline prices. First, we hypothesize that several factors confound calculated, rational decision-making around fuel economy, including the following:

1. Until recently, cars with good fuel economy (in the USA) were most likely to be small, light, "cheap" vehicles, also known derisively as "econo-boxes." Fuel economy was part of this "economical" package, for folks with fewer economic resources.
2. The automotive market offers many sizes, designs, power-trains, brands, interior fabrics, technologies, optional amenities, and colors. Fuel economy is one variable in this complex market, a variable which is easily forgotten when gas prices are low and falling.
3. Most vehicles still have crude fuel use instrumentation designed primarily to provide notice of the need to refuel, not to track fuel use or costs.
4. Given number 3, calculations and systematic record keeping are not "normal" behavior. Those people who do keep records, do so to track engine functioning.
5. Years of declining (real) gasoline prices and increasing vehicle power, size, and energy consuming features eroded the context for higher fuel economy of the 1970s and early 1980s.

But there are new reasons for buyers to pay more attention to fuel economy:

1. Rising and volatile gasoline prices over the past few years.
2. New fuel economy instrumentation.
3. Obvious effects of global climate change due in part to CO_2 emissions from transportation.
4. Increased national dependence on imported oil, highlighted by another war in a key oil-producing region. Even some radical conservatives have recently embraced the idea of "oil independence" in the US and therefore high automotive fuel economy as a strategic national policy.
5. Very high fuel economy of early HEVs opens a new direction in automotive symbols and values.

The combined effects of these two lists of variables create a complex milieu for the value of fuel economy.

3. Fuel economy in the lives of 57 California households

We report here on the role of automotive fuel economy in vehicle purchases and use decisions of 57 northern California households. Our data was collected in 2003–2004 through a pre-interview survey and a 2-hour household interview.

We do not challenge the engineering idea that allocates energy to size, power, or fuel economy, but we do explore consumer values, knowledge, and calculations for fuel use and fuel economy decisions in much greater detail than previous studies. We explore whether fuel economy is only about saving money, and whether the extended model of consumer rationality in transportation research, that sees buyers as making calculated decisions about fuel costs overtime, has any base in observed behavior.

We learn that almost none of our participants know or track how much they spend on gasoline over time. Many do not know the fuel economy (MPG) of their current vehicle(s), much less what they spend cumulatively on gasoline in a month or a year and therefore have no way of knowing how much they might save with a more fuel economical vehicle. Even the accountants, bankers, and

financial analysts we interviewed do not keep track of their gasoline costs other than to note the price of a gallon or tank of gasoline the last time they went to the gas station—the same as any of our households. Moreover, we have some evidence that good fuel economy is sometimes viewed as a moral value.

3.1. Household interviews

We interviewed these households over a 12-month period. Because we review their entire history of automobile ownership, we discussed over 400 vehicles and delved into over 125 specific vehicle transactions. With a few exceptions, interviews were conducted with all relevant household decision makers present. Most of these interviews were conducted at respondents' homes; two were conducted at their place of business and three in restaurants. Their home puts the participants at ease and seeing the home gives researchers greater information about the household.

3.2. Primary sampling attributes

Our goal was not to attempt a representative sample, but to explore the range and variety of behaviors with regard to fuel economy, with some structuring of the sample. We identified nine different "sectors," defined by economic, lifestyle, and knowledge considerations, for which we had simple hunches about their potential choices and values.

We interviewed six households from each of these illustrative sectors, plus three pilot interviews. The households live along a 100-mile stretch of US Interstate 80 in northern California. In addition to families and couples, there were single person households as well as some students with roommates. Participating households had recently purchased or were in the middle of a purchase of a new or used car or truck. Households in our sample own slightly more vehicles, are more likely to live in a small city or a rural area, and are less likely to be retired than if the sample had been drawn at random from the population of California.

These are the ten groups that comprise the sample, with and a brief description of our interest in them:

1. Pilot interviews: three households used to develop interview methods.
2. College and graduate student's nearing graduation or recently graduated: limited income, well educated about environmental issues, at a transition point in their lives.
3. Off-road vehicle users: possibly more aware of fuel economy because of their fuel-consuming hobby.
4. State resource agency employees: might know more about environmental and energy issues in California.
5. Farmers and ranchers: business people who make financial calculations and budgets over annual cycles.
6. Computer hardware and software engineers: probably better connected with global technology developments, high level of quantitative skill.
7. Military households: personal connection to the social costs of the geo-politics of oil, for enlisted personnel lower income creates more budget constraints.
8. Financial services sector: high level of financial quantitative skills they use professionally on a daily basis.
9. Outdoor recreation industry: lifestyle driven, aware of environmental issues, whether or not they are sympathetic to environmental "causes."
10. HEV buyers: already buying fuel-efficient vehicles.

The interviews were conducted in four parts:

1. First, we listen carefully to households talk about past vehicles and purchases, listening for past attention to fuel economy. We are careful not to probe for fuel economy, as we want to elicit past interest in fuel economy, not prompt it during the interview. Here we learn about the development of individual tastes and major influences on vehicle choices such as family, friends, and co-workers, episodes of financial upturns and downturns, experience with past vehicles, etc.
2. Second, we ask about the most recent vehicle purchase in much greater detail. As with the first step, the intent in the second step is to listen for clues as to whether fuel economy was a consideration: again, we do not probe about fuel economy.
3. The third section of the interview was intended to insure that we could listen to households talk about fuel economy as one of several vehicle attributes. Further, we wanted to establish as realistic as possible a context for introducing a "1.5X" fuel economy vehicle in Part Four of the interview.

   We asked most households to design the next vehicle they imagined themselves buying. In a few households, we asked them to reconsider their recent vehicle purchase rather than their next possible vehicle. Because the HEV itself was the context for discussing fuel economy with HEV buyers, we did not conduct this exercise with them.

   The exercise uses a *priority evaluator* (PE) table. After establishing whether they want a truck- or car-based vehicle, we offer a list of vehicle attributes: performance, number of seats, cargo capacity, safety equipment/rating, fuel economy, pollution rating, options packages, and for trucks towing capacity and four-wheel drive. Each attribute is offered in three levels. For example, the seating options for an SUV were four, six, or eight seats, which cost one, two, or three points, respectively. We constrain their vehicle design by limiting their total points. Once they have completed an initial design, we change their available points and ask them to redesign the vehicle.

   Within this exercise we require households to spend more to get higher fuel economy—just as they are being

asked to do now by so many researchers, but contrary to their (later revealed) expectations that "economy" cars cost less.

4. In the fourth part of the interview we let on that we are most interested in fuel economy. Our goals here are to observe households respond to questions about paying more for higher fuel economy and payback periods, and to discover whether households track the basic "building blocks" of rational consideration of fuel economy such as annual fuel costs, MPG, and other data on household travel and fuel use.

4. Findings

4.1. Parts 1 and 2: past and present vehicle purchases

In the absence of prompts from us, few households mention fuel economy when discussing any past vehicle purchases or use. Those who had considered fuel economy did so at a time when they had modest income, when a household member had a long commute, or during the oil price shocks of the 1970s. Also, younger households may recall their parents first buying "economy" cars in the 1970s.

Fuel economy also rarely surfaces when talking about the most recent vehicle purchase. As a group, college students were the most interested in fuel economy. For them, money may be short and gasoline can be the entire cost of operating a vehicle otherwise paid for by their parents. Additionally we heard some mention of fuel economy from enlisted military personnel and other less affluent respondents.

Particularly in middle and upper middle-income households with children, their primary goal for at least one household vehicle was often a vehicle large enough for children, friends, dogs, vacation baggage, and large shopping items. Many were interested also in four-wheel and all-wheel drive for access to winter and off-highway recreation activities (often whether or not these activities were actually undertaken by the household). Families with young children had a strong interest in safety.

4.2. Part 3: using the priority evaluator table to re-examine the current purchase or design the next vehicle

In the PE exercise, we explicitly place fuel economy in a competition with other vehicle attributes. (Recall we did not use the PE exercise in households that had purchased a HEV.) No household appeared to make a strong commitment to high fuel economy for a future vehicle (or a revisited version of a recently purchased vehicle) based on then current (circa 2002–2003) gasoline prices. Households who did choose high or mid-level fuel economy for their vehicles appeared to be doing so out of longer-term commitments to environmental and social issues, or because of high fuel costs at some point in their personal or household histories. Still, in some high fuel use households, fuel economy was surprisingly (to us) undervalued. Some people towing or traveling long-distances seemed satisfied with low fuel economy ratings in the PE table (mirroring what they are achieving in the real world) and choose to spend points elsewhere, even when offered more points. Some full-size truck buyers are interested in lowering their fuel costs. They are likely to see alternatives, such as diesel engines, as desirable.

4.3. Part 4: fuel efficiency and fuel economy

In the final section of the interview we finally reveal to households our interest in fuel economy. Here we learn how typical consumers think, or even if they think about it. We start by asking whether *fuel economy* and *fuel efficiency* mean the same thing or different things to them. It is clear that the definitions of our lay respondents differ from those of experts. The most common "off-the-top-of my-head" response is that the two terms mean the same thing. To many people this meaning is rather abstract—"It's the gasoline it takes to get around, to go all the places we go." As some of them continue to talk, they convince themselves that *fuel economy* is about saving money while *fuel efficiency* is about saving gasoline.

When we ask our respondents to tell us what type of automobile comes to mind when we say "good fuel economy," most think of the smallest, cheapest vehicles. In contrast, "good fuel efficiency" tends to split the respondents into those for whom there is no different image and those who say fuel efficiency evokes images of higher quality vehicles and HEVs.

4.3.1. Willingness to pay for higher fuel economy—do households understand the question?

We then ask households how much they would be willing to pay up front for an automobile with higher fuel economy. The reference vehicle is the one they designed in the PE exercise in Part Three. The fuel economy increase we posit is usually a 1.5X increase. While we occasionally choose a different multiplier than 1.5, we typically chose this number for two reasons. First, it is the maximum possible change in the PE table (and thus might be a change the household actually made in the PE exercise). Second, a 1.5X change is large enough on the one hand to get the attention of people who for the most part are not paying attention to fuel economy, but on the other is within the realm of technical plausibility. Once they have answered the question of how much they would pay, we follow up by asking how they arrived at their answers. We summarize their willingness-to-pay answers in Fig. 4.

In eight of the early interviews we did not ask this question about willingness to pay directly, so no values were solicited. In eight interviews in which we did ask the question, the household could not or would not offer a value. Ten other households offered a range, e.g., "$2000 to $4000" or "$5000 to $7000." Sometimes this range

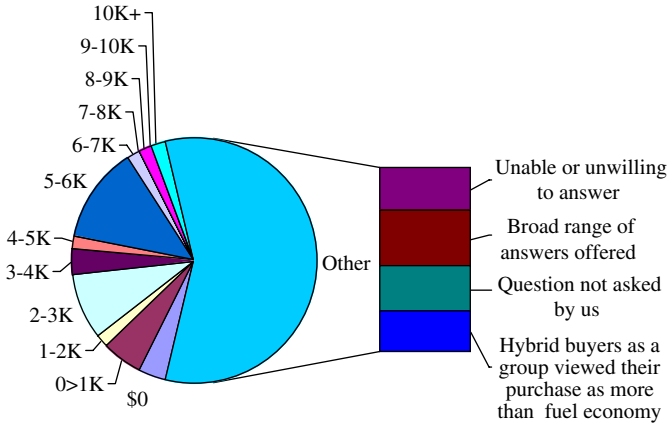

Fig. 4. Distribution of responses to willingness to pay for increased fuel economy.

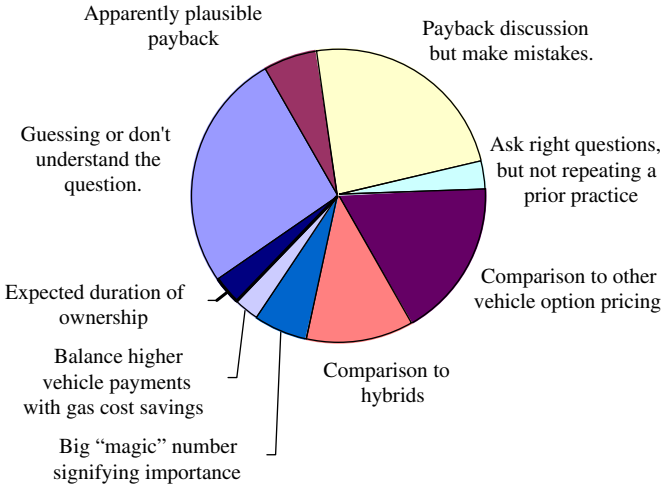

Fig. 5. Basis for willingness to pay answers.

conveyed obvious uncertainty; sometimes these ranges represented disagreement between household members who were unable to agree on an amount in the course of the interview. Among the households who offered specific dollar amounts (or answers in a range less than $1000), values ranged between zero and $10,000. Even excluding the eight households from whom we did not solicit a value, half the households are unable or unwilling to offer a numeric answer.

4.3.2. Basis for willingness to pay responses

How people arrived at their willingness-to-pay responses is summarized in Fig. 5. Only two individuals offer plausible willingness to pay answers arrived at through a process that could be described as economically rational (rather than through simple guessing). We judge the plausibility of their answers based on their producing a consistent set of answers to this question and later questions about the time they are willing to wait to be paid back, how much they drive, and what price they pay for gasoline. Their rationality is limited in the sense that neither based their answer on a net present value calculation but rather on simple payback period, and both implicitly assumed gasoline prices would not change (up or down) appreciably. It is also apparent that these two have not actually calculated a payback period for any of their past motor vehicle purchases.

The most rational response we heard in all the interviews was, "I don't know." A banker immediately recognized the "how much would you pay?" question. He sat up straight and started to verbalize his calculation. As he described the parameters, he realized he had no knowledge of one of them—future gasoline prices. He slumped back in his chair and motioned to his wife to offer her answer because he had none.

At least 14 of our respondent households has one or more member who is either a professional in the financial services sector, likely had at least one collegiate level course covering the topics of payback periods and net present value calculations, or otherwise has high quantitative skills. These include our financial services sector households, our computer hardware/software households, and other households who happened to include a banker and a mathematics professor. These include the eight households in the table who discuss the problem in terms of payback (but make mistakes), the two people who offer plausible payback discussions, and the one person who was asking the right kinds of questions, but clearly had never previously thought about fuel economy in this way.

It was clear that many our respondents were not telling us how much they were *willing to pay* for 1.5 times higher fuel economy, but rather were *guessing what it would cost*. In nine households, our respondents admitted they were guessing or did not really understand the question. Six households arrived at a dollar value through a comparison to other vehicle types, the cost of options packages, and what they experienced as incremental price differences in the market for things like more powerful engines. Some (non-hybrid owners) were already familiar with what they believed was the price premium for hybrids and used that as their basis for answering.

In eight households, their answers followed from a discussion of time—along the lines of a payback calculation—how long they expect to own the vehicle, balancing gasoline cost savings with monthly payments, etc. That is, they tried to "back into" a dollar amount by first addressing the question of how long it might take to be paid back.

A few households offered large round numbers, e.g., $5000, with little explanation. We call these "magic numbers," signals that within the context of an interview, respondents are representing that higher fuel economy was seen a good thing they would like to be seen to support.

4.3.3. How long will people wait for fuel cost savings to payback a purchase premium?

Following the question about how much they would be willing to pay for higher fuel economy, we asked whether they expected this purchase price premium to be paid back

by fuel cost savings, and if so, how they arrived at their estimate of how long they would be willing to wait. Fig. 6 summarizes their responses.

Almost two-thirds of all the households to whom we posed this question would not or could not offer a payback time; most of these said it was just not the way they thought about it. The idea of a payback period for an "investment" in higher fuel economy is not part of the vehicle purchase decision-making even in the most financially skilled of our households. These respondents tend to understand the question immediately, but as one accountant responded, "Oh yea, payback calculations; I would never have thought about it that way."

Six households were clearly guessing; some offered a serial string of numbers in a questioning tone suggesting they hoped we would stop them when they arrived at the correct answer. Another group, either immediately or after some discussion, settled on a time period that corresponded to the term of their vehicle loan. We call this a "temporal anchor," a familiar time period offered in response to an obviously unfamiliar question. The other temporal anchor offered was the time they expected to own the vehicle.

Those who gave the shortest (non-zero) payback periods, i.e., 1–3 years, were being optimistic rather than impatient. When we asked about how they arrived at their answer to the question of how long they would be willing to wait, it became clear these people were over-estimating how much they thought they would save on gasoline. The two households who said they would not be willing to wait at all explained that they believed their spending was so constrained by cash flow they could not pay anything upfront. The three households who offered the longest payback periods based their replies on the belief they would own their vehicles for long periods of time; in effect saying, "I want any purchase price premium to be paid back while I still own the vehicle, but I expect that to be a long time."

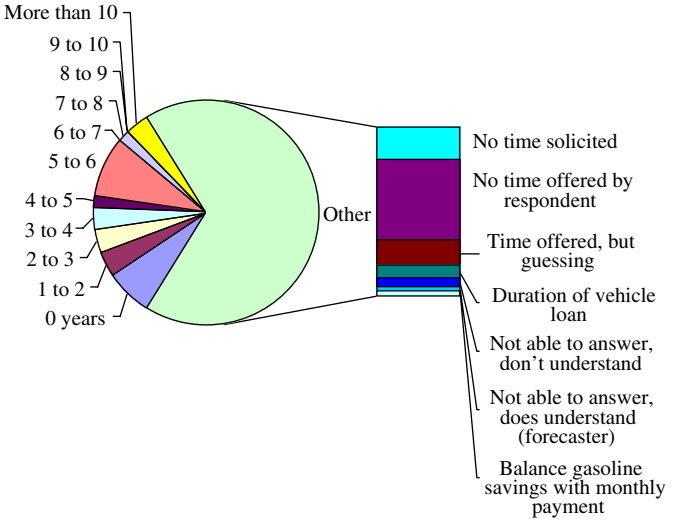

Fig. 6. Willingness to wait to be paid back by higher fuel economy.

The most common mistake respondents made was to overestimate fuel cost savings, and therefore to underestimate the time for fuel savings to payback upfront costs. Inflated estimates of fuel savings are usually the result of overestimating how much fuel they consume. (We discuss the quality of peoples' knowledge of their fuel expenditures in the next section.) Some households made the mistake of assuming they save their entire fuel cost for a year instead of just the savings from a 50 percent improvement in fuel economy. Even households who offered large willingness to pay values often think they can get their "investment" back in a couple of years.

4.4. The building blocks of rational decisions

It is clear few households understand the financial calculations that lie behind questions about "an investment in fuel economy" and payback periods, and that even those few do not apply such knowledge to their household vehicle purchase and use. Do any households have the basic building blocks of rational decision-making—the perfect, or really good, information consumers are assumed to have about their own costs and options for improved fuel economy?

The answer is, "no." Nineteen households admitted they could not tell us the fuel economy rating for one or more of their vehicles. In most households one person could offer the MPG rating of their vehicle while others could not. Even the self-identified knowledgeable person knew their vehicles' MPG with varying degrees of certainty. Only owners of HEVs that have obvious, precise, and visible fuel economy instrumentation consistently offered confident estimates of their MPG. The fuel economy values offered by households came from a variety of sources. Some measured MPG from tank-to-tank of fuel. Some recalled the estimate provided on the window sticker when the vehicle was purchased. A few recalled reading the owner's manual. All respondents who track their fuel economy from tank-to-tank do so as a diagnostic tool to assess vehicle performance over time, not to track fuel costs or economy per se.

4.4.1. Knowledge of fuel expenditures

We asked households how they best understand their fuel expenditures over time, and prompted them with, "annually, monthly, or weekly?" Most chuckled at the idea of knowing their annual fuel cost, it is an unknown number for all but two households who track vehicle mileage and expenditures for business purposes. The time periods for respondents understanding their gasoline expenditures are summarized in Fig. 7.

The largest number of households (27), either said they had no idea of their gasoline expenditures over any period of time (14) or knew only what they spent per tank of gasoline (13). Many of these households tried to develop a "monthly" estimate by summing their recollection of typical gasoline purchases—starting with their estimate of

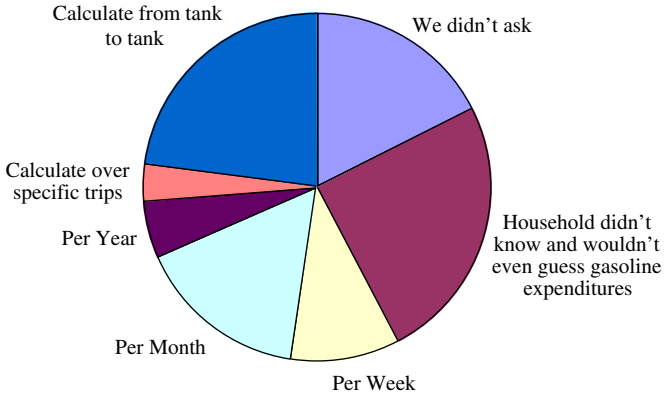

Fig. 7. Basis for households' responding to questions about their gasoline expenditures.

the cost of a tank of gas and multiplying that by their guess as to how many times they refuel per month.

As with the issue of whether people conduct payback or net present value calculations though, the simple fact that people would offer a guess as to their monthly gasoline costs is not the same as their actually measuring gasoline use and expenditures on an ongoing basis. These households were constructing their estimate of fuel costs over time for the first time in their interview.

We conclude that in general our respondents do not track or sum their automotive fuel costs over time. Overall, the most common way people knew their gasoline costs was by the cost of a tank of gas, and this usually from their most recent refueling event. Thirty-one households could recall with some confidence how much they paid for the last tank of gasoline. But, it takes only a few days for the specific data to appear to be forgotten, and a "typical" amount substituted. A few households do have credit cards dedicated to their gasoline purchases, and they seem to have a better handle on monthly costs. Still, many of these households buy gasoline for several vehicles on the same card, and thus do not know how much they spend on gasoline for any one of their vehicles. Of the three households who offered estimates of their *annual* gasoline costs, one was clearly guessing and two were undertaking broad reviews of annual household expenses at the time of their interviews.

4.5. HEV owner interviews

We interviewed HEV buyers because they appeared to have paid for a high-technology approach to better fuel economy. We wanted to explore how they made this decision. The interview protocol for these households was different; we did not prospect the purchase of a vehicle with better fuel economy using a priority evaluator table; instead we spoke directly about their real decision. Additionally we spoke with hybrid buyers about the wider meanings of their purchase, as well as what it was like to own a vehicle with this new technology

None of the eight hybrid owners in our study tracked fuel economy over time. Nor were they any more likely than the other 49 households to know their annual fuel costs. We emphasize that no hybrid owner we interviewed was solely or even importantly interested in saving money on gasoline. They did know a lot more about the vehicle and the environmental issues it addresses than they did about their own gasoline costs.

Buyers of HEVs talked about making a commitment. In addition to any financial commitment, buyers of Toyota's Prius generally had to wait several months for delivery of the vehicle. For several hybrid buyers the idea of commitment included setting an example, being a pioneer, talking to other people about their car. Several had shifted from a larger vehicle to the smaller hybrid. One hybrid buyer also started biking and walking more. For one household, their Civic Hybrid was part of a larger project to reduce their environmental impacts. This household had moved to a "hobby" farm in a remote rural area, which given their job locations and other interests resulted in lots of driving. They are hoping to buy a second hybrid.

Among this group of HEV buyers, the high fuel economy of their hybrid signified some other important value. Some HEV buyers were attracted by the new technology; others by the low emissions of criteria pollutants; and others still by a sense of "living lighter"—getting around while consuming fewer resources.

HEV owners did not in general perceive a specific price difference that they paid for their HEV. One respondent said, "I looked at the whole package, and judged it was worth the price." Further, assessing what is the relevant difference in price and fuel economy (as a determinant of private fuel cost savings) depends on detailed knowledge of the households' vehicle holdings and transactions. Many HEV buyers crossed vehicle classes in order to buy hybrids available at the time of this research. One traded in his Jaguar XJ6, another traded her compact pickup truck, and another bought a Prius rather than a compact SUV.

5. Discussion

Based on what we heard in these interviews, many findings from past and ongoing energy research and analysis that report consumer willingness to pay and payback periods for new fuel economy technology in automobiles seem unrealistic. We expect that most participants in past survey research were responding for the first time to novel questions, not recalling past or probable future behavior. In short, the consumers we spoke to do not think about fuel economy in the same way as experts, nor in the way experts assume consumers do. The problems posed by this mismatch between experts' questions and laypersons' reality are not avoided by inferences based on a rational analytic interpretation of parameters in models correlating vehicle and fuel prices and sales.

We consistently watched consumers overestimate their gasoline cost, express willingness to pay values out of line with an objective view of their potential savings and past behavior, and then offer payback periods that do not reflect their estimate of their expenses. For these people, pointing out their true annual fuel costs and the difference in their costs made possible by higher fuel economy might not be the best strategy to foster purchases of more fuel economical vehicles—if we assume higher fuel economy or fuel efficiency have only private monetary value to economically rational consumers.

Based in part on consumers more positive images of the term *fuel efficiency*, as compared to *fuel economy*, it might be strategic for those interested in promoting good fuel economy to shift their terminology and focus to good fuel efficiency—so long as higher efficiency is put to the service of lower fuel consumption.

We heard from households who were attracted by non-incremental, non-marginal improvements in fuel economy and fuel efficiency such as those offered by hybrids and as offered by us in the course of their interview. The actual buyers of HEVs appear inspired by large changes in fuel economy beyond even what those changes might save them in the cost of gasoline.

If households do not have access to the basic building blocks of information regarding their fuel use and costs, if they demonstrate a lack of understanding or express no experience with algorithmically correct rational calculations, and if some demonstrate they understand such calculations but have never applied this understanding to their household vehicle purchase, then what are consumers doing?

Much recent psychological and sociological theorizing focuses on the use of heuristics, or cognitive shortcuts. Reich (2000), reviewing the work of German social theorist Gerd Gigerenzer, argues that "…rules for decision and action may well be grounded on simplifying and biased assumptions and lead to incoherent results—in short, these rules may be heuristical algorithms instead of determinable algorithms…." Kahneman (2002) argues that such shortcuts are the normal way of making decisions (even among experts) and that calculated rationality occurs only as a deliberate override to such heuristic—or in his terms, *intuitive*—practices. Of particular importance is that certain types of quick decision tools and information are more accessible, and therefore far more commonly used in making decisions.

It may be that such heuristics are used when we ask participants to answer questions like, "How much would you pay for higher fuel economy," or "What is an acceptable payback period?" They may be answering with an accessible rather than an accurate number, just as we heard some households respond with answers that matched their vehicle loan period or expected duration of ownership.

However, fuel economy may be more complicated than a simple set of heuristics, which offer consumers a few quick ways of making decisions in situations of limited information or high complexity. Fuel economy is becoming a public issue, a topic of conversation, advertising, news stories, and display. Automotive advertisements now feature fuel economy ratings and tout the number of vehicles a manufacturer builds that achieve high fuel economy. The prices of a gallon of gasoline and of a barrel of oil are stories on the evening news, in the morning paper, and on automobile-related web sites.

Further, motor vehicles are assigned symbolic meanings. As we find in our interviews, many households express considerable anger towards owners of large SUVs, and are willing and even eager to talk about it. Even owners of small and mid-sized SUVs express anger at drivers of full-size SUVs. Oil companies are also targets. Evidence from this study suggests that a common consumer response to rising gasoline prices is not to change travel or buy more fuel economical vehicles, but simply to get angry with oil companies. Fuel economy is conflated with many of these symbolic meanings and has become part of conversations about larger issues than household budgets.

We offer two hypotheses from this set of interviews.

1. Over the past several decades of declining real gasoline prices and rising personal incomes, consumers engaged in a limited economic rationality, possibly using simplifying heuristics in the place of algorithmically correct evaluations. Abetted by limited fuel use and cost instrumentation, consumers give little attention to fuel economy. If gasoline prices increase enough, consumers will develop more calculating, economically rational decision-making regarding fuel economy.
2. Automobiles are repositories of many high value meanings, some which have important but non-quantifiable/non-monetized value. Because of these meanings, few automobile buyers paid much attention to the small financial differences provided by the historically available differences in fuel economy of otherwise similar vehicles. Even if gasoline prices rise, buyers may respond to shifts in these other meanings rather than respond solely to shifts in fuel costs in economically rational ways.

The first hypothesis simply implies that gasoline has been too cheap for the past few decades for it to be "sensible" for consumers to be "rational." The second states that the value of fuel economy is more than differences in fuel costs, but includes other symbols, meanings, and values, and that those are unlikely to be processed in an economically rational algorithm under any conditions.

Contrary to the first hypothesis though, we found that automobile buyers do not have the basic building blocks to make calculated decisions about better fuel economy, and most do not keep track of fuel cost over any significant time period, be that the life of the vehicle, their duration of ownership, annually or even monthly. Refueling does not always happen on a regular schedule, so even in the context of our interviews, households can only make rough estimates of costs over time. It is clear that even our most

financially skilled buyers have not purchased their cars and trucks based on the application of payback or net present value analyses.

Behavioral vestiges of the last dislocation in gasoline prices and supplies during the 1970s and early 1980s were heard in the interviews, faint echoes of remembered shifts toward more economical vehicles. Under these conditions, policy makers, automobile manufacturers, and consumers pushed the vehicle design envelope in the direction of higher fuel economy. Claims—based on the past twenty years of pushing the design envelope toward greater power, size, and energy-consuming options and accessories—that consumers do not value fuel economy ignore context, assuming that "what consumers want" is invariant.

Even in a sample constructed such as the one in this study, if economic rationality is pervasive in the population, we should have found some one who articulated their automotive purchase and use decisions in a manner consistent with the assumptions of that model. We did not. Therefore, we cannot support the continued assumption that economic rationality is the sole sufficient behavioral model for policymaking and policy analysis of automotive purchases and gasoline consumption. We have presented initial evidence to contradict the first hypothesis and in support of the second. Still, choosing between them would require further study.

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