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ABSTRACT

Consumer purchasing patterns for a standard and an energy-efficient refrigerator are presented. These models differed only in their initial cost and electricity consumption. Consumers tended to buy the more efficient model in regions with higher electricity prices. A distribution of implied consumer discount rates is constructed. Roughly 2/5 of the consumers behaved as if they had real discount rates above 60%, 1/5 between 35 and 60%, and 2/5 less than 35%.

INTRODUCTION

The discount rate used by consumers indicates the extent to which they will invest in energy conservation. It is therefore a key element in predicting the sales of conservation equipment and, eventually, the demand for energy itself. Few consumers know their own discount rate, yet their observed willingness to exchange an investment in energy conservation made today for future energy savings permits calculation of an implied discount rate.

There have been only limited attempts to estimate implied discount rates because such detailed data for individual consumers are rarely available. Moreover, the tradeoff is rarely clean because other elements enter the decision. Many conservation measures, for example, involve a change in amenities or status. The primary data, measure cost and energy savings, are difficult to obtain, even for a small sample. Average values or estimates are often substituted. Corum and O'Neal, for example, created prototype houses to estimate the energy savings from insulation.[1] Johnson relied on utility bills as a proxy for energy efficiency and compared these to the sale prices of houses.[2] Hausman's study used regression techniques to estimate electricity savings from improved air-conditioner efficiencies.[3] The range in reported consumer discount rates is large, from the negative rates found by Johnson to more than 25% cited by Hausman.

In another study, Gately discussed the apparent high discount rates implied by the sale of standard and high-efficiency refrigerators.[4] Con-

sumers evidently purchased the standard refrigerators, even though a small additional investment would enable them to buy a high-efficiency model. The simple existence of the standard model (and the assumption that people bought it) implied that some consumers behaved as if they had discount rates above 300%. We report here consumer purchasing patterns for one model of energy-efficient refrigerator and have calculated implied discount rates for this investment.

THE DATA

A large national retailer sold two models of refrigerators between 1977 and 1979.† The two models had identical consumer features: they were both frostfree and about 17 ft^3 (480 liters) of refrigerated volume.‡ However, the models differed with respect to electricity consumption and initial price: the high-efficiency model cost about $60 more than the standard, but used 410 kWh/yr less electricity. This difference in list prices remained constant throughout the three years (even when the models were offered at discounts), although the total price varied somewhat among regions. A nationwide price survey indicated that the actual difference in price was $40 (the value used in this study). We list in Table 1 the sales of the standard models in each sales region expressed as a fraction of the combined sales of the matched pair. Combined sales of the two models exceeded several thousand units in every sales region.

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† The company has requested anonymity because this is proprietary sales information.

‡ The frostfree, top-door freezer is the most popular type sold in the United States; roughly 50% of total 1980 refrigerator sales are in this category, with most of these in the 17-20 ft^3 category; source: American Home Appliance Manufacturers Industry.

Many other models were sold at the same stores, but the two models were very popular. Table 1 (lower section) shows the approximate contribution of the high-efficiency model to the total sales of refrigerators. In the East region, for example, more than 70% of the total refrigerator sales were either these standard or high-efficiency models. Average 1979 electricity prices for the five sales regions are also shown at the bottom of Table 1.†

The high-efficiency refrigerator was given significant advertising, both at point of sale and through the media. Sales personnel were instructed in its features, and often could tell customers the anticipated electricity and dollar savings.‡ Individual behavior does not significantly affect refrigerator electricity consumption; therefore the published energy data were accurate for most consumers. A prominent consumer magazine also recommended the high-efficiency model and listed the dollar value of the monthly electricity savings based on two electricity rates.

Consumers in regions having high electricity rates bought a higher proportion of the efficient model. The East region, where the average electricity price was 5.5 cents/kWh, reported the highest sales fraction of the efficient model. In the Southwest and Pacific regions, where electricity prices were almost half those of the east, sales of the

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† The regional average electricity prices conceal considerable variations. Average prices in California and Washington (both in the Pacific sales region) were 4.2 cents/kWh and 1.5 cents/kWh, respectively.

‡ The sales reported here occurred before the introduction of the Federal Trade Commission's "Energyguide" appliance labels, so consumers were forced to rely on information provided by the salesperson or printed sources of information.

high-efficiency model accounted for only 24-43% of the matched pair sales. Neither model was popular in the Southwest because consumers in this warm region preferred larger models with built-in icemakers nor did the manufacturer consistently distribute the matched-pair in the southwest. For these reasons, we have excluded the southwest region from further analysis.

ANALYSIS OF IMPLIED DISCOUNT RATES

The economically rational consumer will be indifferent between the standard and high-efficiency model if the present value (using the consumer's discount rate) of the electricity savings equals the additional cost of the high-efficiency model. If the standard model is preferred, then his discount rate must be higher than that when he is assumed to be indifferent. We use this observation to calculate minimum implied discount rates for consumers.

The condition for indifference between the two models occurs when the incremental cost equals the present value of the electricity savings, i.e.,

$$I = P_o E \int_0^n e^{(f-r)} dt \quad , \qquad (1)$$

where I = incremental investment ($), P_o = initial electricity price ($/kWh), E = annual electricity savings (kWh/y), r = real discount rate (per year), f = real electricity price escalation rate (per year), and n = amortization period (years). Integration and rearrangement of Eq. (1) yields

$$\frac{I(f-r)}{P_o E} - e^{(f-r)} + 1 = 0 \quad . \qquad (2)$$

We can solve Eq. (2) for r because we know the incremental price, electricity savings, and electricity prices and their future rate of increase. If electricity costs 5.6 cents/kWh (the 1979 average in the East sales region), then consumer selection of standard over the high-efficiency model implies a real discount rate above 58%.

Table 2 lists real discount rates for a range of electricity prices from 2 - 10 cents/kWh. Since we do not know the consumer's amortization time for refrigerators, we calculated the discount rates for 5, 10, and 20 years; the typical physical lifetime of a refrigerator is 20 years.[5] The implied discount rate is insensitive to the length of the amortization period, even at moderate electricity prices. Thus, this uncertainty is not especially damaging. An adjustment for energy price escalation must be included if the consumers are thought to have considered the rising electricity price in their cost-benefit calculation. This adjustment is explained in the legend for Table 2.

DISCUSSION

The sales data in Table 1, combined with the calculated discount rates in Table 2, suggest that a large proportion of consumers behave as though they had high real discount rates. In the Pacific sales region, for example, 60% of the refrigerator buyers in 1979 behaved as if they had discount rates above 34% (because they bought the standard model). In the South sales region, 59% of the consumers appeared to have

discount rates above 41%.

We used these results to construct a distribution of consumer discount rates. We know some variation in discount rates must be present because of the split in sales. Some consumers (perhaps the wealthier ones) will have lower discount rates while, others (perhaps the poorer) will have higher rates. Hausman, for example, reported decreasing discount rates with increasing income. Further, we assumed that the distribution of consumer discount rates is the same for all sales regions. In this way, data for one region can be applied nationwide.

Figure 1 shows the distribution of implied discount rates indicated by our data. We assumed that all consumers had discount rates below 120% and above -20% in order to provide closure. The data are too scanty to construct a smooth distribution. Nevertheless, Fig. 1 suggests that considerable variation in discount rates exists: about two-fifths of the consumers act as though they had real discount rates below 35%, one-fifth between 35% and 60%, and another two-fifths greater than 60%. The equivalent nominal rates would be about 10% higher.

There is an implicit story behind this analysis. The consumer has already chosen both the class of refrigerator and the store in which he will buy it. Upon entering the store, he is confronted with the final decision, namely, whether to buy the standard or high-efficiency model. This may be realistic for some consumers because the models are in the most popular size and class, and the manufacturer is a respected source of appliances. But there are several equally plausible purchasing scenarios, for which the consumer never compares the standard to the

efficient model. For example, the consumer may have compared high-efficiency refrigerators offered by other manufacturers and found the purchased unit to be superior (or inferior). Store managers reported a significant increase in sales of the high-efficiency model after the consumer magazine published its recommendation, which supports the latter selection process. Alternative selection procedures distort the matched-pair analysis performed here by implying a greater preference for the high-efficiency model.

A consumer especially sensitive to energy prices might switch to an entirely different class of refrigerator. Partial defrost refrigerators, for instance, consume several hundred kWh per year less than the frost-free models.[5] Sales data for all refrigerators (by class and manufacturer) would be needed to account for alternative purchasing decisions. Nevertheless, it is significant that a large proportion of consumers avoided an energy-conservation investment that had little risk and a payback period of less than three years.

Aggregate data must be treated cautiously because we cannot be certain that the purchaser and the user are the same person. Appliances are also purchased by home builders and landlords. These buyers lack any incentive to invest in appliances with higher efficiencies because they do not pay for appliance electricity consumption.[†] Contractors and landlords could be responsible for the continued sales of standard models, while consumers who expect to pay the electric bills are buying

[†] Some refrigerator manufacturers sell half of their total production to home builders; source: David Cook, Business Editor, The Christian Science Monitor, personal communication, February 18, 1982. We estimate that about one-third of all refrigerators are purchased by builders and landlords who will not be paying for the electricity consumption.

the efficient units. However, the manufacturer of these refrigerators has conducted numerous customer surveys and found that very few landlords or contractors buy either model. We can infer that essentially all the buyers of these two models will be paying the electricity bills. We are, in fact, measuring an implied discount rate because the benefits and costs of the investment accrue to the same person.

CONCLUSIONS

We have shown that three-fifths of the refrigerator buyers had an implied discount rate greater than 35%, that is, they avoided a conservation investment with a simple payback time of three years. In spite of the aggregate form of the data, the results are particularly accurate because: the two refrigerators provided an identical amenity, the user's behavior did not significantly affect the energy consumption, and the incremental cost was constant and the sales environment consistent. We also know that the consumer was provided relatively good information regarding the expected energy savings. Finally, we are confident that the purchasers expected to pay for the electricity consumption.

The data nevertheless cannot tell us whether the high implied discount rate is a result of a high actual discount rate or some other factor not accounted for in this study. Kempton and Montgomery offer several explanations for consumer actions that imply high apparent discount rates.[6] Poor access to information, in particular, may account for the observed consumer behavior. However, consumer information in our case was better than in virtually any other energy-related investment (i.e., insulation, efficient air conditioners, etc.). The sales data reflect consumer behavior under the best-informed circumstances;

consumers will probably be even less inclined to invest in other energy-efficient devices.

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Table 1. Sales patterns for the matched pair of standard and high-efficiency refrigerators. Average regional electricity prices were calculated by using electricity sales and revenues for each state.

Year	Percentage of matched-pair sales that were the standard model (standard / matched-pair) in various regions; based on data supplied by the manufacturer				
	Midwest	East	South	Southwest	Pacific
1977	46	37	54	73	67
1978	46	35	69	67	57
1979	45	40	59	76	60
Average electricity prices in cents/kWh for 1979 †	5.5	5.6	4.0	4.1	3.4

Year	Sales of high-efficiency refrigerators expressed as a percentage of sales of all models of this brand; based on data supplied by the manufacturer				
1977	29	42	13	6	10
1978	27	42	8	7	16
1979	26	46	9	4	15

†Based on Edison Electric Institute, Statistical Yearbook of the Electric Utility Industry/1979, Edison Electric Institute, Washington, D.C. (1980).

Table 2. Implied discount rates given different assumptions for electricity prices and amortization periods. A consumer will be indifferent between the purchase of the high-efficiency and standard refrigerators at the specified electricity price and amortization period. All of these calculations assume that the incremental cost of the high-efficiency refrigerator was $40, the incremental energy savings were 410 kWh/y, and there was no (real) electricity price escalation. In the Pacific region, for example, a consumer using a 34% discount rate will be indifferent between the two models (assuming a 10-year amortization) if electricity prices do not increase. The discount rates listed in the table must be increased if a consumer is to remain indifferent in the face of anticipated electricity price inflation. If electricity prices are expected to increase at a 10% nominal rate, then the consumer must use a 44% discount rate.

Implied real discount rates
for selected electricity prices
and amortization times

Initial price	Amortization time			Location
	5 Years	10 Years	20 Years	
2 cents/kWh	1%	17%	21%	
3 cents/kWh	19%	29%	31%	
3.4 cents/kWh	26%	34%	35%	Pacific
4 cents/kWh	34%	41%	42%	South
5 cents/kWh	46%	51%	52%	
5.5 cents/kWh	53%	56%	56%	Midwest
5.6 cents/kWh	54%	58%	58%	East
6 cents/kWh	58%	62%	62%	
8 cents/kWh	80%	82%	82%	
10 cents/kWh	102%	102%	102%	

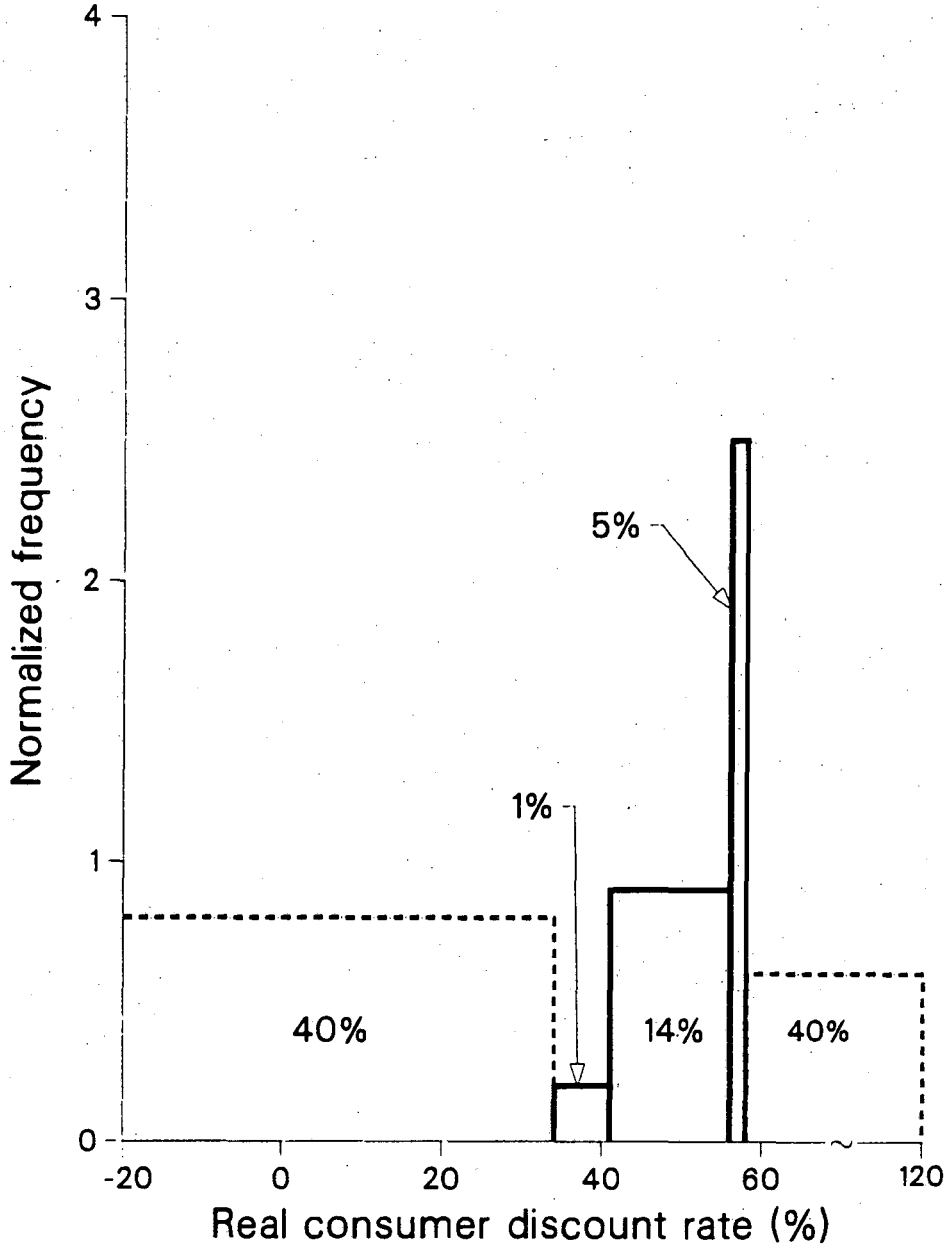

Fig. 1. The distribution of consumer discount rates implied by consumer purchasing patterns of energy-efficient refrigerators. The East region data show that 40% of the consumers acted as though they had real discount rates above 58%, and the Midwest region show that 45% of the consumers used discount rates above 56%. Therefore, 5% of the consumers had real discount rates between 56 and 58%. The remaining boxes to the left were constructed in a similar fashion. The dashed boxes at the two ends are based on the assumption that there are no discount rates less than -20% or above 120%. Equivalent nominal discount rates are about 10% higher than those shown. Adjusting for positive electricity price escalation or nominal prices corresponds to shifting the distribution to the right by the appropriate percentage.

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