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PATERNALISM AND ENERGY EFFICIENCY:
AN OVERVIEW

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ABSTRACT

This review paper provides an overview of the application of behavioral public economics to energy efficiency. I document policymakers' arguments for "paternalistic" energy efficiency policies, formalize with a simple model of misoptimizing consumers, review and critique empirical evidence, and suggest future research directions. While empirical results suggest that policies to address imperfect information or internalities may increase welfare in some cases, some existing policies may be mistargeted or of the wrong magnitudes.

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1 Introduction

Governments frequently intervene to protect citizens from our own choices. For example, the US and many other countries tax or ban hard drugs, alcohol, and cigarettes. Many areas have motorcycle helmet and automobile seat belt laws. We have safety standards for food and other products. Usury laws and other regulations protect consumers from their own financial decisions. "Life-cycle myopia" is one potential reason for federal retirement savings programs (Feldstein and Liebman 2002).

In the absence of models with imperfect information or internalities, economics would have little useful to say about these policies: with rational consumers and perfect information, any restriction of consumer choice mechanically reduces consumer welfare, essentially by assumption. The development of behavioral public economics provides the tools to formalize and test hypotheses about internalities and to evaluate the welfare effects of paternalistic policies.[1] "Paternalistic" is not a pejorative word here - it is a descriptive term that clarifies policy goals and defines empirical hypotheses.

This paper is an overview of part of the literature that applies the logic of behavioral public economics to energy efficiency policy. Aside from externality reduction, which of course would be best achieved through Pigouvian taxes, consumer mistakes are important justifications for policies such as energy efficiency subsidies and minimum standards. (I use "mistakes" to refer to both imperfect information and internalities, and these issues are related in that they both cause consumers' choices to not maximize their own welfare and could systematically affect demand for energy efficient durable goods.) I begin by reviewing this policy argument and formalizing it in a simple consumer choice model. I use the model to characterize three categories of empirical tests: comparing demand responses to prices vs. energy costs, measuring effects of nudges, and belief elicitation. These tests have direct analogies in other domains such as consumer finance and health, and the categorization is similar to discussions in DellaVigna (2009) and Mullainathan, Schwartzstein, and Congdon (2012). I then discuss policy implications and important directions for future research.

There are two important related areas that this review does *not* cover. The first is the literature that shows how energy use feedback, social information, goal setting, and other "behavior levers" influence energy use. I omit these because, as we shall see, the most costly policies to be evaluated are subsidies and standards that are partially justified by consumer mistakes. Thus, it is particularly important for research in this area to empirically measure mistakes and evaluate policy based on the estimates. By contrast, most "behavior levers" papers are not structured to clearly measure consumer bias and distinguish this from the effects of persuasion, and so the regulatory policy

[1] In the past ten years, a growing number of papers have made empirical or theoretical contributions in this area, including Baicker, Mullainathan, and Schwartzstein (2012), Bernheim and Rangel (2004, 2009), Carroll, Choi, Laibson, Madrian, and Metrick (2009), Gabaix and Laibson (2006), Grubb (2014), Grubb and Osborne (2013), Gruber and Koszegi (2004), Gul and Pesendorfer (2007), Gruber and Mullainathan (2005), Mullainathan, Schwartzstein, and Congdon (2012), O'Donoghue and Rabin (2006), and others.

implications are less clear. Second, I leave aside "inter-consumer" inefficiencies that could affect energy efficiency investments, such as information asymmetries between landlords and tenants or home sellers and home buyers. These principal-agent problems, colloquially called "landlord-tenant" problems, are studied by Davis (2012), Gillingham, Harding, and Rapson (2012), Myers (2014), and others.

2 Background

2.1 Why Energy Matters

Expenditures on energy and energy-using durables represent a significant share of the economy in industrialized countries. In 2011, US households purchased $361 billion worth of energy-using durable goods such as cars, appliances, and heating and cooling equipment (BLS 2014). These households also spent $325 billion per year on gasoline and $245 billion per year on electricity, natural gas, and fuel oil. Even relatively small inefficiencies in these markets could quickly add up to large welfare losses.

There is also increased policy interest due to energy use externalities, including greenhouse gas and local pollution emissions and national security concerns related to oil imports. US household energy use imposes $40 billion in externalities from carbon emissions[2], plus additional externalities from local air and water pollution. Uninternalized externalities plus other energy pricing distortions introduce second best interactions. As a simple example, mistakes that increase energy use also increase externalities. Allcott, Mullainathan, and Taubinsky (2014, "AMT") formalize these interactions, for example showing that there can be an "Internality Dividend" from externality taxes: when internalities reduce demand for energy efficient durable goods, a carbon tax can generate larger welfare gains by inducing consumers to buy more energy efficient durables.

2.2 Energy Efficiency Policies

As Allcott and Greenstone (2012) discuss, the United States has a number of policies that encourage energy efficiency, many of which were originally promulgated as energy prices rose in the 1970s. Table 1 presents the most significant US policies, organized into three categories. Many other industrialized countries have analogous policies.

The first category is standards. The Energy Policy and Conservation Act of 1975 called for minimum energy efficiency standards for home appliances. The first meaningful nationwide standards were finally implemented in 1990, and since then the standards have been strengthened and additional products included. The Energy Independence and Security Act of 2007 set minimum

[2]This number is the product of the $38 social cost of carbon for 2013 estimated by the Interagency Working Group on Social Cost of Carbon (2013) and total household carbon emissions from energy use estimated by the US Energy Information Administration (2014).

lighting efficiency standards that ban traditional incandescent lightbulbs between 2012 and 2014 and will be tightened further in 2020. Argentina, Australia, Brazil, Canada, China, Cuba, the European Union, Israel, Malaysia, Russia, and Switzerland have also banned some or all incandescent light bulbs. Many states have building codes that mandate minimum insulation levels and other energy efficiency measures. Corporate Average Fuel Economy (CAFE) standards require that new cars and trucks meet a minimum average mile per gallon (MPG) rating.

The second category is price policies, i.e. taxes and subsidies. There were federal income tax credits of up to \$3,400 for hybrid vehicles from 2006 to 2010, and credits of up to \$7,500 are currently available for plug-in hybrids. There are federal "gas guzzler taxes" range from \$1,000 to \$7,700 on the sale of low-MPG passenger cars. The Weatherization Assistance Program grants \$250 million annually for improved insulation, air sealing, and other weatherization measures at approximately 100,000 low-income homes. Electricity bill surcharges fund billions of dollars of utility-managed "demand-side management" programs, which include subsidized home energy audits, energy efficiency information provision, and subsidies for energy efficient appliances, weatherization, and other investments. The 2009 American Recovery and Reinvestment Act included substantial increases in energy efficiency subsidies. In total, that legislation and related economic stimulus bills included \$17 billion in energy efficiency spending, including additional weatherization subsidies and automobile and appliance cash-for-clunkers programs.

The final category is information and marketing. The US government requires all new vehicles to have fuel economy information labels, and appliances must be labeled with informational "yellow tags." Furthermore, the Environmental Protection Agency runs the Energy Star labeling and marketing program. As the right-most column suggests, information and marketing are cheap compared to the fiscal cost of subsidies and the production costs of energy efficient durables.

2.3 Quotes: The Paternalistic Rationale for Energy Efficiency Policy

Energy efficiency policies can address several different market failures, including energy use externalities, asymmetric information problems, and non-appropriability of returns to innovation. Imperfect information and internalities, however, are an important part of the policy discussion. This section documents that with several examples.

The Final Regulatory Impact Analysis for the 2012-2016 CAFE standard (NHTSA 2010) finds that \$15 billion per year in consumer welfare gains will accrue to consumers who do not currently demand higher fuel-economy vehicles but would purchase them under the policy. Without these private gains, the policy is welfare-reducing. In other words, externalities alone do not come close to justifying the CAFE policy's stringency. The document states (page 2):

> *Although the economy-wide or "social" benefits from requiring higher fuel economy represent an important share of the total economic benefits from raising CAFE standards,*

NHTSA estimates that benefits to vehicle buyers themselves will significantly exceed the costs of complying with the stricter fuel economy standards this rule establishes. [...] This raises the question of why current purchasing patterns do not result in higher average fuel economy, and why stricter fuel efficiency standards should be necessary to achieve that goal. To address this issue, the analysis examines possible explanations for this apparent paradox, including discrepancies between the consumers' perceptions of the value of fuel savings and those calculated by the agency.

The Regulatory Impact Analysis for Australia's phase-out of traditional incandescent lightbulbs (DEHWA 2008) argues that internalities and information failures justify the policy, as well as asymmetric information in housing markets. Page vii states:

[Incandescent lightbulbs] continue to sell remarkably well because, if their energy costs are ignored, they appear cheap. More efficient lamps such as CFLs and halogen types are facing a number of problems breaking into the market. Currently a CFL sells for up to five times more than a regular GLS lamp.

There are significant information failures and split incentive problems in the market for energy efficient lamps. Energy bills are aggregated and periodic and therefore do not provide immediate feedback on the effectiveness of individual energy saving investments. Consumers must therefore gather information and perform a reasonably sophisticated calculation to compare the life-cycle costs of tungsten filament lamps and CFLs. But many lack the skills. For others, the amounts saved are too small to justify the effort or they do not remain at the same address long enough to benefit fully from a long lived energy saving lamp.

Lightbulb manufacturers and environmental groups lobbied together for the US lighting efficiency standards. In congressional testimony, the National Electrical Manufacturers Association argued (US GPO 2007):

The entire discussion of "phase out of least efficient general service light bulbs" has been at the industry's initiative ... New standards-setting legislation is needed in order to further educate consumers on the benefits of energy-efficient products.

Interestingly, this argument posits that lack of consumer education is best addressed by a product ban, not an improved consumer education policy.[3]

In analysis of the same lighting standards, the Natural Resources Defense Council (2011) writes:

[3] Perhaps unsurprisingly, US Senator Rand Paul has strong views on this argument. During congressional testimony by Kathleen Hogan, Deputy Assistant Secretary for Energy Efficiency at the Department of Energy, Paul said (ABC 2011), "You're really anti-choice on every other consumer item that you've listed here, including light bulbs, refrigerators, toilets – you name it, you can't go around your house without being told what to buy. You restrict my choices, you don't care about my choices." Paul continues, "This is what your energy efficiency standards are. Call it what it is. You prevent people from making things that consumers want."

> *Some in Congress are considering repealing the new efficiency standards before they even take effect. That would take away $12.5 billion in consumer savings—something none of us can afford.*

Of course, such private cost savings could only reflect welfare gains in the presence of mistakes or inter-consumer market failures. Similarly, the White House budget justification for appliance energy efficiency standards reads, "The Budget also helps consumers save money through the continued introduction of appliance efficiency standards" (White House 2013).

In Senate testimony in support of energy efficiency standards, the executive director of the American Council for an Energy Efficient Economy listed several market failures addressed by standards, including "Rush purchases when an existing appliance breaks down, providing no time to comparison shop." (Nadel 2011).

Some of the earliest behavioral language is from Jerry Hausman's (1979) seminal analysis of the implied discount rates that rationalize consumers' tradeoffs between purchase price and energy efficiency in air conditioner choices. Page 51 states:

> *This finding of a high individual discount rate does not surprise most economists. At least since Pigou, many economists have commented on a "defective telescopic faculty." A simple fact emerges that in making decisions which involve discounting over time, individuals behave in a manner which implies a much higher discount rate than can be explained in terms of the opportunity cost of funds available in credit markets. Since this individual discount rate substantially exceeds the social discount rate used in benefit-cost calculations, the divergence might be narrowed by policies which lead to purchases of more energy-efficient equipment.*

Other academics since Hausman have studied this argument. For example, Fischer, Harrington, and Parry (2007) and Parry, Evans, and Oates (2010) use simulation models to analyze whether mistakes might justify energy efficiency policies. The latter paper considers two market failures that could justify energy efficiency standards: externalities and what they call "misperceptions market failures."

Gayer (2011) writes:

> *Energy-efficiency regulations and fuel economy regulations are therefore justified by [cost-benefit analyses] only by presuming that consumers are unable to make market decisions that yield personal savings, that the regulator is able to identify these consumer mistakes, and that the regulator should correct economic harm that people do to themselves.*

As a final example, the Parry, Walls, and Harrington (2007) review of fuel economy policies in the Journal of Economic Literature concluded:

Higher fuel economy standards significantly increase efficiency only if carbon and oil dependence externalities greatly exceed the mainstream estimates . . . or if consumers perceive only about a third of the actual fuel economy benefits.

Unfortunately, there is little in the way of solid empirical (as opposed to anecdotal) evidence on this hotly contested issue ...

The rest of the paper formalizes these policy assertions and gives an overview of recent empirical evidence.

3 Model

3.1 Setup

This section formalizes policy assertions about consumer mistakes in a very simple model. It roughly follows Allcott and Taubinsky (2014, "AT") and AMT, but it also draws on work by Heutel (2011), Sallee (2014), and the frameworks in DellaVigna (2009) and Mullainathan, Schwartzstein, and Congdon (2012).

Consumers have unit demand and choose between two energy-using durable goods, indexed $j \in \{E, I\}$. Good E is more energy efficient than good I, with energy requirement $e_E < e_I$ per unit of usage. The goods are produced at marginal cost c_j, and markets are perfectly competitive, with $p_j = c_j$. Consumers have exogenous utilization of m units per unit time, the energy cost is g, and consumers use discount factor δ. Total lifetime energy costs for good j are thus $G_j \equiv \sum_{t=0}^{T} \delta^t m e_j g$. Consumers receive usage utility v_j from owning good j. Define differences $p \equiv p_E - p_I$, $G = G_E - G_I$, and $v = v_E - v_I$.

3.2 Specific Behavioral Models of Mistakes

Rational, fully informed consumers purchase good E if and only if the net benefits outweigh the relative purchase price, i.e. if $v - G > p$. Since $G < 0$, the left hand side adds the energy cost savings to usage utility difference. By contrast, a biased consumer might misperceive energy cost savings by amount b, purchasing good E if and only if $v - G - b > p$. Bias b could be positive or negative. As defined, $b > 0$ implies that a consumer undervalues energy cost savings and is thus less likely to buy good E, while $b < 0$ implies the opposite.

Biases could arise from the following sources:

Present bias. If consumers are present biased with β, δ preferences as in Laibson (1997), and if they cannot save or borrow between periods, they downweight the future energy cost savings G by factor β, purchasing good E if $v - \beta G > p$.[4]

[4] Because consumers in developed countries often can save and borrow to buy energy-using durables, the present bias model may not be very plausible. Home buying is a clear example: because of mortgages, the purchase price,

Biased beliefs. Consumers' beliefs about energy costs could be exogenously biased by proportion ϕ. For example, they could perceive that energy prices are $\widetilde{g} = \phi g$, or that total energy costs are $\widetilde{G} = \phi G$. In this case, they purchase good E if $v - \phi G > p$.

Exogenous inattention. Similar to Chetty, Looney, and Kroft (2009), share λ of the population could be attentive to energy costs G, while share $1-\lambda$ are exogenously inattentive, purchasing E if $v > p$.

Endogenous inattention. In rational inattention models such as Gabaix (2014) and Sallee (2014), consumers pay more attention to an attribute if it is more likely to matter in their purchase decision. A simple way to capture this is to allow $\lambda = \lambda(G)$, with $\frac{\partial \lambda}{\partial G} > 0$.

In the present bias and biased beliefs models, respectively, $b = (1-\beta)G$ and $b = (1-\phi)G$. Inattentive consumers have $b = G$.

3.3 Policy Implications of Mistakes

If factors such as the four above cause consumers to under-purchase good E, the logic of O'Donoghue and Rabin (2006) suggests that policies analogous to internality taxes could increase welfare. Consider a social planner that sets subsidy s for good E using public funds raised from lump-sum taxation. Define the triple $\theta = \{v, G, b\}$, and assume that the joint distribution $f_\theta(\theta)$ is continuous with support such that there is always positive demand for both goods. For expositional simplicity, assume that there are no distortions other than consumer mistakes.[5]

If all consumers have homogeneous bias $b^\dagger$, then subsidy $s = b^\dagger$ causes consumers to purchase good E if and only if $v - G - b^\dagger > p - s$. The s and $b^\dagger$ cancel, and consumers make the same purchase that they would make if they were rational and perfectly informed. Thus, the welfare-maximizing subsidy is $s^* = b^\dagger$: a subsidy that exactly offsets the bias.

When consumers have heterogeneous bias, AT show that the average marginal bias function $B(p)$ is a sufficient statistic for the optimal subsidy. Formally, $B(p)$ is the average b of all consumers that are marginal at price p: $B(p) = \frac{\int_\theta b \cdot M(\theta,p) \cdot f_\theta(\theta) d\theta}{\int_\theta M(\theta,p) \cdot f_\theta(\theta) d\theta}$, where $M(\theta, p) = 1(v - G - b = p)$ as an indicator function for whether a consumer of type θ is on the margin at price p.

Relative to no subsidy, the welfare effect of a subsidy of amount s is:

$$\Delta W(s) = \int_{p=c-s}^{c} \int_\theta \underbrace{(v - G - c)}_{\textit{Allocative gain}} \cdot \underbrace{M(\theta, p) \cdot f_\theta(\theta) d\theta}_{\textit{Number of consumers marginal at } p} dp \tag{1}$$

The term $(v - G - c)$ is the allocative gain when a consumer purchases good E instead of good I. It measures the difference between a consumer's true utility gain $v - G$ and the relative production

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home energy costs, and consumption value of the home are all flows that occur in the future. Present-bias might cause consumers to delay searching for a home, but it should not cause them to underweight energy costs relative to purchase prices when choosing between homes.

[5] AT and AMT consider the case with both internalities and externalities, and it would be interesting to extend the model in other ways.

cost c. If and only if the allocative gain is positive, then the social planner would like the consumer to purchase good E. Equation (1) can also be re-written as:

$$\Delta W(s) = \int_{p=c-s}^{c} \left(\underbrace{B(p)}_{Internality\ reduction} - \underbrace{s}_{Harberger\ distortion} \right) \cdot \underbrace{\int_{\theta} M(\theta, p) \cdot f_{\theta}(\theta) d\theta}_{Number\ of\ consumers\ marginal\ at\ p} dp \quad (2)$$

AT use this to highlight the two effects of a corrective subsidy. First, the subsidy increases allocative efficiency through internality reduction, measured by $B(p)$. Second, however, it distorts consumers' perceived optimum by amount s, which would integrate to a standard Harberger triangle. If the average marginal bias $B(p)$ is larger than the marginal Harberger distortion s, a marginal increase in the subsidy increases welfare because on average, marginal consumers' true relative utility is larger than relative production cost.

This logic implies that the optimal subsidy s^* must equal the average marginal bias:

$$s^* = B(c - s^*) \quad (3)$$

AT, AMT, Baicker, Mullainathan, and Schwartzstein (2013), and Mullainathan, Schwartzstein, and Congdon (2012) derive this basic result that the optimal internality tax equals the average marginal internality. The math directly parallels Diamond (1973), who shows that the optimal externality tax equals the average marginal externality.

These basic formulas have rich empirical content and important policy implications. At least in simple models, the most important policies listed in Table 1 are isomorphic to a subsidy s. Subsidies for Energy Star appliances and weatherization can be analyzed directly, although in many settings it would be useful to extend the model to incorporate more than two products. With unit demand and lump-sum taxation or revenue recycling, a gas guzzler tax or analogous tax on good I is isomorphic to a subsidy, and a minimum energy efficiency standard is an infinite tax on good I. CAFE standards impose a shadow cost on vehicle sales that can be approximated as a subsidy for high-MPG vehicles.

Equations (2) and (3) emphasize the importance of empirical work that can identify $B(p)$. This highlights some issues that are relevant, and others that are not. First, $B(p)$ could naturally be heterogeneous at different p, and different types of consumers could be marginal to different policies. Thus, to set and evaluate subsidies and standards, it is insufficient to know an average bias, and it is certainly insufficient to argue qualitatively that "some consumers are biased." Second, $B(p)$ is a "reduced form" description of the behavioral models described above in Section 3.2. Once we know $B(p)$, the optimal subsidy and welfare evaluation does not depend on whether consumers are present biased, inattentive, or biased in some other way.

4 Empirical Tests

This section discusses three empirical tests: comparing demand responses to prices vs. energy costs, measuring effects of nudges, and belief elicitation. These tests are directly analogous to the three empirical studies in Chetty, Looney, and Kroft (2009) and are parallel to categories of tests described in Mullainathan, Schwartzstein, and Congdon (2012). The first two tests also parallel two of DellaVigna's (2009) proposed methods of testing for inattention, although as we shall see, they are joint tests of inattention and other models.

4.1 Comparing Demand Responses

A general test for systematically misperceived costs is to compare demand response to a correctly-perceived cost vs. a potentially misperceived cost. This is the approach followed by Abaluck and Gruber (2011), Barber, Odean, and Zheng (2005), Chetty, Looney, and Kroft (2009), Finkelstein (2009), Hossain and Morgan (2006), and others when studying sales taxes, shipping and handling charges, highway tolls, and other potentially shrouded costs.

The energy efficiency version of this test is to compare demand response to price vs. energy cost. Consumers should care only about the total lifetime cost of using a car, not the individual components of that cost. Thus, consumers should be indifferent between a dollar in upfront price and a dollar in the present discounted value of energy costs. A set of seminal papers implemented this test in the energy literature, including Dubin (1992), Dubin and McFadden (1984), Goldberg (1998), and Hausman (1979). A simple representation of the approach is to imagine cross-sectional data on market shares and product attributes in a logit model. Define s_j, X_j, and ξ_j as the market share, observed characteristics, and unobserved characteristic of product j. In the representative consumer logit model, the market share equation is

$$ln(s_j) = -\eta(p_j + \gamma G_j) + \alpha X_j + \xi_j. \tag{4}$$

If the estimated $\hat{\gamma}$ is smaller (larger) than one, this implies that consumers undervalue (overvalue) one dollar of energy cost G relative to purchase price p. A crucial part of the approach is estimating G. This requires expectations of future energy costs[6], utilization patterns, and discount rates. Of course, estimating the "implicit discount rate" that gives $\gamma = 1$ does not eliminate the need to take a stand on discount rates, as once an implicit discount rate is estimated, it must be compared to some benchmark rate to determine if consumers are behaving according to some

[6]See Allcott (2011), Allcott and Wozny (2012), and Anderson, Kellogg, and Sallee (2013) for evidence on this issue. Anderson, Kellogg, and Sallee (2013) use Michigan Survey of Consumers (MSC) data from 1993-2010 to show that on average, consumers believed that the future real price of gasoline would equal the current price. However, both oil futures markets and MSC consumers believed that the price shocks of 2008 were temporary. Allcott and Wozny (2012) show that used vehicle prices move as if consumers' forecasts are some combination of current and futures prices.

benchmark model. The need to make assumptions to calculate G makes it more complicated to implement this test with energy efficiency relative to sales taxes, shipping and handling fees, or other costs that are easily quantified and are paid at the time of purchase. On the other hand, other product attributes - a car's horsepower, the amount of strawberry jam in a yogurt, etc. - cannot be monetized, and this test could not be implemented at all.

One of the problems with this test is the endogeneity of both p and G: as Berry, Levinsohn, and Pakes (1995) and others have pointed out, prices are likely to be correlated with unobserved characteristics ξ. Furthermore, fuel economy, which generates the cross-sectional variation in G_j, is also likely to be correlated with ξ. Intuitively, an "economy" rental car both has high fuel economy and fewer amenities, and not all amenities are observed by the econometrician. Allcott and Wozny (2012) show that fuel economy is highly negatively correlated with price in the cross section, suggesting the low-fuel economy vehicles have more observed and unobserved amenities.

To address these issues, Allcott and Wozny (2012, "AW"), Busse, Knittel, and Zettelmeyer (2013, "BKZ"), and Sallee, West and Fan (2009) exploit variation in g and p from panel data on used auto markets. Allow jat to index a model j of age a at time t, for example a three-year-old Honda Civic DX in 2006. In used markets, s_{ja} is fixed over time by definition because vehicles of a given model year have already been produced. (AW exclude vehicles older than 15 years, as they reject that scrappage is exogenous to gasoline prices for these older vehicles.) Defining ξ_{ja} as a model fixed effect, including time indicators τ_t, Equation (4) can be re-arranged as:

$$p_{jat} = \gamma G_{jat} + \xi_{ja} + \tau_t + \epsilon_{jat}. \tag{5}$$

Figure 1 gives graphical intuition for the identification. This figure is taken directly from AW. It is constructed by grouping above-median and below-median fuel economy vehicles into composite groups, analogous to goods E and I. Each point on the graph is a month of the sample, from 1999 through the end of 2008. The y-axis plots the mean price difference $p_I - p_E = -p$, while the x-axis plots the mean gas cost difference $G_I - G_E = -G$. Notice that low-MPG cars are both more expensive and have higher G, so $-p$ and $-G$ are both positive. This graph plots raw data, before removing fixed effects or including other controls. The graph shows that the line slopes downward: as gas prices increase, the relative gas costs of good I increase, and relative prices drop in response. The more responsive are relative prices to gasoline costs, the more that we infer that consumers value fuel economy.

AW estimate a 15 percent implied discount rate, meaning that $\gamma = 1$ when they assume $\delta = \frac{1}{1.15}$. They calculate consumers' weighted average intertemporal opportunity cost of capital based on auto loan interest rates and returns to the S&P 500, and weight these two by the share of consumers that pay with loans vs. cash. This weighted average is 6 percent, which gives $\delta = \frac{1}{1+6\%}$. At this δ, the $\hat{\gamma}$ in AW's primary specification is 0.76. They also estimate $\hat{\gamma}$ for a range of alternative assumptions and specifications.

Using an analogous approach that compares vehicles in different quartiles of the MPG distribution, BKZ report a range of implied discount rates from -6.8 percent to 20.9 percent, depending on the assumptions used to calculate G and the quartiles being compared. When using assumptions that correspond most closely to AW's primary specification (vehicle-miles traveled and survival probabilities from the National Highway Transportation Safety Administration), the average implied discount rate for used vehicles is 13 percent. At $\delta = \frac{1}{1+6\%}$, the BKZ $\hat{\gamma} = 0.78$.

4.1.1 What Do Demand Responses Identify?

In the choice models from Section 3, what does this estimated $\hat{\gamma} = -\frac{dp}{dG}$ represent? For expositional simplicity, assume for this section that v is the only source of heterogeneity across consumers. For the exogenous and endogenous inattention models, also assume that $b \perp v$, and take a first-order approximation to demand, so that the marginal distribution of v, denoted $f_v(v)$ with CDF $F_v(v)$, is locally uniform.[7]

Consider first the case with informed and rational consumers. Because only v varies across consumers, there is some marginal consumer with $v = v^*$, and all consumers with $v < v^*$ purchase good I. Given that market share is constant in used vehicle markets, v^* must remain the same as p and G change. Mathematically, $v^* = p + G$. Taking the total derivative gives $dv^* = dp + dG$. Given that $dv^* = 0$, rearranging gives $-\frac{dp}{dG} = -1$. This says that relative prices and relative gasoline costs must offset each other one-for-one in the standard model in order to keep the same marginal consumer indifferent.

Similarly taking total derivatives, we can see that $-\frac{dp}{dG}$ equals β and ϕ in the present bias and biased beliefs models, respectively. In the exogenous inattention model, the market share of good I is $s_I = \lambda F_v(p + G) + (1 - \lambda)F_v(p)$. Taking the total derivative, $ds_I = \lambda \left(f_v(dp) + f_v(dG) \right) + (1 - \lambda) f_v(dp)$, which gives $-\frac{dp}{dG} = \lambda$. Thus, the approach of comparing demand responses jointly identifies the average bias among consumers with a combination of present bias, biased beliefs, and exogenous inattention.

In the endogenous inattention model, however, taking the total derivative gives $-\frac{dp}{dG} = \lambda(G) + \lambda' \frac{G}{dG}$: relative price moves *more* than would be predicted in the exogenous inattention model. Intuitively, as gas prices increase, the relative prices of high-MPG vehicles increase both because they are more valuable to attentive consumers and because more consumers become attentive and thus are willing to pay for their fuel economy. Thus, when inattention is endogenous, the comparing demand responses identification strategy will overstate the share of attentive consumers λ at initial prices. This is an issue not just for AW and BKZ, but for papers in other domains such as Chetty, Looney, and Kroft (2009) that use an analogous approach to identify the magnitude of inattention.[8]

[7] AT and AMT derive these results in less restrictive settings.

[8] AT also show that even when each consumer's attention or bias is exogenous, comparing demand responses only approximates the average marginal bias $B(p)$ when b is heterogeneous across consumers. They show that the

4.1.2 Endogenous Inattention

Endogenous inattention might be particularly relevant for energy efficiency given the dramatic and highly-publicized fluctuations in oil prices. Endogenous attention models such as Gabaix (2014) and Sallee (2014) generate several predictions. In these models, the share of consumers that attend to an attribute is increasing in the importance of that attribute in the decision problem. In the context of the above model of energy efficiency, this implies that θ is increasing in energy price g. Similarly, λ is increasing in utilization m: more utilization increases the financial importance of energy efficiency. Furthermore, attention might vary across consumers due to variation in cognitive costs, not just gains from attention. Below I provide some suggestive empirical evidence of endogenous inattention.

Figure 1 presents graphical evidence that λ increased as gas prices increased over the AW study period. From 1999-2003, gasoline prices were relatively low, and the slope of $\frac{dp}{dG}$ is relatively flat. From 2004-March 2008, gasoline prices were at a higher average, and the slope becomes steeper. From April-December 2008, as gas prices reached almost unprecedented highs, the slope of $\frac{dp}{dG}$ is close to -1. More formally, AW show that the estimated γ is larger when excluding 1999-2003 and smaller when excluding April-December 2008.

Survey evidence provides some additional evidence on endogenous attention. The Vehicle Ownership and Alternatives Survey, or VOAS (Allcott 2011, 2013), asked a nationally-representative sample of Americans about gas prices, their current vehicle, total gasoline expenditures, and counterfactual gasoline expenditures had they bought their second choice vehicle or a different replacement vehicle with randomly-selected MPG difference. The median survey completion time was ten minutes. At the end of the survey, respondents were asked: *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?*

As shown in Table 2 and reported in Allcott (2011), 40 percent of Americans reported that they did not think about fuel costs at all during their most recent purchase. Using these responses, I construct two variables: 1(Thought) is an indicator for whether the consumer answered in one of the latter four categories, i.e. did *not* report that "I did not think about fuel costs at all." The Calculation Effort variable orders the five responses as 1-5 from top to bottom and normalizes to mean zero, standard deviation one.

Table 3 reports regressions of these two measures of cognitive effort on potential explanatory factors available in the VOAS. "Gas Price at Purchase" is the US average retail gasoline price in the month that the vehicle was purchased, inflated to April 2014 dollars. Implied Vehicle-Miles Traveled is backed out from self-reported gasoline expenditures using the current vehicle MPG

approximation can be highly inexact, which provides a further challenge to this approach.

rating and gasoline prices. Environmentalist is the consumer's response to the question, "Would you describe yourself as an environmentalist?" "Yes, definitely," "Yes, somewhat," and "No" are coded as 1, 1/2, and 0, respectively.

Column 1 shows that a \$1 increase in gasoline prices is associated with a 5.7 percentage point increase in the probability that vehicle buyers report thinking about gasoline prices. Column 2 shows that a \$1 increase in gasoline prices is associated with a 0.148 standard deviation increase in self-reported calculation effort.[9] The coefficients on natural log of vehicle-miles traveled m are positive, although not statistically significant in Column 1. These two variables are consistent with a model in which consumers pay more attention to fuel economy when it has larger financial implications, either because they drive more miles or because gas prices are higher. Calculation effort is also positively associated with education, which is consistent with a model in which education is correlated with lower cognitive costs. Self-described environmentalists also are more attentive to fuel costs, a result which I return to in Section 5.1.

Finally, Google Trends search statistics can be used to provide data on how consumers gather information on fuel economy. For each search term, Google Trends can report the frequency of that search relative to all searches on the internet, beginning in 2004. I sum the relative frequencies for five fuel economy-related search terms - gas mileage, best gas mileage, fuel economy, hybrid vehicles, and hybrid cars - and normalize so that the 2014 average is 100. Figure 3 plots this search frequency on the left y-axis, comparing it to gasoline prices on the right y-axis. There is a remarkably sharp short-term correlation between gas prices and fuel economy-related searches, which is consistent with additional information gathering as gas prices rise. Of course, to take such a correlation seriously in the context of a model, one would need a setting that allows shifts in information gathering or cognitive effort to be cleanly distinguished from shifts in the demand curve that a standard full attention model would predict.

4.2 Estimating Effects of Nudges

Following Thaler and Sunstein (2009), I define a "pure nudge" as an intervention that eliminates bias but has no other effects. For example, providing information on energy costs can cause consumers who were previously uninformed or inattentive to make privately-optimal decisions. In theory, pure nudges can identify the average marginal bias function. To see this, consider the set of consumers who have baseline willingness-to-pay (WTP) of $v - G - b = p$ and are thus marginal at price p. Since the pure nudge causes consumers to make the same decisions they would make if they were informed and rational, their average WTP *after* being given a pure nudge is just their average $(v - G)$. Thus, the average WTP change from a pure nudge for consumers marginal at price p equals the average marginal bias:

[9] Column 2 is a modified version of Table 2 in Allcott (2011).

$$\tau(p) = \frac{\int_\theta (v-G)\cdot M(\theta,p)\cdot f_\theta(\theta)d\theta}{\int_\theta M(\theta,p)\cdot f_\theta(\theta)d\theta} - (v-G-b) = B(p) \tag{6}$$

Carrera and Villas-Boas (2014), Chetty, Looney, and Kroft (2009), Choi, Laibson, and Madrian (2010), Kling *et al.* (2012), and others measure the effects of information in choices between generic and branded drugs, sales taxes, retirement savings, health insurance, and other domains. DellaVigna (2009) points to Chetty, Looney, and Kroft (2009) as an example of how treatment effects from experimentally-provided information can be a measure of bias from inattention. Of course, pure nudges only identify the magnitudes of the specific biases they target: information provision can eliminate imperfect information and inattention, but it does not affect or identify present bias. Offering commitment contracts could identify present bias for sophisticates, but this might not affect or identify imperfect information.

In the context of energy efficiency, the nudge identification strategy might take the form of measuring effects of durable good energy cost information. Allcott and Taubinsky (2014) and Allcott and Knittel (2014) each run two informational field experiments, with buyers of lightbulbs and cars, respectively. The AT study is motivated by what they call the "Lightbulb Paradox": despite the fact that a normal 60-watt-equivalent Compact Fluorescent Lightbulb (CFL) saves \$40 in electricity and bulb replacement costs over its rated eight-year life relative to traditional incandescent bulbs, only 28 percent of light sockets in American homes that could accommodate CFLs actually had them as of 2010. Is this low market share due to preferences, i.e. the distribution of v in the model above? Or is this due to imperfect information or inattention, i.e. ϕ and θ from the model?

Only very specific experimental designs can plausibly use Equation (6) to identify $B(p)$. First, experimental or quasi-experimental designs are obviously needed to consistently identify a treatment effect τ. Second, one needs a design that allows the measurement of $\tau(p)$ at different p. To do this, one must observe consumers' WTP *before* being given a pure nudge to know which consumers are marginal at a given p and then measure the nudge's effect on WTP for these specific consumers. Third, the treatment must be a pure nudge, without affecting consumers through persuasion, demand effects, or other mechanisms. This highlights perhaps the crucial drawback of this identification strategy: it is difficult to design interventions that plausibly approximate a pure nudge, and it is not clear how such an assumption could be decisively tested.

The AT experiment using Time-Sharing Experiments for the Social Sciences (TESS) attempts to satisfy these three criteria. A crucial feature is the within-subject design. All consumers in the experiment were given a \$10 shopping budget and asked to make choices between CFLs (good E) and incandescents (good I). Each consumer made baseline choices using a 15-part multiple price list. The treatment group was then given hard information about cost savings from CFLs, while the control group received information that was parallel in form but vacuous in content.

Each consumer then made endline lightbulb choices on an identical 15-part multiple price list. Consumers' decisions were incentive-compatible: one of the 30 choices was randomly selected to be the consumer's "official purchase," and consumers were shipped the lightbulbs that they had chosen at that relative price and given the remainder of their \$10 shopping budget. This within-subject design identifies $\tau(p)$ by measuring the average treatment effect on WTP for consumers at each level of baseline WTP.

The information treatment was designed to plausibly approximate a pure nudge. It provided only hard information on lightbulb costs, without persuasive cues such as social comparisons or environmental framing. Care was taken to avoid demand effects, where experimental subjects might be more or less likely to purchase energy efficient goods not due to new information but because they wish to comply with (or perhaps defy) the perceived wishes of the experimenter. In addition, AT take steps to ensure and document that treated consumers understood, believed, and internalized the information. Despite this, they view their information treatments as only approximations to a pure nudge, and they carry out analyses under alternative assumptions.

Figure 3 illustrates AT's main results. The graph presents a discrete version of Equation (2) above. The dashed line is the demand curve from the baseline multiple price list. The unsubsidized market equilibrium is at a relative price of 0, with CFL market share of approximately 0.7. The vertical black lines mark off the effects of discrete increases in the subsidy to different relative prices on the multiple price list. The shaded rectangles above the x-axis are the average treatment effect at each level of initial WTP, which by assumption equal the average marginal bias $B(p)$. The triangle and trapezoids below the x-axis are the "Harberger distortion," in which the subsidy moves consumers away from their perceived private optimum. A subsidy of \$1 moves CFL market share to about 0.82, generating internality reduction equal to the leftmost shaded rectangle but Harberger distortion equal to the leftmost triangle. Incremental increases in the subsidy increase welfare until the incremental internality reduction above the x-axis is larger than the incremental Harberger trapezoid below the x-axis. The optimal subsidy for this experimental population is \$3.

In the model with unit demand and lump sum revenue recycling, a ban on good I is equivalent to subsidy $s = \infty$. The welfare effect equals the sum of blue rectangles net of the sum of red rectangles, which is negative. In AT's model, the ban on incandescent lightbulbs therefore reduces welfare. Intuitively, there are a large group of consumers who strongly prefer incandescent lightbulbs, even after being informed about the CFL's cost advantages.

This nudge-based identification strategy has several important advantages. First, AT show that unlike comparing demand responses, the nudge approach provides a consistent estimate of the baseline level of bias even if the bias is endogenous or heterogeneous. Second, the nudge approach requires none of the assumptions on discount rates, gas price forecasts, and utilization that are required to calculate G in order to compare demand responses. Third, when paired with the multiple price lists and within-subject design of the lightbulb experiment, the nudge approach allows the analyst to infer the joint distribution of baseline demand and $B(p)$, which is required both for setting the globally-optimal subsidy and for evaluating the welfare effects of a ban. An important future research area would be to design a natural field experiment that has the conceptual advantages of the AT experiment without the artefactual setting.

4.2.1 Takeup of Energy Efficiency Commitment Contracts

Of course, information is not the only type of nudge, and biased beliefs and inattention are not the only types of internalities. Another type of internality that has been proposed in the literature is present bias, as in Heutel (2011). One way to test for the presence of sophisticated present biased consumers is to measure takeup of commitment devices that induce people to save energy later. One highly-publicized commitment device is stickK.com, which allows people to individually tailor commitment contracts. stickK.com reports that only 0.3 percent of their commitment contracts are categorized as "Green Initiatives," while 0.8 percent are "Home Improvement and DIY" and 3 percent are "Money & Finance." Energy efficiency contracts are likely to be a small subset of these three categories. By contrast, other categories are much more popular, such as weight loss (35 percent), exercise (21 percent), other health and wellness (17 percent), career (8 percent), and education and knowledge (7 percent).

Similar evidence can be found in Harding and Hsiaw (2014), who study a program that invited electricity consumers to set energy conservation goals and also provided conservation information and usage feedback. In the Harding and Hsiaw (2014) model, failing to reach a goal imposes a utility cost due to reference-dependent preferences, and present-biased consumers thus view the program as a commitment device. While it is difficult to measure takeup rates conditional on being aware of the program, the authors present two pieces of evidence to suggest that takeup rates are low. First, while the program was marketed throughout the greater Chicago metropolitan area, only 2487 households enrolled. Second, when the authors took a random sample of 10,000 households in the zip codes where there was any enrollment, only 36 had actually enrolled.

In summary, commitment device takeup rates from stickK.com and Harding and Hsiaw (2014) suggest that few consumers are both present biased and sophisticated. Unless the share of sophisticates relative to naifs is very high, this suggests that present bias does not have a large impact on energy consumption. While this does not say that low-cost commitment devices should not be offered, it does imply that present bias may not be an important internality that could justify energy efficiency subsidies and standards.

4.3 Belief Elicitation

Starbucks customers tend to overestimate the calories in drinks and underestimate the calories in food (Bollinger, Leslie, and Sorensen 2011). People signing up for gyms are overconfident about their future attendance and about their likelihood of canceling automatically renewed memberships (DellaVigna and Malmendier 2006). More than 70 percent of seniors choosing between Medicare plans underestimate potential cost savings from switching (Kling *et al.* 2012). Spinnewijn (2014) shows that the unemployed overestimate how quickly they will find work. Could consumers have systematically biased beliefs about the financial benefits of energy efficiency?

There is some evidence of misperceived energy costs from the psychology literature. Attari *et al.* (2010) show the consumers misestimate the value of different energy conservation actions and underestimate the energy use from heating, cooling, and other large energy uses relative to the energy use of a lightbulb. Larrick and Soll (2008) show that consumers overestimate the fuel cost savings from high-fuel economy vehicles due to "MPG Illusion," which is caused by reporting gasoline use in miles per gallon, which is $1/e_j$. Turrentine and Kurani (2007) show that even well-educated and quantitatively-oriented auto owners have trouble with the net present value calculations required to estimate G_j.

While these and other related papers are interesting and important, this evidence that consumers misperceive energy costs does not necessarily show that consumers misperceive energy costs *in ways that cause them to underpurchase energy efficiency.* The Vehicle Ownership and Alternatives Survey (Allcott 2011, 2013) is a nationally-representative survey on the Time-Sharing Experiments for the Social Sciences (TESS) platform, designed to test whether consumers systematically underestimate the fuel cost savings from higher-MPG vehicles. The VOAS asks consumers what vehicle they currently drive, how much they spend on gasoline, and how much they would spend on gasoline if they had bought their second-choice vehicle or another "replacement vehicle" with randomly-selected MPG difference. These questions are used to construct "valuation ratios": the share of true fuel cost differences that consumers perceive. This was denoted ϕ in the model in Section 3. Indexing the current vehicle as $j = o$ and an alternative vehicle as $j = a$, the valuation ratio for consumer i is

$$\phi_{ia} = \frac{\widetilde{G}_{ia} - \widetilde{G}_{io}}{G_{ia} - G_{io}}. \tag{7}$$

Consumers were told to assume that they drove the alternative vehicles the same amount as their current vehicle, which would allow m to be assumed constant. To measure and limit potential confusion, various response frames were randomized across consumers. For example, some were told to report annual gasoline cost estimates, while others were told to report estimates over the full vehicle life. Some consumers were asked for absolute levels of gasoline costs, while others were told to report cost savings or additional costs relative to their current vehicle.

Figure 4 plots the distribution of valuation ratios between current vehicles and second choice vehicles. If all consumers were perfectly informed and reported correctly on the survey, the distribution would have point mass at $\phi = 1$. In fact, the figure shows that valuation ratios are quite dispersed, likely reflecting a combination of imperfect information and reporting error. The large mass at zero represents consumers who incorrectly report that their current vehicle and second choice vehicle have "exactly the same" fuel economy. Allcott (2013) shows that on average, consumers correctly underestimate or perhaps slightly underestimate the financial benefits of higher-MPG vehicles.

There are two major problems with the belief elicitation approach to measuring internalities. The first is that because the goal is to measure beliefs as they existed at the time of purchase, the survey must induce accurate recall without additional calculation. Making the belief elicitation fully incentive compatible could induce survey respondents to look up fuel economy ratings and calculate answers on a calculator or spreadsheet. On the other hand, providing no incentives could lead to thoughtless answers. The VOAS offered moderate incentives (up to $10) with a vague criteria for payout: if an answer "makes sense" given answers to other questions. Allcott (2013) shows that results are indistinguishable between consumers randomly assigned to be offered incentives vs. not offered.

The second major problem is that stated beliefs have wide variance, and it is not clear whether this reflects true variation in beliefs or reporting error. The average marginal ϕ is object of interest to estimate $B(p)$, but the standard error on the estimated average can be large. Allcott (2013) also estimates median regressions as an alternative measure of central tendency.

One benefit of belief elicitation is that it provides a direct measure of biased beliefs, whereas the comparing demand responses approach could estimate a combination of biases, and the informational nudge could estimate effects of both biased beliefs and inattention.

5 Policy Implications

5.1 Targeting

Biases, when they exist, are almost certainly heterogeneous. For example, Figure 4 suggests that some consumers overestimate the private value of energy efficiency, even as other consumers underestimate. The optimal price policy to address heterogeneous bias includes consumer-specific subsidies tailored to each consumer's bias b. Given that consumer-specific policies are not practically feasible, Equation (3) shows that the optimal uniform subsidy s is a compromise between (i.e., the average of) the optimal consumer-specific subsidies. A uniform subsidy distorts decisions of less biased consumers even as it improves decisions by more biased types.

Ideally, a policy could approximate a pure nudge, which preferentially affects decisions by biased types without affecting the already-optimal decisions of rational types. One might think of a poorly-targeted policy as the opposite of a pure nudge: a policy that preferentially affects decisions by less-biased types. At best, poorly targeted policies are disadvantageous because they might address only a small share of the total allocative inefficiency caused by consumer mistakes.

At worst, a poorly-targeted subsidy could reduce welfare if $s > 0$ but the marginal consumers have $B(p) < 0$. Bernheim and Rangel (2004) give an intuitive example: if addicts are more biased but are highly inelastic to sin taxes, then a sin tax addresses little of the welfare losses from addiction. Furthermore, if rational types are relatively elastic, then a sin tax of any non-trivial magnitude might reduce welfare by inducing many rational types to underconsume the sin good.

There are at least two mechanisms that might cause some energy efficiency efficiency subsidies to be poorly targeted. First, many consumers are unaware of subsidies such as the weatherization incentives offered by local utilities, and the consumers who are most aware of and attentive to energy costs are also more likely to be aware of energy efficiency subsidies. Second, some energy efficiency investments are niche goods, such as hybrid cars and weatherization, with small market shares and only environmentalists near the margin. As shown in Table 3, environmentalist consumers are more likely to be attentive to energy costs, suggesting that their average bias is smaller. In belief elicitation surveys in several different contexts, I also find that self-identified environmentalists perceive larger private cost savings from energy efficient goods, which provides a second reason why environmentalists might tend to have smaller (or perhaps negative) b. In the context of the model, v is thus negatively correlated with b, but c is sufficiently high that good I's market share is large. Unless a subsidy is so large as to substantially affect market shares and place more non-environmentalists on the margin, the average marginal bias is likely to be smaller than the population average bias.

Table 4 presents suggestive empirical evidence on these two mechanisms. Column 1 analyzes energy efficiency program participation for a sample of about 75,000 residential consumers at a large US utility. The dependent variable is an indicator for whether the household claimed a utility subsidy for energy efficient appliances, insulation, heating, ventilation, and air conditioning, or similar investments between January 2007 and April 2009. About ten percent of households receive the subsidy. While this takeup rate is large compared to other utilities, these energy efficiency investments still only appeal to a niche group of households. Results show that subsidy recipients are more likely to be environmentalists, as measured by whether they have solar energy systems or voluntarily pay extra for renewable energy as part of the utility's green pricing program. Additionally, subsidy recipients are wealthy and are also less likely to rent, which suggests that the subsidies are also poorly targeted to address credit constraints and "landlord-tenant" information asymmetries.

Columns 2 and 3 consider the federal Residential Energy Credits, which provide income tax credits for home energy efficiency investments.[10] The TESS survey platform asks participants if they qualified for this credit in the past two years, and I acquired responses for all consumers in the AT lightbulbs experiment and the VOAS. Columns 2 and 3 combine these two datasets. About ten

[10] Some households also qualify by purchasing household-scale solar, geothermal, and wind energy systems. See http://www.irs.gov/pub/irs-pdf/f5695.pdf for the official IRS form.

percent of households report taking up the credit, which is likely an overestimate but still shows that the subsidized energy efficiency investments have only niche appeal. The explanatory variables 1(Thought) and Calculation Effort are the same variables from Table 3. These two variables are available only from the VOAS and are coded as zero for consumers in the AT lightbulbs data; the regressions include a separate intercept for VOAS consumers. As with the utility subsidy, results show that environmentalists and consumers who report being less attentive to energy costs are less likely to take up the tax credit. Also like the utility subsidy, the federal tax credit is regressive, as it preferentially accrues to higher-income households.

Columns 1-3 show that the *average* adopters of subsidized energy efficient goods are more likely to be environmentalists and attentive types. If we further assume that adoption would not occur in the absence of the subsidy - that is, that $c > v - G - b$ for all consumers - then these are also the consumers that are marginal at prices between c and $c - s$.

Columns 4 and 5 study whether subsidy awareness could be a mechanism for poor targeting. The AT TESS study asks consumers whether energy efficiency rebates or loans are available in their area.[11] There were five possible responses: "Yes," "I think so, but I'm not sure," "I'm not sure at all," "I think not, but I'm not sure," and "No." Because rebates or loans exist in most parts of the United States, responses are a rough measure of awareness of subsidy availability. I coded responses from 1-5, with 5 being "Yes" and 1 being "No," and normalized the variable to mean zero, standard deviation one. Regressing this variable on demographics shows that self-identified environmentalists are much more likely to be aware of subsidies, which mechanically will make their purchases more elastic to subsidies. Column 5 includes state fixed effects to control for potential correlations between environmentalism and subsidy availability; the results are unchanged.

In sum, Table 4 suggests that some energy efficiency subsidies may not target the market failures they were designed to target. Instead, they primarily pay wealthy environmentalists to become even more green. Notwithstanding, this empirical evidence is only suggestive. It would be an interesting and important contribution to (1) convincingly identify biased consumers and (2) convincingly test whether more biased consumers are marginal to a policy.

5.2 Calibrating Magnitudes

Some of the empirical results discussed above suggest that some consumers are biased in some contexts, which provides qualitative support for the idea that paternalistic energy efficiency policies could increase welfare. However, Equation (3) specifies the quantitatively optimal policy to address consumer bias, and AMT, AT, and Heutel (2011) derive optimal policies when there are also externalities or other market failures. To my knowledge, however, the processes that most utilities

[11] Specifically, the question was: "Some states and local areas have rebates, low-interest loans, or other incentives available for energy efficiency. These might include rebates for Energy Star appliances or energy efficient light bulbs, low-interest loans for energy-saving home improvements, government-funded weatherization, and other programs. Are any such programs available in your area?"

and government agencies undertake when setting subsidies for weatherization or energy efficient goods bear no resemblance to this theoretically-desirable process of measuring market failures and basing corrective policies on these measurements. Instead, the subsidies are often set to exhaust the available budget or to maximize quantity effects per subsidy dollar spent. As a result, the subsidies in effect are almost certain to be inefficiently large or small.[12]

There have been several welfare evaluations of paternalistically-motivated energy efficiency policies. AMT, Fischer, Harrington, and Parry (2007), Heutel (2011), and Parry, Evans, and Oates (2010) use different models to show that CAFE standards are much more stringent than can be justified by the largest estimates of consumer bias in AW, BKZ, and Allcott (2013). Similarly, AT's estimates discussed above show that if imperfect information and inattention are the only market inefficiencies, an incandescent lightbulb ban reduces welfare. On the other hand, results from AT's TESS experiment suggest that the optimal subsidy for a 60-Watt CFL is \$3, which is larger than the typical subsidies offered by electric utilities over the past few years.

6 Open Research Questions

Many research questions remain. In this section, I sketch four of them.

First, what discount factor δ should be used? Allcott and Wozny (2012) attempt to calculate a weighted average across vehicle buyers, using survey data on savings and borrowing rates and the share of consumers that use loans vs. pay from savings. Most other papers in the literature are even more informal. There are several problems with the approaches that have been used. First, opportunity costs of capital vary across consumers, so a more realistic approach would be to incorporate this distribution in a model with consumer heterogeneity. Second, the relevant δ reflects opportunity cost of capital for the marginal dollar, which might be difficult to infer. For example, within the large group of consumers that purchase cars using both cash and auto loans, some are cash constrained and draw their marginal dollar from an increased loan, while others reach a maximum loan amount and draw their marginal dollar from cash or savings. Third, many individuals hold both savings at low interest rates and credit card debt at high interest rates, and the appropriate discount rates would depend on whether an energy efficiency investment decreases savings or increases debt. Laibson, Repetto, and Tobacman (2007) study this tension, estimating that consumers use a 40 percent short-term annualized discount rate and a 4.3 percent long-term annualized discount rate. Without understanding broader issues of how individuals discount future cash flows, it is difficult to make progress on whether consumers misoptimize when choosing energy efficiency and whether regulators should intervene. Based on the small or null effects of information provision experiments such as Allcott and Sweeney (2014), AT, and others,

[12] By contrast, the Department of Energy sets energy efficiency standards so as to equate the marginal cost of more energy efficient (lower e_j) goods with the marginal reduction in G_j. While this is non-trivial to implement in practice, at least the process is theoretically optimal in a simple model.

it could be that the "high" implicit discount rates estimated by Hausman (1979) and the literature that follows largely reflect well-informed consumers making decisions consistent with the behavior estimated by Laibson, Repetto, and Tobacman (2007).

Second, if consumers misoptimize, how does this affect firms' incentives to develop, offer, and price energy efficient goods? Gabaix and Laibson (2006) study firms' incentives to debias consumers about add-on costs like energy efficiency, but a key feature of that model is that the firm selling the base good also sells the add-on at some profit. By contrast, retailers of durable goods do not sell energy, so they in theory have stronger incentives to debias compared to the Gabaix and Laibson (2006) "curse of debiasing." There is a growing literature on firms' incentives in marketing energy efficiency. Allcott and Sweeney (2014) use a field experiment to study one retailer's ability to inform consumers about energy efficiency, and Houde (2014b) shows how firms bunch product characteristics around the minimum eligibility criteria for Energy Star. Fischer (2010) studies how internalities interact with market power in firms' decisions to provide higher-fuel economy vehicles, and how this affects the optimal determination of minimum standards and gasoline taxes. Sallee (2014) analyzes firms' incentives to increase energy efficiency when consumers are endogenously inattentive.

Third, what is the best way to disclose energy efficiency information given consumers' limited time or cognitive ability? Sallee (2014) suggests that coarse information such as the binary Energy Star certification might be easier to understand. Estimates in Houde (2014a) suggest that some appliance buyers respond primarily to coarse information in the Energy Star label, while others respond to the continuous energy cost information in yellow tags, while a third group responds to neither.

Fourth, in an endogenous inattention model, how do consumers form initial beliefs about the importance of energy efficiency when deciding whether to attend to this attribute? In Sallee (2014), for example, consumers have beliefs about the variance of energy costs across products, and in Gabaix (2014), consumers must have analogous initial beliefs about how much any attribute matters. Conlisk (1996), Gabaix, Laibson, Moloche, and Weinberg (2006), Lipman (1991), and others provide some insight in other contexts.

7 Conclusion

As documented in Section 2.3, paternalism is an important factor used to justify energy efficiency policies. In recent years, models like the one in Section 3 have formalized this rationale, and three categories of empirical tests have been used to estimate consumer bias. Although the results are far from ironclad or comprehensive, there is some evidence that some consumers are imperfectly informed or inattentive when purchasing energy-using durables. In the absence of other market failures, however, the estimated magnitudes of bias cannot justify the stringency of some important energy efficiency policies. Furthermore, some existing policies do not appear to effectively target the market failures that they were supposedly designed to address.

There is much work still to be done. Models can be further extended to study other cases, for example with imperfect competition or endogenously-determined product attributes. There may be other categories of empirical tests or better ways to implement the three tests described above. And as rigorous evidence grows, it will be crucial to bring these results to policymakers.

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Tables

Table 1: **Major US Energy Efficiency Policies**

Policy	Years	Magnitude
	Standards	
Appliance efficiency standards	1990-	$2.9 billion annual cost
Building codes	1978-	
CAFE standards	1978-	$10 billion annual cost
	Prices	
Federal Hybrid Vehicle Tax Credit	2006-2010	$426 million annual credit
Gas guzzler tax	1980-	$200 million annual revenues
Weatherization Assistance Program	1976-	$250 million annual cost
Demand-Side Management	1978-	$3.6 billion annual cost
2009 Economic Stimulus	2009-	$17 billion total
	Information and Marketing	
Fuel economy labels	mid-1970s	
Appliance "yellow tags"	1980	
Energy Star program	1992	$50 million annual cost

Notes: This is a modified version of a table from Allcott and Greenstone (2012).

Table 2: **Fuel Cost Calculation Effort in Vehicle Ownership and Alternatives Survey**

When you were deciding whether to purchase your vehicle … how precisely did you calculate the potential fuel costs for your vehicle and other vehicles you could have bought?

Response	Share
I did not think about fuel costs at all	0.40
I did think some about fuel costs, but I did not do any calculations.	0.35
I calculated some, but not as precisely as I did just now in this survey.	0.13
I calculated about the same as I did just now in this survey.	0.08
I calculated more precisely than I did just now during this survey.	0.03

Source: Allcott (2011).

Table 3: **Correlates of Fuel Cost Calculation Effort**

	(1)	(2)
Dependent Variable:	1(Thought)	Calculation Effort
Gas Price at Purchase ($/gallon)	0.057	0.148
	(0.023)**	(0.046)***
ln(Implied Vehicle-Miles Traveled)	0.024	0.069
	(0.018)	(0.034)**
Environmentalist	0.093	0.254
	(0.056)*	(0.115)**
Income ($ millions)	0.467	0.201
	(0.418)	(0.859)
Education (Years)	0.026	0.051
	(0.007)***	(0.015)***
Age	-0.001	-0.006
	(0.001)	(0.002)**
1(Male)	0.045	0.211
	(0.034)	(0.070)***
1(Rural)	-0.026	-0.132
	(0.047)	(0.082)
N	1,445	1,444

Notes: The outcome variables are measures of fuel cost calculation effort based on data from Table 2. These are OLS regressions with robust standard errors in parentheses. *, **, ***: Statistically different from zero with 90, 95, and 99 percent confidence, respectively.

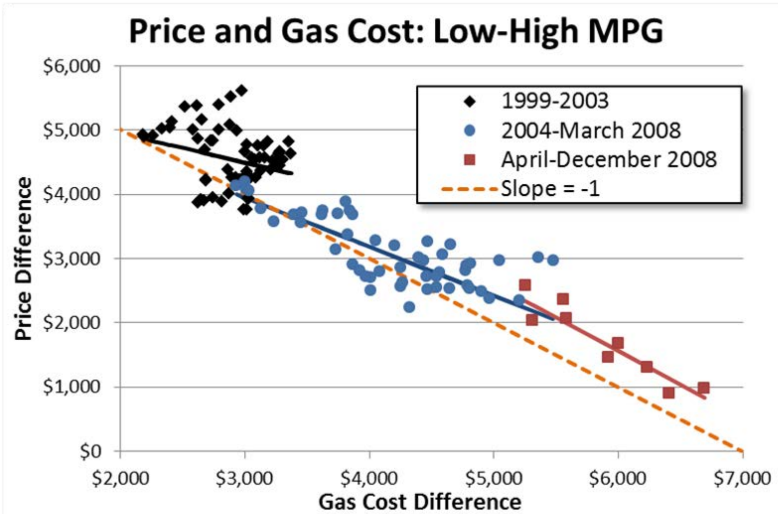
Table 4: **Targeting of Energy Efficiency Policy**

	(1)	(2)	(3)	(4)	(5)
Dependent Variable:	1(Take up Utility Subsidy)	1(Take up Tax Credit)	1(Take up Tax Credit)	Awareness of Local Subsidy	Awareness of Local Subsidy
1(Green Pricing Participant)	0.015				
	(0.004)***				
1(Installed Solar System)	0.892				
	(0.002)***				
Environmentalist		0.120	0.120	0.310	0.248
		(0.024)***	(0.024)***	(0.117)***	(0.116)**
1(Thought)		0.071			
		(0.018)***			
Calculation Effort			0.027		
			(0.011)**		
1(Rent)	-0.068	-0.041	-0.041	-0.062	-0.084
	(0.007)***	(0.015)***	(0.016)***	(0.080)	(0.081)
Income ($ millions)	0.543	0.365	0.375	1.323	1.022
	(0.066)***	(0.155)**	(0.154)**	(0.692)*	(0.720)
1(VOAS)		-0.064	-0.021		
		(0.014)***	(0.014)		
N	75,591	2,983	2,982	1,516	1,516
Mean of Dependent Variable	0.105	0.102	0.102	0	0
State Fixed Effects	No	No	No	No	Yes
Dataset:	Utility	VOAS and Lightbulbs	VOAS and Lightbulbs	Lightbulbs	Lightbulbs

Notes: Columns 2 and 3 use a combined sample from the Vehicle Ownership and Alternative Survey and the Allcott and Taubinsky (2014) TESS experiment. These are OLS regressions with robust standard errors in parentheses. *, **, ***: Statistically different from zero with 90, 95, and 99 percent confidence, respectively.

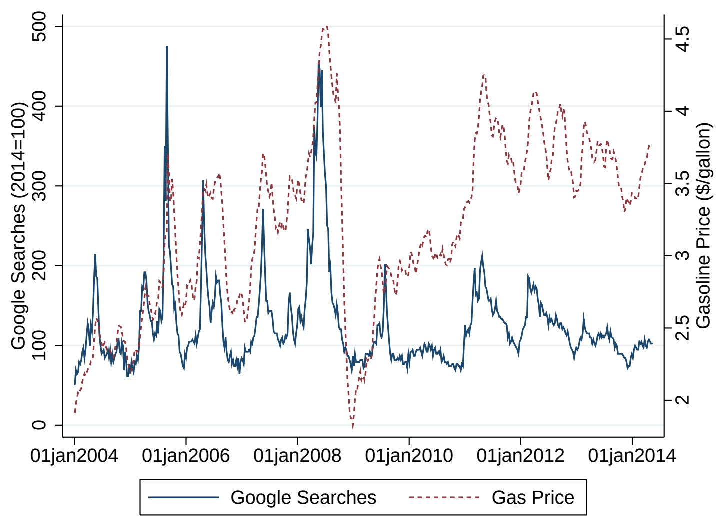
Figures

Figure 1: **Comparing Demand Responses: Graphical Results**



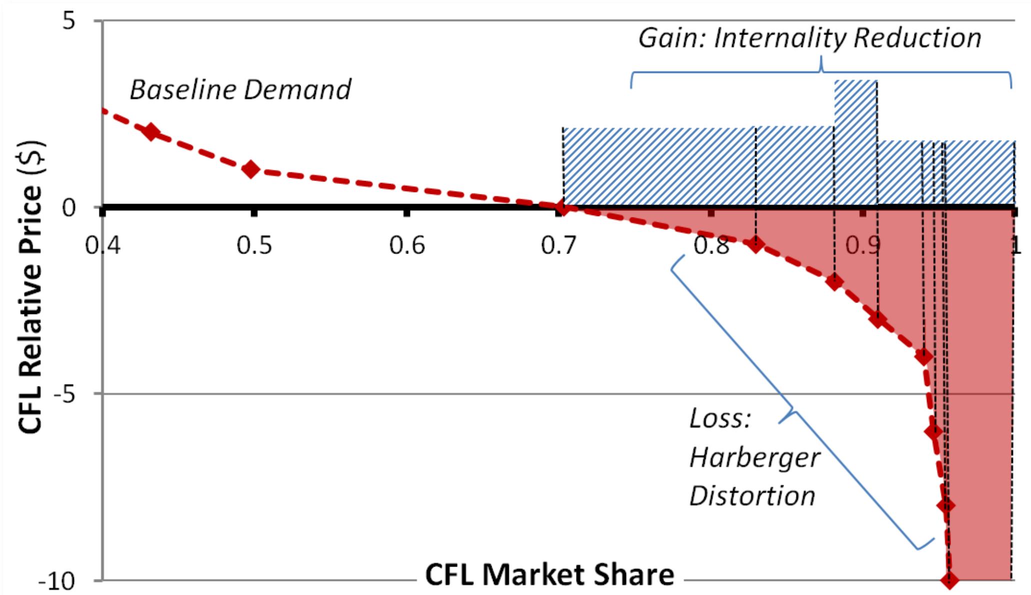
Notes: The vertical axis presents the difference in average prices between below-median MPG and above-median MPG used vehicles. The horizontal axis presents the difference in average present discounted value of gasoline costs. Each dot represents a month of the sample, from January 1999 through December 2008. Source: Allcott and Wozny (2012).

Figure 2: **Gasoline Prices and Google Trends Searches**



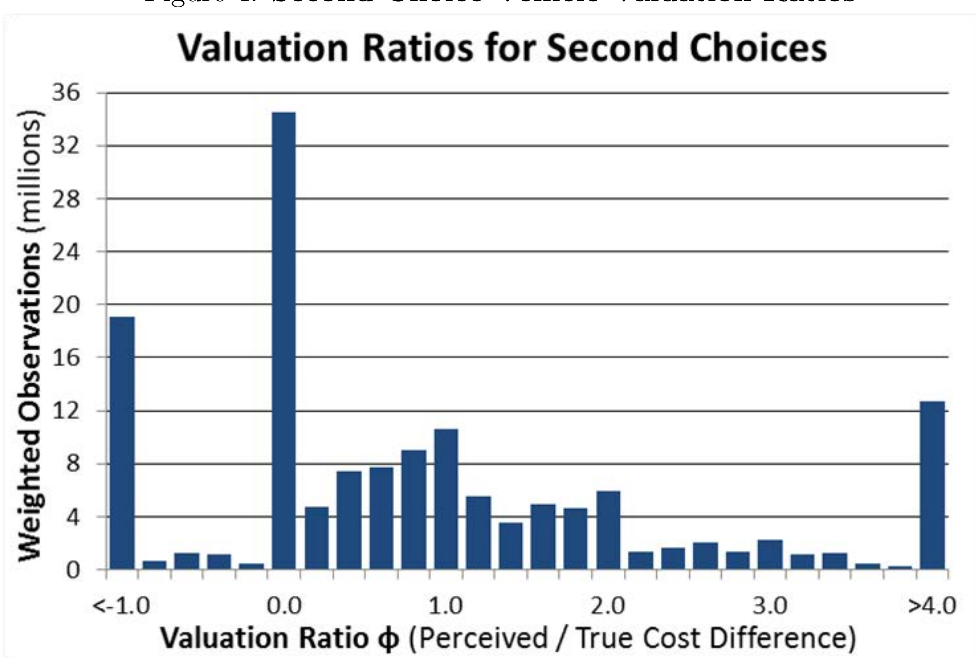
Notes: Google Searches is the frequency of five fuel economy-related search terms (gas mileage, best gas mileage, fuel economy, hybrid vehicles, hybrid cars) using Google Trends data. Gasoline Price is the "Weekly US All Grades All Formulations Retail Gasoline Price" from the US Energy Information Administration.

Figure 3: **Welfare Effects of CFL Subsidies**



Notes: This figure illustrates the welfare effects of increases in the CFL subsidy using the TESS experiment results. Observations are weighted for national representativeness. Source: Allcott and Taubinsky (2014).

Figure 4: **Second Choice Vehicle Valuation Ratios**



Notes: This figure shows the distribution of valuation ratios for second choice vehicles from the Vehicle Ownership and Alternatives Survey. Source: Allcott (2013).