Consumers' Perceptions and Misperceptions of Energy Costs

By Hunt Allcott*

Economic decisions depend on preferences over outcomes and beliefs about how each possible choice maps into these outcomes. While economists often estimate preferences, we typically assume beliefs, often under some combination of rational expectations, perfect information, and unbounded computational capacity. In some domains, however, there is evidence that these assumptions are not realistic (Charles F. Manski 2004). For example, people have systematically biased beliefs about food calorie content (Bryan Bollinger, Phillip Leslie, and Alan Sorensen 2011), returns to schooling (Robert Jensen 2010), potential earnings in other countries (David McKenzie, John Gibson, and Steven Stillman 2007), and their own likelihood of gym attendance (Stefano DellaVigna and Ulrike Malmendier 2006).

When choosing between energy-using durable goods such as autos and air conditioners, consumers are assumed to form beliefs about the energy costs of different models. This requires consumers to form expectations of future energy prices, forecast their usage, know each product's energy efficiency rating, and combine this information to compute a total energy cost. There is evidence from other social sciences that consumers are not very good at this calculation (Thomas S. Turrentine and Kenneth S. Kurani

2007) and that beliefs may have particular systematic biases (Shahzeen Z. Attari et al. 2010).

Perhaps the most noted perceptual error in this domain is "MPG Illusion," under which people intuitively think that automobile fuel costs scale linearly in miles per gallon (MPG), whereas they in fact scale linearly in gallons per mile (Richard P. Larrick and Jack B. Soll 2008). As an example, consider two pairs of vehicles. The first pair is two vans, one rated at 11 MPG and the other at 13 MPG, and the second pair is two cars rated at 29 and 49 MPG. Many people intuitively believe that conditional on gas price and miles driven, the difference in fuel costs between the second pair is much larger, because the difference in MPG is much larger. In fact, the fuel cost differences are almost exactly the same: the difference between each pair of vehicles in gallons of gasoline consumed per mile driven is 0.014. Interestingly, if this misperception has any magnitude outside of the laboratory, it would make us more likely to buy a Hummer *and* more likely to buy a Prius, while making us less likely to buy a medium-MPG car. This is because it causes us to underestimate the relative costs of the lowest-MPG vehicles and overestimate the relative savings of the highest-MPG vehicles.

It turns out that these issues are more than just psychologically interesting: they are fundamentally important to policy decisions. The idea that cognitive errors reduce demand for energy efficient autos was a primary regulatory justification[1] for the recent increase in Corporate Average Fuel Economy (CAFE) standards, which require automakers to sell more energy efficient vehicles than would naturally be sold in equilibrium. Unless consumers mistakenly underestimate or are inattentive to fuel costs, however, CAFE standards are a highly inefficient approach to reducing externalities from gasoline use when compared to a Pigouvian tax (Mark R. Jacobsen

[1] See page 2 of the National Highway Traffic Safety Administration's (2010) Regulatory Impact Analysis, or further discussion in Allcott (2010).

2010; Alan J. Krupnick et al. 2010). But while important and costly energy policies such as CAFE are partially predicated on the idea that consumers are misoptimizing, a recent survey in the *Journal of Economic Literature* concludes that "there is little in the way of solid empirical (as opposed to anecdotal) evidence on this hotly contested issue" (Ian W. H. Parry, Margaret Walls, and Winston Harrington 2007).

The Vehicle Ownership and Alternatives Survey (VOAS) was designed to help fill this gap in evidence. This 2,100-person nationally representative survey includes detailed demographic and vehicle ownership data and elicits expectations of future fuel prices. The survey also includes fuel costs for respondents' current vehicles and perceived costs for alternative vehicles with different fuel economy ratings. The VOAS was designed specifically for the analysis in Allcott (2010), and interested readers should refer to that paper for detail on the survey, empirical results, and economic implications.

This paper reports three initial stylized facts from the VOAS. First, American consumers devote very little cognitive attention to fuel costs when they purchase autos. Second, as predicted by MPG Illusion, consumers underestimate the energy cost differences between low-MPG vehicles and overestimate the cost differences between high-MPG vehicles. Third, Americans appear knowledgeable about current gas prices, and the modal respondent predicted that real gasoline prices would remain unchanged over the next several years, consistent with prices implied by the oil futures curve at the time of the survey. There is a right tail of people, however, who believe that gasoline prices will increase, and mean and median predictions were both significantly above the mode.

These stylized facts suggest the importance of reevaluating economic models that assume unbounded computational capacity, rational expectations, and equal attention to prices versus other product costs. For three reasons, however, one should take great care in drawing policy implications. First, misperceptions and nonrational expectations can, in general, cause consumers to underinvest or overinvest in energy efficiency, so it is not necessarily true that a corrective policy would increase energy efficiency. Second, simply because we make mistakes does not imply that the welfare costs of these mistakes are large. Allcott (2010) addresses this

formally by integrating the VOAS into a structural demand model and simulating the effects of misperceived fuel costs on market demand and welfare. Third, even if misoptimization does cause significant underinvestment in energy efficiency, it is not necessarily true that subsidizing or mandating the sale of energy efficient products increases welfare (Allcott, Sendhil Mullainathan, and Dmitry Taubinsky 2010).

I. Data

The VOAS was administered in October 2010 by Knowledge Networks, a research company that maintains perhaps the highest-quality publicly available survey platform. Potential participants are selected using both Random Digit Dialing and Address-Based Sampling, meaning that the sample can include the many households with unlisted phone numbers, cellular phones only, or no phone at all. Selected households are aggressively recruited to participate, and unselected volunteers are not allowed to join. Surveys are administered via computer-assisted self-interview, and households with no computer are given one. Therefore, although participants are likely to be unrepresentative on unobservables related to value of time and willingness to participate in surveys, the study population is as close as reasonably possible to being representative on unobservables. All results reported herein are weighted to be nationally representative on a set of observed characteristics.

The VOAS included four main sets of questions. The first set asked about each respondent's "current vehicle," including the make, model, model year, engine size, whether manual or automatic, and whether two-wheel or four-wheel drive. The second set elicited respondents' beliefs about current and future gasoline prices and the total costs to fuel their vehicles. The third set asked respondents their "second choice vehicle," i.e., the vehicle that they would have bought if the model they actually did buy did not exist, and elicited perceived fuel cost differences between the current and second-choice vehicles. The fourth set instructed respondents to assume that they owned a "replacement vehicle" with a randomly selected difference in MPG and elicited perceived cost differences between that vehicle and the current vehicle.

The benefit of designing a new survey for belief elicitation was that great care could be

taken in phrasing precise questions with useful economic interpretations. For example, respondents were told to assume that they drove the current, second-choice, and replacement vehicles the same amount, so perceived differences in fuel costs result only from differences in MPG. They were also told in simple language to ignore consumer price inflation, so gasoline price expectations can be interpreted in real dollars.

The objective of the third and fourth sets of questions was to induce respondents to accurately report beliefs that they presumably had formed at the time they purchased their vehicles. To address potential concerns over respondent effort, half of respondents were randomly assigned to an "incentive-aligned" condition, under which they received a small amount of money for internally consistent responses. The objective was to give enough incentive to accurately report existing beliefs without providing an incentive so large as to induce respondents to precisely calculate the correct answers. To address potential concerns over whether particular question frames could affect results, beliefs were elicited under 48 different randomly assigned frames. For example, half of respondents (the "Flow" group) were asked to report the flow of gasoline expenditures for their current vehicle on a weekly, monthly, or annual basis. The other half (the "Total" group) were asked how long they expected to hold the vehicle before replacing it and then asked how much they would spend in total on gasoline during that future holding period.

II. Results

A. *Cognitive Effort*

The first stylized fact is that Americans devote little cognitive effort to calculating fuel costs when choosing between vehicles. After the four sets of questions detailed above, the VOAS included a final question: *In this survey, we asked you to calculate fuel costs fairly mathematically and precisely. Think back to the time when you were deciding whether to purchase your vehicle. At that time, how precisely did you calculate the potential fuel costs for your vehicle and other vehicles you could have bought?*

Table 1 presents the responses. Forty percent of respondents did not think about fuel costs

Table 1—How Precisely Did You Calculate Fuel Costs for Your Vehicle?

1. I did not think about fuel costs at all when making my decision	40%
2. I did think some about fuel costs when making my decision, but I did not do any calculations at all.	35%
3. I calculated some, but not as precisely as I did just now in this survey.	13%
4. I calculated about the same as I did just now in this survey.	8%
5. I calculated more precisely than I did just now during this survey.	3%

at all during their most recent purchase, and 89 percent calculated fuel costs less precisely than they had in the survey. For comparison, the median respondent completed the entire survey in ten minutes.

Reported cognitive effort is associated with observable factors in intuitive ways. I construct a "Calculation" variable that codes the five possible responses from Table 1 as values 1 to 5, then standardizes the values to mean 0 and standard deviation 1. Columns 1 and 2 of Table 2 present pairwise and conditional correlations, respectively, between Calculation and a set of observables, using OLS regressions with robust standard errors. The "Liberal" variable is self-reported political ideology, normalized to mean 0, standard deviation 1, with more liberal being more positive. "Gas Price" is the US average retail gasoline price in the month that the respondent purchased his or her current vehicle. As an example of how to read the results, observe that one additional year of education is correlated with a 0.059 standard deviation increase in Calculation in the univariate regression in column 1, while the correlation conditional on other variables in the multivariate regression in column 2 is 0.055. The regressions also show that older people and those in rural areas calculate less, while men report calculating more.

Column 3 of Table 2 regresses the MPG of the vehicle purchased on self-reported Calculation and the same set of additional covariates. Consumers who devoted one standard deviation more cognitive attention to calculating fuel costs purchased vehicles with 0.90 MPG higher fuel economy. This correlation could arise either because calculating fuel costs causes people to recognize the importance of fuel economy or

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TABLE 2—HOW PRECISELY DID YOU CALCULATE FUEL COSTS FOR YOUR VEHICLE?

Dependent variable: Regression:	Calculation Pairwise correlation (1)	Calculation Conditional correlation (2)	MPG Conditional correlation (3)
Calculation			0.90 0.19***
Income ($000's)	0.0019 0.00065***	0.00001 0.0007	−0.0076 0.0038**
Education (years)	0.059 0.012***	0.055 0.013***	0.42 0.072***
Age (years)	−0.0051 0.0018***	−0.0037 0.0018**	−0.00093 0.011
1(male)	0.190 0.06***	0.18 0.06***	−1.04 0.30***
1(rural)	−0.20 0.068***	−0.15 0.070**	−0.89 0.40**
Liberal	0.056 0.031*	0.038 0.031	0.22 0.17
Gas price ($/gal)	0.15 0.045***	0.14 0.045***	0.54 0.30*
Constant		−1.00 0.24***	16 1.50***
Observations		1,953	1,953
R^2		0.050	0.089

Notes: Robust standard errors below coefficients. See text for explanation of columns 1, 2, and 3.

 ***Significant at the 1 percent level.
 **Significant at the 5 percent level.
 *Significant at the 10 percent level.

because some third unobserved factor is associated with both Calculation and preferences for high-MPG vehicles.

Are these results consistent with a model of "rational computation"? In such a model, a consumer has a probability distribution over fuel cost differences between vehicles in his choice set and can improve the precision of this distribution by gathering information or otherwise devoting effort to the calculation. Such a model suggests several potential reasons to devote little cognitive effort to calculating fuel costs, some of which are more plausible than others.

First, it could be that not a lot of money is at stake. Relative to the value of a few minutes of time, however, this is not the case. A typical consumer who buys a 21-MPG vehicle instead of a 20-MPG vehicle saves $82.50 per year on gas at current prices. A vehicle at the twenty-fifth percentile of the MPG distribution (19 MPG) costs $3,000 less to fuel than a vehicle at the seventy-fifth percentile (24 MPG), when discounting at 9 percent over a typical vehicle lifetime. Consumers do appear to calculate more when

higher gas prices magnify these cost differences: Table 2 shows that a one dollar increase in gasoline prices is correlated with a 0.15 standard deviation increase in Calculation.

A second potential reason is that initial perceptions could already be quite precise. However, although consumers may not be aware of their imprecision, perceived cost differences across vehicles with different MPG ratings have substantial noise around their true values (Allcott 2010). A third potential reason, which seems quite plausible, is that many consumers have sufficiently strong preferences for a particular vehicle that additional calculation would be unlikely to affect their decisions. For example, a consumer may be relatively certain that he needs a pickup truck of a particular size, meaning that the fuel economy ratings of vehicles under consideration may be quite similar.

A fourth potential reason is that the costs of carrying out this calculation are high. Heterogeneity in costs could generate heterogeneity in cognitive effort: for example, more highly educated people can presumably calculate more easily
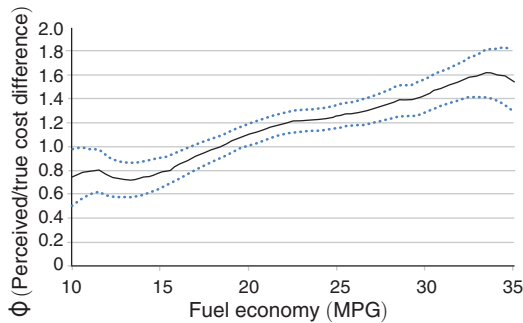
FIGURE 1. PERCEIVED VALUE OF FUEL ECONOMY

FIGURE 2. EXPECTED PRICES VERSUS SPOT AND FUTURES

and thus should calculate more. Results in columns 1 and 2 of Table 2 are consistent with this type of heterogeneity.

Inattention, or "myopia" in the sense of Xavier Gabaix and David Laibson (2006), could also explain why 40 percent of consumers report not thinking about fuel costs at all. In Gabaix and Laibson's model, "add-on" costs are less salient than purchase prices, and consumers do not rationally gather information or form beliefs about the cost of "shrouded attributes." Future fuel costs, as well as insurance, maintenance, financing, and dealership transactions costs, are analogous to "add-on" costs in that consumers perceive them separately from purchase prices.

B. *Systematically Biased Beliefs*

The second stylized fact is that consumers underestimate the energy cost differences between low-MPG vehicles and overestimate cost differences between high-MPG vehicles. To see how this can be determined, recall that holding fuel prices and utilization constant, total fuel costs scale linearly in a vehicle's gallons per mile. Thus, given a consumer's reported fuel costs for his current vehicle, the true fuel cost difference between that vehicle and any other vehicle with a different fuel economy can be calculated. Each VOAS respondent reports perceived fuel cost differences between his current vehicle and both the "second choice vehicle" and the "replacement vehicle." These two perceived cost differences are divided by the true differences to generate ratios denoted ϕ. Under perfect information and unbounded computational capacity, ϕ equals one.
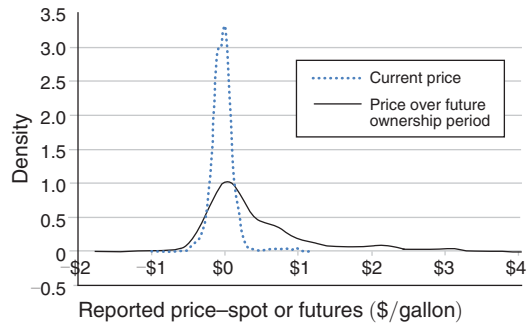
Figure 1 displays the relationship between ϕ and current vehicle fuel economy, estimated nonparametrically using a standard running mean smoother displaying 90 percent confidence intervals. If consumers systematically underestimate the financial value of fuel economy, this line lies below one. If consumers systematically overestimate the financial value of fuel economy, this line lies above one. To see the relationship under MPG Illusion, recall the example from the introduction: consumers evaluating low-MPG vehicles tend to underestimate, while consumers evaluating high-MPG vehicles tend to overestimate. This would give an upward slope to the line as MPG increases. As shown in Figure 2, the data are starkly symptomatic of MPG Illusion: the line slopes upward, crossing one at about 20 MPG.

Allcott (2010) simulates how eliminating this misperception would affect market shares. Consumers shift away from both high-MPG hybrids and low-MPG trucks and purchase more medium MPG vehicles. In aggregate, MPG Illusion has a theoretically ambiguous effect on the average MPG of vehicles sold. These results contrast with informal interpretations of MPG Illusion and other misperceptions of energy costs, which often implicitly assume that they reduce demand for energy efficient products.

C. *Gasoline Price Expectations*

The third stylized fact is that while Americans do appear to know current fuel prices, they expect real prices to rise in the future, a belief that corresponds neither to a martingale nor the prices implied by the oil futures market.

As described above, the VOAS randomly assigned respondents to either the "Flow" group or the "Total" group. The Flow group was asked to report the current local gas price. The dotted line in Figure 2 graphs the distribution of the differences between these reported current prices and the regional average fuel prices reported by the Energy Information Administration (EIA). As one might expect, this difference clusters tightly around zero. Survey responses average less than five cents different from the regional fuel price, and any dispersion is likely explained by unobserved local price variation plus perhaps some recall error.

The VOAS asked the Total group how long they expected to own their current vehicle before replacing it, and then elicited expectations of the average fuel price over that future period. The solid black line in Figure 2 reflects the distribution of the difference between these expectations and the regional gasoline price over that period implied by oil futures. This implied future price is constructed by taking the average of NYMEX oil futures prices over the respondent's expected future holding period, deflating to real dollars using inflation expectations implied by Treasury Inflation-Protected Securities prices, dividing this by the current oil price, and then multiplying this ratio of future to current prices by the EIA current regional fuel price. If respondents' beliefs corresponded exactly to the futures curve and included the same unobserved local price variation, one would expect this solid black distribution to be identical to the dotted black distribution. Note that the NYMEX oil futures curve for October 2010 implied almost constant real prices for the next ten years, so the conclusions are almost identical if comparing beliefs against current fuel prices.

As Figure 2 shows, the modal American expects average real fuel prices to remain essentially constant over the future holding period. The distribution, however, has positive skew. The median (mean) American expects to own his current vehicle for 3 (4.4) years before buying a new one. Over this future holding period, the median American expected real fuel prices to average 22 cents higher than the prices implied by the futures market. The mean expected future fuel price was $0.53 higher than futures prices. Even excluding a small group of outliers who report believing

that future gas prices will average more than $10 per gallon, the mean expected price is still $0.30 higher than futures prices.

People who believe that gas prices will increase are statistically slightly older and lower-income, but expected price increases are otherwise uncorrelated with observables. The longer the future holding period, the more that consumers expect prices to rise: the median expected prices over the next five and nine years are $0.54 and $0.94, respectively, above the futures market price.

These results have two implications.[2] First, the difference between consumers' expectations and futures market prices suggests that consumers should want to trade in futures markets. It would be interesting to corroborate this belief elicitation by testing whether consumers who say they expect prices to increase are more interested in buying oil futures. Second, notice that if consumers believe that fuel prices will increase, they should be more likely to invest in energy efficiency compared to a setting in which beliefs match the spot or futures markets.

III. Conclusion

In some sense, results like these are unsurprising: consumers constantly make complicated decisions under imperfect information without the luxury of fully calculating the implications, and there is a literature that documents both noise and bias in our beliefs in a variety of settings. Whether misperceptions matter for economic models and for policy depends on how much they affect choices and welfare, a question that Allcott (2010) examines using VOAS data.

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[2] In a recent paper, Soren T. Anderson, Ryan Kellogg, and James M. Sallee (2011) analyze a series of repeated cross sections of consumers' gasoline price expectations elicited as part of the Michigan Survey of Consumers (MSC). The authors fail to reject that consumers' beliefs correspond to a martingale over the period 1993–2010. Two factors appear to explain the qualitative difference in our results. First, the relationship between current prices and expectations varies over time, and at the time the VOAS was administered in late 2010, MSC respondents did expect a small real increase in gas prices. Furthermore, although the authors argue that responses should be interpreted in nominal dollars, it is not entirely clear whether MSC survey respondents were thinking in real or nominal terms. If MSC responses are interpreted as being in real dollars, the results are more closely consistent with those of the VOAS.

What is especially interesting about these three initial stylized facts from the VOAS is that they show how misperceptions and expectations that differ from market predictions do not generically reduce demand for energy efficiency. Expected energy price increases bolster demand for energy efficiency, while inattention to energy costs would decrease demand, and the effects of MPG Illusion are theoretically ambiguous. Although it is frequently argued that misperceived energy costs help justify policies to encourage the sale of energy efficient automobiles, air conditioners, and other durable goods, these results illustrate one reason why this argument does not always follow.

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