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Analysis

Labeling energy cost on light bulbs lowers implicit discount rates

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ABSTRACT

Lighting accounts for nearly 20% of overall U.S. electricity consumption and 18% of U.S. residential electricity consumption. A transition to alternative energy-efficient technologies could reduce this energy consumption considerably. To quantify the influence of factors that drive consumer choices for light bulbs, we conducted a choice-based conjoint field experiment with 183 participants. We estimated discrete choice models from the data, and found that politically liberal consumers have a stronger preference for compact fluorescent lighting technology and for low energy consumption. Greater willingness to pay for lower energy consumption and longer life was observed in conditions where estimated operating cost information was provided. Providing estimated annual cost information to consumers reduced their implicit discount rate by a factor of five, lowering barriers to adoption of energy efficient alternatives with higher up-front costs; however, even with cost information provided, consumers continued to use implicit discount rates of around 100%, which is larger than that experienced for other energy technologies.

1. Introduction

In 2008, residential compact fluorescent lamp (CFL) socket saturation[1] was 10% nationwide (D&R International, Ltd., 2009), with the remainder being almost entirely incandescent bulbs. About half of the total lighting service (in terms of lumens) was provided by incandescent bulbs, and a little over 20% was provided by CFL bulbs (Navigant Consulting, 2010), suggesting that further adoption of CFLs – or other efficient lighting technologies, such as light emitting diodes – could achieve considerable energy savings in the residential sector. In many cases, these efficient alternatives would also save money for households. The slow transition to CFLs does not seem to be due to poor public awareness, since about 70% of Americans know about CFLs (Sylvania, 2010). These data suggest that there may be other barriers that keep consumers from adopting CFLs.

Engineering economic analyses have long suggested that there is a gap between current residential energy consumption and optimal levels that could be achieved if the most energy-efficient and cost-effective end-use technologies providing the same level of energy services were adopted instead (Hirst and Brown, 1990; Jaffe and Stavins, 1994). There have been numerous studies analyzing potential reasons that prevent optimal efficiency from being achieved (Anderson and Claxton, 1982; Brown, 2001; Golove and Eto, 1996), including low price of energy caused by distortional regulation, misplaced incentives between tenants and landlords (also known as the principal-agent problem), lack of access to financing options (Blumstein et al., 1980), uncertainty in the future price of electricity or other fuels, low priority of energy issues for consumers among other types of expenditures (Brown, 2001), consumers' limited cognitive capacity (Anderson and Claxton, 1982), and the fact that energy efficiency often is inseparable from other unwanted features in products (Golove and Eto, 1996). A recent report from the National Acedemies of Science (2009) states that well-designed policies such as building energy codes, Energy Star product labeling, and efficiency standards could help overcome these barriers and that these policy initiatives already achieve primary energy savings of about 13 quadrillion BTU per year.

Researchers have taken various approaches to measure the relative priority consumers place on energy efficiency versus upfront cost when making technology purchases, including implicit discount rates (IDRs) (Gately, 1980; Meier and Whittier, 1983). The IDR, or hurdle rate, is the value of the discount rate for a hypothetical net-present-value-maximizing consumer that best matches observed choice behavior. When viewed from the framing of classical economic discounting, consumers appear to behave as though they are using the implicit discount rate to value current vs. future costs (with some error).

The IDRs are used as inputs in many energy-economy models to explain how the share of end-use energy technologies evolves over time. For example, the Energy Information Agency's (EIA) National Energy Modeling Systems (NEMS), assumes hurdle rates for consumer appliances that range from 15% (gas furnace) to 90% (electric clothes dryer) depending on the residential end-uses considered (U.S. EIA,

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[1] Socket saturation is frequently used as a measure of market penetration of a specific type of light bulb. It is defined as a percentage of total number of bulb sockets that contain a specific type of light bulb.

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2011). There are debates on the usefulness and appropriate ranges of such estimates of IDRs as a means of describing consumer choices and behavior (Frederick et al., 2002). Attributing consumers' choices solely to their discount rates can lead to misunderstanding consumer behavior, since other factors such as the effect of marketing and advertising, lack of knowledge, or imperfect substitutability across two competing technologies also play a role in choices (Mulder, 2005). However, in terms of energy system modeling, using high discount rates to explain technology choices by consumers is still the standard approach.

To improve understanding of barriers to adoption of energy-efficient lighting, we perform choice-based conjoint experiments and assess the following:

1. We measure consumer preferences and willingness to pay (WTP) for general illumination, and we identify barriers to the adoption of efficient lighting technologies. Specifically, we quantify the importance of product attributes (price, wattage, brightness, lifetime, and technology type) and consumer characteristics (income, education, housing characteristics, political views, perception of climate change, and perception of toxicity issues) in determining bulb choice. Using WTP allows us to directly compare preferences for distinct attributes that have different units.
2. We estimate IDRs for lighting technologies.
3. The Federal Trade Commission (FTC) implemented a new label that includes estimated operation cost information and is required on lamp packages starting in 2012. We measure the effect of labeling estimated bulb operation cost on resulting choices, WTP, and IDRs.

In the next section, we summarize the literature on IDRs and discrete choice analysis. Based on this understanding, the method and the results of our experiment will be explained in Sections 3 and 4 respectively, and in Section 5 we conclude.

2. Previous Work on Eliciting Implicit Discount Rates for Energy-Saving Household Appliances

Research on consumers' IDRs started in the 1980s using two general methods: 1) asking participants hypothetical questions about the future savings they would require before making investments in energy efficiency (see, for example, Houston, 1983), and more commonly, 2) building econometric models of consumer utility or other quantities and comparing coefficients for price and/or annual operating cost variables. The second method can implicitly derive discount rates without forcing participants to answer speculative questions like the first method does. We use a variant of this second method with a nonlinear model specification explained in the next section.

Table 1 provides a summary of several studies that elicited IDR for end-use energy technologies over time. We provide more detail regarding the study from Hausman (1979), who constructed an individual choice model for air conditioners (AC), as it has the closest formulation to our model. In this model, each individual chooses a specific AC that maximizes his or her utility function. The utility function posed is:

$$U_j = -\beta_1 \cdot OCost_j - \beta_2 \cdot Price_j - \beta_3 \cdot Discomfort_j + \varepsilon_j, \tag{1}$$

where U_j is the utility gained by selecting product j, $OCost_j$ is the annual electricity cost ($/year) due to AC use, $Price_j$ is the initial purchase cost ($), $Discomfort_j$ is the discomfort level that increases as the temperature setting for the AC increases, and ε_j is the error term. From purchase records and capacity/efficiency information of ACs in the market, Hausman estimated the coefficients in the utility function using maximum likelihood estimation. The author assumes that the utility depends on annualized capital cost, so that β_2 is an annualizing factor. Then, the implicit discount rate r can be computed using the capital recovery factor for a given AC lifetime q:

$$\hat{\beta}_2 = \hat{\beta}_1 \frac{r(1+r)^q}{(1+r)^q - 1}. \tag{2}$$

The resulting IDRs in the study ranged from 5% to 89% depending on household income level.

Frederick et al. (2002) emphasize that the intertemporal choices, such as investments in energy-efficiency, are not only influenced by time preferences – what they define as “the preference for immediate utility over delayed utility” – which we measure with IDRs. Rather, they are determined jointly by various confounding factors such as

Table 1
Selective reviews of studies on implicit discount rate implied by purchases of energy efficient goods.

Study	Product	Data source	Year of data retrieval	Range of estimated discount rate	Method
Hausman (1979)	Room AC	46 samples from an MRI energy consumption survey and AHAM product directory	1978	5.1% ~ 89% (with income effect added)	Econometric model (discrete choice analysis)
Gately (1980)	17 cu-ft. refrigerator	Price data of models from three major manufacturers	Jan 1978	45% ~ 300%	Unspecified
Houston (1983)	Hypothetical device	Mail survey (1081 samples from Indiana)	1979	10% ~ 50% (given as choices in the survey): with mean of 22.5%	Direct inquiry
Meier and Whittier (1983)	17 cu-ft. refrigerator	Price data from a nationwide retailer	1977–1979	1% ~ 102%	Price and energy use comparison
Dreyfus and Viscusi (1995)	Automobile	Residential Transportation Energy Consumption Survey by DOE (1775 observations)	1988	11% ~ 17%	Econometric model (Nonlinear least square)
Ruderman et al. (1987)	Heating and cooling equipment, refrigerator	Appliance purchase cost and efficiency data from DOE and other reports, and historical shipping data from DOE	1972–1980	18% ~ 825%	Lifecycle cost minimization
Doane and Hartman (1984)	Thermal shell, window and door, water heating, space heating	Customer energy use survey by an utility (GPU, now FirstEnergy) (882 households), cost and savings estimates from Lawrence Berkeley Natl lab	1982	0% ~ 400%	Econometric model (discrete choice analysis)
Mau et al. (2008)	Hybrid electric car and hydrogen fuel cell vehicles	Mail survey (916 for HEV, 1019 for HFCV)	2002	21% ~ 49%	Controlled experiment (discrete choice analysis)
This study	Light bulbs	Choice-based conjoint experiment with 183 participants	2011	Explained below	Controlled experiment (discrete choice analysis)