Consumer Choice of Energy-Using Durables—Competing Interpretations

Kevin B. Fitzgerald, Wharton School, University of Pennsylvania

Over the past twenty years, a number of studies have shown that a substantial share of consumers continue to purchase energy-using durables that are less energy efficient than would be optimal, both individually and socially. More recently, several authors have argued that this apparently sub-optimal behavior may actually be rational as it is consistent with a well-functioning market in which consumers form rational expectations about future energy prices and technology improvements. This paper presents a competing model of individual choice—consumers are boundedly rational or imperfect welfare maximizers. Data from market studies and energy conservation experiments are examined from the perspectives of both models. Only the boundedly rational model can explain fundamental observations at the individual level. Moreover, the boundedly rational model does this with much less stringent requirements on consumer rationality than the rational expectations model.

INTRODUCTION

In the two decades following the oil crises of the 1970s, a wide variety of federal and state policies were enacted to encourage energy conservation and utilities offered over 2,000 demand-side management (DSM) programs, many of which were aimed at inducing consumers to invest in energy conservation measures. Yet, recent engineering-economic studies continue to show that a pervasive and costly ''energy-efficiency gap'' exists in the US economy. There is a fundamental disagreement within the energy analysis community about the underlying causes of this gap (Huntington, Schipper & Sanstad 1994). An extensive body of evidence exists that shows consumers consistently forego cost-effective investments in energy efficient technologies. Some analysts interpret this as *prima facie* evidence of alleged market barriers, market imperfections, or even market failures. Others maintain that while no market is ideal, markets for efficient technologies and energy conservation measures do not exhibit the characteristics of market failures that would constitute legitimate grounds for intervention. Rather, a slow diffusion of efficient technologies (and, hence, a persistent energy-efficiency gap) is to be expected if agents in the market form rational expectations about future energy prices and technology improvements.

This paper argues that: (1) while there is some empirical support for imperfections in energy-using durable goods markets, they are not at the heart of the under-investment problem; (2) the rational expectations hypothesis cannot explain observed discount rates and fails fit the facts; and (3) bounded rationality and common anomalies in choice over time are chief underlying causes of the persistent ''energy-efficiency gap''. In the first section, the ''energy-efficiency gap'' is characterized in terms of stylized findings. Evidence for and against alleged market failures is reviewed and the rational expectations explanation of delayed investment is presented in the second section. Finally, generalized anomalies in consumer choice over time from the behavioral and social sciences are presented and are shown to fit observations about the ''energy-efficiency gap'' well. As such, an argument is made that these anomalies are root causes of systemic under-investment in energy efficiency throughout the economy.

THE ''ENERGY-EFFICIENCY GAP''

Despite the fact that many energy-efficient technologies are mature, have been widely available for over a decade, and have been cost-effective at prevailing energy prices, they have been slow to displace less energy-efficient models in the marketplace. By conservative estimates, if the most efficient cost-effective technologies were to replace the existing stock in all sectors of the economy by the year 2000, US electricity consumption could be reduced by roughly 25% for less than 4¢/kWh, well below the average cost of electricity supply of roughly 7¢/kWh (EPRI 1990). As shown in Figure 1, the largest contributors to potential savings are from efficient technologies for industrial process heating and motor drives, commercial lighting and cooling, and residential appliances and space heating.[1]

The energy conservation supply curves in Figure 1 represent conservative estimates of the ''maximum technical potential'' (MTP) of efficient technologies—a conservative energy efficiency frontier that would be approached in the medium term by idealized markets if cost-effective efficient technologies were to entirely displace less cost-effective standard technologies. Taking these estimates at face value for the moment, the economic consequences of these poten-

Figure 1. Maximum Technical Potential Estimates (EPRI 1990)

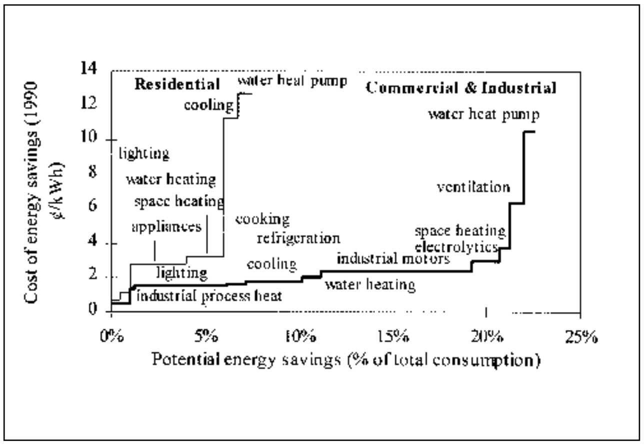
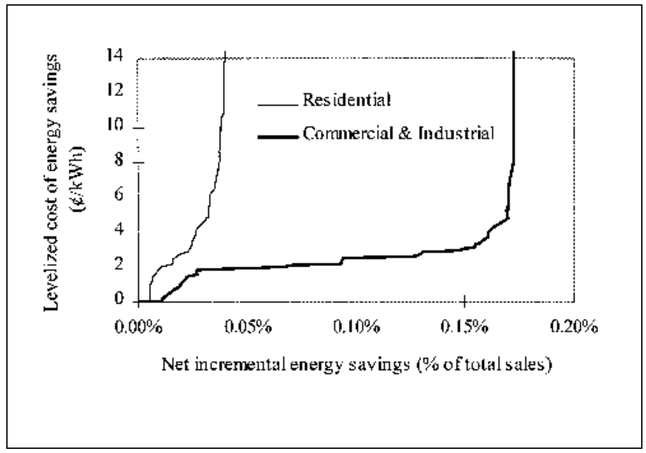


Figure 2. Costs of Energy Conservation Programs of 12 NORDAX utilities in 1991 and 1992



tial efficiency improvements would be substantial. Compared to the industry average Long Run Marginal Cost of 7¢/kWh, a 25% reduction in electricity consumption at a marginal cost of 4¢/kWh saved would constitute a $30 billion annual savings for the US economy. As such, the widespread diffusion of efficient technologies could raise social welfare by lowering the total resource cost of energy use in the economy.

Even though the most attractive technologies would be cost-effective for most consumers, even at discount rates well above capital market and consumer credit rates, this does not mean that $100 bills are laying on the sidewalk waiting to be picked up. Rather, the ''energy-efficiency gap'' has persisted and actual energy conservation programs have been able to achieve only a tiny fraction of the overall potential displayed in Figure 1. Figure 2 displays reported costs and expected annualized savings from the full scale energy conservation programs administered by twelve member utilities of the Northeast Data Exchange in 1991 and 1992 (NORDAX 1993). While the sectoral energy conservation supply curves in Figure 2 are not maximum *achievable* potentials, they do represent the expectations of utilities with some of the most aggressive and well-targeted energy conservation DSM portfolios.

It is readily apparent that actual energy conservation programs—designed with over a decade of program experience and in response to regulatory initiatives—are expected to achieve two orders of magnitude less savings than the MTP estimates in Figure 1. Yet even these reported costs may be consistently underestimated and projected savings consistently overestimated (Joskow and Marron 1992). The bottom line is that it appears to be much more difficult and expensive in practice to influence consumers in all sectors to adopt energy conservation measures than the MTP estimates imply.

Revealed preferences in market purchases

The ''energy-efficiency gap'' has been further characterized by empirical studies of consumer durable goods choice. In one of the first examinations of actual purchases of energy-using durables, Hausman (1979) showed that even in the face of rapidly rising energy prices after 1973, most consumers continued to purchase appliances that did not minimize life-cycle costs at market discount rates. Hausman examined electricity use for air-conditioning in 46 Michigan households that purchased a new window air conditioner in 1978. He found that if these households were purchasing air-conditioners to maximize utility (minimize life cycle costs to meet their cooling needs) subject to budget constraints, their choices implied discount rates from roughly market rates (~5%) for the wealthiest households to about 90% for the poorest households (see Table 1). Noting that lower income households consistently purchased the least efficient models, Hausman argued that efficiency standards would adversely impact poorer households. Conversely, since low income households display the highest discount rates, educational programs that encourage more informed choice would mainly benefit low income families.

Hausman noted that high discount rates are a stylized fact in this type of choice situation:

> At least since Pigou, many economist have commented on a ''defective telescopic faculty''. A simple fact emerges that in making decisions involving discounting over time, individuals behave in a manner which implies a much higher discount rate than can be explained in terms of the opportunity costs of funds available in credit markets (p. 51).

Hausman did not speculate on why this divergence exists, nor did he assume that full information would eliminate the

Table 1. *Implicit discount rates for room air conditioner purchases*

mean income	number of observations	implicit discount rate
$6,000	6	89%
$10,000	15	39%
$15,000	16	27%
$25,000	17	17%
$35,000	8	8.9%
$50,000	3	5.1%

Source: Hausman, 1979.

gap. Rather, his analysis quantified the divergence between choices that would be optimal if based on consumer credit rates and actual choice made by consumers.

Following Hausman, several studies showed that personal discount rates implicit in actual market purchases of major energy-using appliances range from 5% to over 80%, with lower income consumers revealing higher discount rates (Train 1985). The highest implicit discount rates were evident in purchases of refrigerators (40% to over 100%) and other home appliances such as hot water heaters, clothes washers and dryers, and dishwashers (15% to 60%). Implicit discount rates were closest to the market cost of capital for air conditioner purchases. Relative to other appliances, energy use is a dominant characteristic of air conditioners and consumers appear to be paying attention to this in making their purchasing decisions.

Expressed preferences under perfect information

Information imperfections and uncertainty have been alleged to be the chief causes of sub-optimal consumer choice in arguments for and against government intervention in energy conservation markets. With this in mind, it is important to note that experimental evidence has consistently shown that even under perfect information with no uncertainty, the expressed preferences of most consumers still exhibit Pigou's ''defective telescopic faculty''. McRae (1980) asked homeowners ''Suppose you were buying a new refrigerator and could get one that cost $100 more but saved on electricity bills. How much would you have to save per month to spend the extra $100?'' Results are shown in Table 2. The mean response was just over $4, with an implied discount rate of 53% (assuming a 10 year refrigerator life). Almost half of the respondents said they would require $2 in monthly savings (21% implicit discount rate). Over 40% of respondents required $4 or more in monthly savings (implicit discount rates from 48% to over 100%). These results have been replicated many times in other experiments since 1980. Apparently, a large share of homeowners have trouble with discounting, do not view energy saving measures as investments, or have some other way of looking at the matter. But a key finding from this experimental work is that there is something beyond lack of information and uncertainty that leads a large share of people to undervalue future savings when compared to out-of-pocket costs.

Hedonic studies of housing markets

Finally, several hedonic studies of home sales prices have been undertaken to determine if energy conservation investments are efficiently capitalized in these markets. Using a 2 stage least-squares model and a sample of 1317 home sales in Knoxville, Tennessee in 1978, Johnson & Kaserman (1983) found that a $1 reduction in annual fuel bills would increase the market value of the house by $20.73, all else equal. A more flexible form Box-Cox model was employed by Dinan & Mirankowski (1989) to examine data from 234 single-family homes sold in Des Moines, Iowa in 1982. They found that the expected selling price of a home increased by

Table 2. *Implicit Discount Rates Without Uncertainty*

$ savings/mo required	proportion of respondents (%)	implicit discount rate[a]
1	5%	4%
2	49%	21%
3	6%	35%
4	15%	48%
5	14%	60%
6+	12%	72+%

Source: McRae, 1980.
[a] Discount rates at 10 year investment life.

$11.63 due to a $1 decrease in the level of fuel expenditures. Over a range of reasonable assumptions on expected fuel price increases and remaining years left in a home, implicit discount rates in these housing markets are between 2% and 17% (Johnson & Kaserman, p. 384). As such, housing markets on the whole appear to be efficiently capitalizing (and possibly even overcapitalizing) energy conservation measures.

Stylized findings

Several stylized findings may be abstracted from this characterization of the ‘‘energy-efficiency gap’’. 1) While the potential economic savings from cost-effective efficient technologies are substantial, getting consumers in all sectors to make the most cost-effective choices is a difficult and costly task. 2) Discount rates implicit in actual durable goods choice are inversely correlated with income. This is no surprise and is consistent with the observation that actual cash in hand is relatively more dear to lower income households. 3) Implicit discount rates are highest for durables that are not perceived to be major energy users, are much closer to market rates when energy use is a dominant characteristic (as with air-conditioners), and are indistinguishable from market rates when bundled together in the housing market. Consumers appear to pay attention to the tradeoff between initial cost and operating costs when expected operating costs are substantial and when the stakes are high. 4) High discount rates, similar to those found in market studies, may be replicated in appliance choice experiments where information is perfect and uncertainty plays no role. Any theory purporting to have identified a root cause of the ‘‘energy-efficiency gap’’ must be consistent with these stylized findings.

COMPETING INTERPRETATIONS: MARKET FAILURE & RATIONAL EXPECTATIONS

Why is it that consumers routinely fail to invest in readily available efficient technologies and energy conservation measures that would appear to raise their own welfare (when evaluated at reasonable discount rates)? Answers to this question vary broadly, but two competing lines of argument dominate the literature. The first focuses on information imperfections as a key cause of inefficient choice. The second, and more recent, interpretation attributes the gap to delayed investment in energy-efficiency as a rational strategy to hedge for energy and technology price uncertainty. Both interpretations are examined in this section.

Information imperfections

Numerous information imperfections in energy equipment markets have been alleged to cause under-investment in end use efficiency (Carlsmith et al. 1990; Fischer & Rothkopf 1989; Howarth & Andersson 1993; Howarth & Sanstad 1995; Sutherland 1991a). In fact, almost all arguments for market failures as causes of sub-optimal consumer choice in this area have invoked: incomplete information; asymmetric information; or high transaction costs.

Incomplete information. In the wake of the oil price shocks of the 1970s, it became clear that the market was not providing complete information about the energy use and operating costs of major energy-using durables. To redress this situation, the federal government mandated in 1978 that major energy-using durables display Energuide labels that clearly quantified average operating costs under a range of fuel prices. Though a thorough evaluation was never undertaken, the Energuide labels appear to have had little discernible effect on consumer choice (McNiell & Wilkie 1979; U.S. Congress 1992).[2] As these labels display expected operating costs, but did not substantially improve consumer choice, either consumers are ill-equipped to do the life-cycle cost calculations or are generally more interested in other appliance attributes.

Another argument that invokes incomplete information is that the financial savings that would accrue from typical energy conservation measures, such as weather-stripping or added insulation or from more efficient appliances, are somehow hidden from consumers. Consumers get an electricity bill at the end of the month that gives no information on how much electricity or gas was used for each end use. Most people correctly identify space heating and air conditioning as major energy uses in the home (USDOE 1986). But people commonly overestimate the contribution of lighting and underestimate the contributions of refrigeration and water heating to monthly bills (Stern 1986). However, underinvestment in energy efficiency that may arise from these misperceptions are not due to incomplete information in the marketplace for energy-using durables or energy conservation measures. Rather, they arise from insufficient attention paid to energy use characteristics.

Asymmetric information. Information asymmetries are at the heart of some alleged failures of housing and rental markets to fully exploit potential cost savings from investments in energy conservation measures.

It has been argued that since architects, developers, and contractors choose thermal shell improvements and major appliances and they have incentive to keep the final offering prices low, they are often averse to paying extra for appliances and thermal shell improvements that would raise prices and pay back to the owner-occupant over time. But the hedonic studies reviewed above (Dinan & Mirankowski 1989; Johnson & Kaserman 1983) suggest that housing markets efficiently capitalize energy conservation measures.

Rental markets present a more serious problem. Since renters are less likely to make energy efficiency investments that they will benefit from only as long as they are in the apartment than people who own their homes and are more able to fully capitalize the value of their investment in the sales price. Moreover, tenants who pay utilities in the rent have no incentive to conserve as they do not obtain the savings. Finally, landlords letting to tenants who pay their own energy bills have little incentive to invest in efficiency improvements unless energy efficiency is important enough to renters that it can be captured in increased rents. If this problem actually does lead to under-investment in conservation, the economic consequences could be substantial since roughly 1/3 of housing units in the United States are rental units.

A recent study of thermal shell improvements, HVAC measures, and efficient lighting in US commercial buildings found no statistical association between occupancy and installed conservation measures (Sutherland 1991b). This finding may reflect professional management and cost minimizing tenants in commercial buildings. Using data from over 1500 single-family homes in the mid-West and Northeast from the 1987 Residential Energy Consumption Survey (USDOE 1989), an analysis of installed conservation measures was conducted and results are displayed in Table 3.[3] Occupancy status is the only household characteristic that consistently and significantly explains the presence of each of 5 conservation measures. Independent of household income and home age, owner-occupied homes in the mid-West and Northeast are significantly more likely to have these thermal integrity measures installed than rented units.

Transaction costs. If the costs of making a market transaction are high relative to expected benefits to all parties, such costs could prevent the transaction from taking place. However, there is no reason to believe that markets for energy conservation measures or for energy-using durables are particularly different from the costs of researching markets for other goods in the economy.

Moreover, market research costs have been substantially reduced by the prominent display of Energuide labels on home appliances and by low or no cost energy audits offered to home owners and commercial and industrial plant mangers by utilities under federal and PUC mandates. If high transaction costs were a key barrier to investments in energy conservation measures, one would expect that a large share of households would have eagerly enlisted for low cost home energy audits under the Residential Conservation Service. But the actual record is dismal. Over a ten year period, most homes nationwide were repeatedly offered low or no cost energy audits. But over this period only 10% of all households that were offered these audits actually had an energy audit performed (U.S. Congress 1992).[4] Audits in the commercial and industrial sectors have a similar track record. As such, the record indicates that transaction costs cannot explain the persistence of foregone opportunities for cost effective energy conservation improvements in the residential sector, commercial enterprises, and industrial applications.

Delayed investment as a rational strategy

More recently, several authors have argued that, on the whole, energy markets are competitive and high revealed discount rates are actually rational (Hassett & Metcalf 1993a; Metcalf 1994; Sutherland 1991a). The risk averse consumer, it is argued, will form rational expectations about the volatility of future energy prices and will discount the value of uncertain future savings at a higher rate than would be applied to certain savings. In addition, Hassett & Metcalf (1993a) show that the option value of delaying investments can explain why many consumers consistently forego opportunities that would be clearly in their interest in a deterministic world. This theory predicts that we should expect higher discount rates for irreversible physical assets than for liquid financial assets, especially if assets in the choice set are becoming more efficient over time. But using the same model and data, Sanstad, Blumstein & Stoft (1995) show that this effect could be expected to raise consumer discount rates for energy-efficiency investments only marginally above market rates. As such, this hypothesis cannot explain the high discount rates revealed in actual consumer purchases.

Nonetheless, these are positive findings in the effort to uncover the root causes of the energy-efficiency gap. They indicate that we should expect to see implicit discount rates in markets for energy-using durables that are somewhat above those for liquid financial assets. But adopting this view as an important root cause of (illusory) under-investment in energy-efficiency requires that we assume that normal consumers are very sophisticated rational agents who possess a high level of information processing capacity. This assumption flies in the face of findings from the behavioral sciences and social psychology on individual choice.

Summary

While there is some empirical support for the claim that the landlord/tenant problem widens the ‘‘energy-efficiency gap’’, it cannot explain the wide variation in implicit discount rates with the lowest rates for the most energy intensive appliances and market rates for home purchases. Option value and irreversibility also cannot explain this stylized fact. Moreover, the rational expectation hypothesis relies on the almost certainly untrue assumption that most consumers are as rational as analysts in the energy policy community. Finally, experimental results have shown that consumers exhibit high implicit discount rates even under full informa-

Table 3. Logistic Regression of Household Factors on Residential Conservation Measures

Variable	Home has caulking	Home has weather stripping	HVAC ducts insulated	Hot water pipes insulated	Water heater insulated
Household	0.0061	0.0037	0.0052	0.0035	− 0.0005
income	(4.3175)	(1.8517)	(3.4812)	(1.7455)	(0.0342)
(’000$/yr)	(0.0377)	(0.1736)	(0.0621)	(0.1864)	(0.8533)
Education of	0.0824	0.0881	0.0371	0.0561	0.0646
household head	(13.6699)	(16.8107)	(2.4286)	(6.2885)	(7.5231)
(yrs)	(0.0002)	(0.0000)	(0.1191)	(0.0122)	(0.0061)
Age of	− 0.0088	0.0009	− 0.0024	− 0.0069	0.0003
household head	(6.5660)	(0.0742)	(0.4235)	(3.9836)	(0.0082)
(yrs)	(0.0104)	(0.7854)	(0.5152)	(0.0459)	(0.9276)
Gender of	0.0733	0.0868	0.0032	-0.0075	0.0759
household head	(1.8583)	(2.9147)	(0.0031)	(0.0199)	(1.8111)
(F = 0 M = 1)	(0.1728)	(0.0878)	(0.9553)	(0.8879)	(0.1784)
Age of home	0.0005	0.0021	− 0.0088	− 0.0026	− 0.0001
(yrs)	(0.0304)	(0.6087)	(9.0864)	(0.8717)	(0.0023)
	(0.8616)	(0.4353)	(0.0026)	(0.3505)	(0.9618)
Residential	− 0.0861	− 0.0415	− 0.0235	0.0356	0.0167
tariff	(5.0979)	(1.3332)	(0.3369)	(0.8801)	(0.1746)
(cents/kWh)	(0.0240)	(0.2482)	(0.5616)	(0.3482)	(0.6761)
Own = 1 Rent = 0	0.3895	0.2887	0.2975	0.3236	0.4395
(11% rentals)	(21.0104)	(12.4091)	(6.6187)	(9.9133)	(13.2762)
	(0.0000)	(0.0004)	(0.0101)	(0.0016)	(0.0003)
Constant	0.5435	− 0.5132	− 1.4955	− 1.8933	− 2.5492
	(1.3898)	(1.3708)	(9.2104)	(16.7011)	(26.9432)
	(0.2384)	(0.2417)	(0.0024)	(0.0000)	(0.0000)
Cases	1856	1863	1832	1834	1863
Model Chi-square	80.462	53.558	39.604	42.092	31.305
Model Significance	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0001)
Mean of Dep Var	0.72	0.68	0.23	0.28	0.23

Data source: USDOE, 1989.
Wald statistics and significance levels are presented below each estimated coefficient.
Models estimated for single family dwellings in the Northeast and Midwest.

tion with no uncertainty. Without substantial grounds for market failures or for assuming super-rationality as primary causes of the ‘‘energy-efficiency gap’’, consumers must be employing something other than the normative theory of discounted utility as a basis for choice in this context. The next section provides an overview of positive models of choice.

BOUNDED RATIONALITY

While information imperfections may very well widen the ‘‘energy-efficiency gap’’, a more fundamental cause of the gap may be the divergence between normative and positive models of choice, so called ‘‘anomalies’’. Anomalies in intertemporal choice have been the subject of much research at the frontiers of economics and psychology in the past 15 years (Fischburn & Rubenstein 1982; Kahneman & Tversky 1979; Loewenstein & Prelec 1992; Thaler 1980, 1981, 1987–1995). As shown below, consumer choice of energy-using durables is susceptible to these anomalies and this may underlie the failure of early energy conservation policies and programs that were designed under the basic assumption of consumer rationality.

In the early 1980s, policy makers were openly perplexed at why so few homeowners made energy efficient investments when they were well publicized by national energy conservation campaigns and were clearly in their own financial interests. According to Aronson (1990), this puzzlement was based on a limited vision of human behavior in which energy was viewed as a commodity in a free marketplace and consumers were assumed to collect all relevant information to make choices that maximize expected utility. A long tradition in social psychology shows that actual human behavior is more complex than the normative model assumes.

Stylized findings from positive models of choice

In actual choices over time, individuals consistently and systematically violate the fundamental axioms of discounted utility theory. While many generalizations can be made, this discussion focuses on three robust findings: gain-loss asymmetry; the common-difference effect; and the absolute magnitude effect (Loewenstein & Prelec 1992). Results from one of the first experiments to show these effects clearly are reproduced from Thaler (1981, p. 204) in Table 4 below. These effects have been replicated in many different settings since Thaler's work.

Table 4. *Median Responses and (Implicit Annual Discount Rates)*

Amount of prize now	Later prize paid in: 3 months	1 year	3 years
$15	$30 (277%)	$60 (139%)	$100 (63%)
$250	$300 (73%)	$350 (34%)	$500 (23%)
$3000	$3500 (62%)	$4000 (29%)	$6000 (23%)
Amount of fine now	**Later fine due in: 3 months**	**1 year**	**3 years**
$15	$16 (26%)	$20 (29%)	$28 (20%)
$100	$102 (6%)	$118 (16%)	$155 (15%)
$250	$251 (1%)	$270 (8%)	$310 (7%)

Source: Thaler, 1980.

Students at the University of Oregon were asked to suppose they had won a money prize which they could take now or wait until later. They were asked how much they would require to make waiting just as attractive as getting the money now. Median responses (and implicit discount rates) are displayed in the first three rows of Table 4. Similarly, they were asked to assume they had received a traffic ticket that could be paid now or later. In all cases, subjects were instructed to assume there was no risk of not getting the reward (or of avoiding the fine) if they waited. Responses for fines are shown in the last three rows of Table 4.

Gain-loss asymmetry. Closely related to ''loss aversion'' from Prospect theory (Kahneman & Tversky 1979), one key stylized finding is that future gains are commonly discounted at much higher rates than equivalent future losses. In Table 4 this can be seen in comparing implicit discount rates for the $250 prize with those for the $250 fine. Discounted utility theory admits no distinction between gains and losses: a $250 prize paid in one year should have as much positive present value as a $250 fine assessed in one year has negative present value; that is they should be discounted at the same rate.

Common difference effect. Discounted utility theory requires that a one month delay (the common difference) be discounted at the same rate whether it is a delay from today to next month or a delay from one year away to one year and one month away. But this requirement is clearly at odds with common-sense thinking and with the results in Table 4. Notice that short delays in receiving a prize are stiffly discounted, but that longer delays are discounted less. One possible interpretation is that there is some fixed *psychic* cost to waiting that becomes less significant as the waiting period is stretched. Whatever the explanation, this common behavior is inconsistent with discounted utility theory.

Absolute magnitude effect. Perhaps the most important finding for the present inquiry is the ''absolute magnitude effect''. As has been observed in many choice situations: when outcomes are substantial, people make choices that exhibit discount rates closer to market rates than when outcomes are inconsequential. This finding is illustrated graphically in Table 4. Respondents required $4,000 to delay a substantial $3,000 prize for one year (29% implicit annual discount rate), but the same respondents required $60 to delay a small $15 prize for one year (implicit discount rate of 139%). The larger the stakes, the closer are expressed choices to the requirements of the normative discounted utility model. Conversely, respondents in this and many other studies appear to require substantial remuneration (very high implicit discount rates) to wait for small gains.

Are these root causes of the ''energy-efficiency gap''?

Consumer choice between an efficient and a standard model of any given energy-using durable is often framed as a deliberative tradeoff between higher initial costs and lower operating costs. Certainly actual choice contexts are much richer than this one dimension. But even when constrained to this one dimension, it is easy to see the roots of the ''energy-efficiency gap'' in these three anomalies. According to gain-loss asymmetry, gains (energy savings) will be discounted at proportionately higher rates than losses (higher initial costs). The common difference effect suggests that a consumer may require and extraordinarily high proportional return to accept any delay in payback, even modest delays on the order of a few months. Because most energy conservation investments can be modeled as a large up front cost that pays back in a continuous stream of small savings, it is most susceptible to the absolute magnitude effect. If savings are seen as small gains, they tend to be discounted very heavily when the consumer deliberates. If energy use is a major characteristic of the appliance under consideration or if the purchase is a major expenditure for the household, the absolute magnitude effect predicts that the consumer will more often ''get it right''.

Taken together, the implications of these three anomalies are consistent with the stylized findings on the ''energy-efficiency gap'' set out above. These anomalies are systemic and, thus, would be difficult and probably expensive to overcome. These anomalies predict that investment decisions with a major energy use dimension will suffer less proportional discounting than investment choices for durables that have many different characteristics in addition to using energy. Moreover, if the value of energy savings that might accrue from a more efficient model are small in absolute or relative terms, they may be discounted heavily, resulting in extremely high implicit discount rates. Finally, these anomalies are present under perfect information with no risk.

CONCLUSION

Some empirical evidence has been identified that supports the claim that the landlord/tenant problem leads to under-investments in energy conservation measures. However, neither this nor other alleged information imperfections can be considered as root causes of the ''energy-efficiency gap''. The argument that the gap is an illusion and that the markets are behaving in a superbly rationally manner was discredited on its own grounds and even more fundamentally in the grounds that it does not explain any of the chief stylized characteristics of the ''energy-efficiency gap''. Conversely, certain anomalies in consumer choice over time not only fit the facts, but also illuminate the challenges ahead. It is clear that relying on market mechanisms alone will not lead to economically efficient levels of energy efficiency. It is also clear that continued efforts to provide clear information on energy use and costs, while necessary as the basis for deliberative choice, will not be sufficient to close the gap. Innovative and creative thinking will be needed to package energy conservation in such a fashion as to circumvent the psychophysical characteristics that appear to be common and active influences on actual choice over time.

The $100 bills that were laying on the sidewalk are being picked up. The most profitable arbitrage opportunities that these anomalies give rise to are being exploited by the rapidly growing Energy Service Company Industry. Recent exponential growth in shared savings and leased equipment contracts between ESCOs and public and commercial buildings indicates such innovation is underway.

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ENDNOTES

1. The y-axis displays the difference between life-cycle costs of an efficient and a standard device for each end use estimated using conservative cost and energy consumption assumptions at market discount rates. The x-axis shows projections of installed capacity for each end use.

2. There is, however, some evidence that labeling did lead some manufacturers to remove the least efficient models from the market (Robinson 1991).

3. Apartment dwellers are not included in the analysis since the RECS did not gather information on these conservation measures in multiple-unit dwellings.

4. These low response rates may also be due to many people mistakenly believing that their homes are already energy-efficient.

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