Retrospective Analysis of National Energy Efficiency Standards for Refrigerators

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Most policy discussions of mandatory energy performance standards have drawn on the results of prospective forecasting. In order to evaluate the effectiveness of policies such as standards, however, one must measure actual impacts in terms of product offerings, impact on manufacturers, and consumer effects. This paper reports results of a retrospective evaluation of the 1990 and 1993 U.S. energy performance standards for refrigerators. We consider the effects of appliance performance standards on: (1) real refrigerator prices; (2) refrigerator volumes and amenities; and (3) low-income households. As no single dataset contains all of the information needed for this analysis, we assess the first two points using a hedonic analysis of actual sales data, while we address the third point using refrigerator ownership data from California. Following the introduction of performance standards, (a) real prices for refrigerators did not increase, and in some cases decreased; (b) refrigerator features, such as size and amenities, were not diminished; and (c) lower income households were just as likely to have high efficiency units as higher income households. These results characterize impacts of the standards on consumers only; additional research is needed to assess the impacts on manufacturers.

INTRODUCTION

In 1990, the federal government imposed the first national minimum energy efficiency performance standards on a range of household appliances, including refrigerators and freezers.[1] In 1993 performance standards for refrigerator units were updated and strengthened (U.S. DOE 1989). The standards set minimum annual energy consumption requirements for seven product classes of refrigerators, which are based on freezer defrost type and location, and the presence of through the door water and ice features. Product class 3, refrigerators with auto defrost top-mount freezers, is by far the most popular model, representing roughly 50 percent of all refrigerator sales in 1995 (AHAM 1995). As a result of the standards, average annual energy consumption in new refrigerators has dropped from 974 kWh/year in 1987, when NAECA was passed, to 653 kWh/year in 1994 (AHAM 1995).

While previous studies of the effects of efficiency regulations have focused on projected changes in appliance purchase prices and operating costs (U.S. DOE 1995), the imposition of the standards can also affect the quality of the regulated products. Consequently, it is important to evaluate specific tradeoffs between a good's energy efficiency, price, and the services it provides. This paper provides a retrospective analysis of the effect of U.S. energy performance standards on the characteristics of refrigerators using hedonic pricing techniques. The intent of this analysis is to determine if consumers faced increased prices or reduced amenities as a result of manufacturers' meeting the increased efficiency levels of the standards.

In addition to understanding amenity and price effects associated with the imposition of energy performance standards, it is also important to analyze any potential equity effects of standards. It has been argued that by eliminating low-end products and raising appliance prices, the standards may impose disproportionate costs on low-income households (Sutherland 1991). Were this true, one would expect to see low-income households increasingly purchasing used rather than new units, or deferring purchases altogether (i.e., the share of older vintage refrigerators in low-income households would increase as a result of the standards). This paper examines the effects of standards on lower income households in California, where standard levels comparable to the 1990 U.S. standards have been in effect since 1987. Analysis of the California data provides an indication of the potential impacts of national standards on low-income households.

CHANGES IN REFRIGERATOR PRICES AND FEATURES

Methodology

For the hedonic portion of this analysis, data for monthly retail sales from a commercial source were used and supplemented with manufacturer data on size and efficiency of specific refrigerator models. The ELCAP database (Elrick and Lavidge 1993) provides monthly refrigerator sales and

average sales price by model for several store types and regions. We obtained data for ten months during the years 1987/88 and for all twelve months of each of 1990 and 1993; these data represent refrigerator sales prior to the 1990 standards, and after imposition of the 1990 and 1993 standards. Sales are reported by several types of retailers, including traditional retail stores, department stores, and warehouse discount outlets. Although the data represent sales of over 200,000 units every year, which is between two and three percent of all new refrigerators sold in the U.S., the data are voluntarily supplied by retailers (i.e., the sample is not necessarily consistent or statistically representative of the U.S. market). This dataset is unique in that it contains actual, rather than list, average sales prices by model, as well as information on some of the attributes of each model (e.g., presence of ice-makers, vegetable and/or meat bins, wire and/or glass shelving, etc.). These data were reported by four regions of the United States, which correspond to the four Census divisions. Data on cubic footage of total volume, fresh food volume, and freezer volume, and the average daily electricity consumption for each model were taken from the Association of Home Appliance Manufacturers product directories (AHAM 1986, 1987, 1989, and 1992) to supplement the ELCAP dataset.

The technique of hedonic regression is a standard method of analyzing the relationships between prices and characteristics of specific goods. Conventional price indices, such as the Consumer Price Index (CPI), assume that the characteristics of a good remain the same over time. However, where technological progress has occurred and performance related attributes of a product have changed, exact price indices are no longer meaningful (Bitros & Panas 1988; Triplett 1989). In contrast the hedonic hypothesis considers the behavioral aspects of the sale of a bundle of characteristics. Depending on which side the transaction is analyzed, either the firm's goal of maximizing revenue or the rational consumer's goal of maximizing utility will be reflected in the bundle of characteristics produced or selected, and thus in the hedonic relationship. We used the reduced form of the hedonic relationship to capture both supply side and demand side influences (Lucas 1975; Halvorsen & Pollakowski 1981; Arguea, Hsiao & Taylor 1994). Two critical assumptions to the analysis are that both producers and consumers are price takers, i.e. the market is competitive, and that the goods under analysis exhibit economically identifiable and differentiable characteristics (Triplett 1975,1986; Rosen 1979; McConnell & Phipps 1987).

Our hedonic analysis used a quadratic semi-log functional form which allows for the evaluation of trade-offs between food and freezer compartment volumes and increases in energy efficiency (and decreases in annual operating costs), with respect to changes in selling price.[2]

Results

Table 1 presents the estimation results for three models: a pooled specification across the three time periods (1987/88 to 1993), as well as from 1987/88 to 1990 and 1990 to 1993. The use of a pooled, time-series/cross-section model specification allows for the isolation of changes in price due to general price effects over time from the effects of changes in quality, attributes, or technology. The coefficients in Table 1 are relative to the base case refrigerator: a top mount, auto-defrost refrigerator with wire and glass shelves and an optional icemaker, sold in traditional retail stores in the northeastern U.S.

Our coefficients for the year of sale variable indicate that, for all refrigerators represented in the sample, current prices increased by between 1.4 and 1.5 percent per year from 1987/88 through 1993; similar rates of secular change are indicated in the time coefficients for the two sub-period models. These results are consistent with a previously observed annual increase in current refrigerator prices of 1.1% between 1948 and 1983 (Gordon 1990). The U.S. Bureau of Labor Statistics found increases in current refrigerator prices of approximately 1.4% per year during the early 1980s, just prior to the imposition of standards. Tests for the statistical difference between the three models (footnote on Table 1) indicate that there is a statistically significant difference between the pooled model and the two time period models. This suggests that any changes in price since the imposition of standards are due to factors other than general price effects over time.

The coefficients for annual energy use are significant, but small, indicating that annual energy use had little impact on the price of the basic unit. Since energy consumption is a non-linear function of both food and freezer volumes, these coefficients may also be reflecting changes in refrigerator volume. The signs and magnitudes of these parameters indicate that changes in food or freezer volumes in response to changes in annual energy consumption would also be small.

The product class variables in Table 1 have the most impact on price. Product classes are defined by freezer type and location, as well as the presence of through the door features. In addition, refrigerators from higher product classes generally have more desirable amenities, such as factory-installed icemakers, all glass shelving, and meat storage bins. Table 2 shows the distribution of units sold for various amenities, by product class and standard level. In general, the units meeting the 1990 standard levels had either similar amenities or improved amenities; this trend continued with the introduction of units meeting the 1993 standard levels.[3] The most dramatic changes occurred in product class 7 (side-by-side refrigerator/freezer with through the door ice/water features); after imposition of the 1990 standard, almost all of these

Table 1. *Parameter Estimates for Hedonic Price Index Model*

Variable Name (Standard Error of Estimate in Parentheses)	1987–1993[1]	1987–1990[2]	1990–1993[3]
Intercept	5.870 (0.05)	6.098 (0.07)	5.788 (0.05)
Sale in 1990	−0.026 (0.004)	−0.026 (0.004)	—
Sale in 1993	−0.108 (0.01)	—	−0.082 (0.003)
Volume of freezer compartment in cubic feet	0.159 (0.01)	0.030 (0.01)	0.169 (0.01)
Volume of food compartment in cubic feet	−0.024 (0.01)	−0.070 (0.01)	−0.013** (0.01)
Annual energy usage in kilowatt hours	−0.0003 (0.0001)	0.0003 (0.0001)	−0.0004 (0.0001)
Freezer volume * Freezer volume	0.005 (0.001)	−0.017 (0.002)	0.006 (0.001)
Freezer volume * Food volume	−0.002** (0.001)	−0.005 (0.001)	−0.001** (0.001)
Freezer volume * Annual energy usage	−0.0001 (0.000)	0.0002 (0.00002)	−0.0001 (0.00001)
Food volume * Food volume	0.007 (0.001)	0.013 (0.001)	0.006 (0.0009)
Food volume * Annual energy usage	−0.00002 (0.00001)	−0.00001* (0.00001)	−0.00001 (0.00001)
Annual energy usage * Annual energy usage	0.0000001 (0.000)	−0.000001 (0.00)	0.000001 (0.00)
Sale from warehouse discount outlets	−0.052 (0.002)	−0.041 (0.003)	−0.047 (0.002)
Sale from department store outlets	0.023 (0.003)	0.022 (0.005)	0.03 (0.004)
Presence of wire shelves only	−0.193 (0.01)	−0.088 (0.02)	−0.197 (0.01)
Presence of glass shelves only	−0.087 (0.01)	0.002** (0.02)	−0.076 (0.01)
Presence of factory installed ice maker	0.041 (0.004)	0.060 (0.004)	0.034 (0.004)
Occurrence in Class 1: Manual defrost refrigerators and refrigerator/freezers.	−0.063 (0.01)	−0.204 (0.01)	−0.042 (0.008)
Occurrence in Class 2: Partial auto-defrost refrigerator/ freezers.	−0.036 (0.01)	−0.041 (0.01)	−0.018 (0.008)
Occurrence in Class 4: Side-mount auto-defrost refrigerator/ freezers.	0.153 (0.01)	0.169 (0.01)	0.155 (0.005)
Occurrence in Class 5: Bottom-mount auto-defrost refrigerator/freezers.	0.216 (0.01)	0.272 (0.01)	0.199 (0.007)

continued

Table 1. *Parameter Estimates for Hedonic Price Index Model* (continued)

Variable Name (Standard Error of Estimate in Parentheses)	1987–1993[1]	1987–1990[2]	1990–1993[3]
Occurrence in Class 6: Top-mount auto-defrost refrigerator/ freezers with through the door features.	0.218 (0.01)	0.178 (0.01)	0.256 (0.008)
Occurrence in Class 7: Side-mount auto-defrost refrigerator/ freezers with through the door features.	0.378 (0.01)	0.357 (0.01)	0.379 (0.006)
Sale in the western region of U.S.	−0.008 (0.003)	−0.025 (0.004)	−0.005* (0.003)
Sale in the southern region of U.S.	−0.018 (0.003)	−0.016 (0.004)	−0.014 (0.003)
Sale in the midwestern region of U.S.	−0.014 (0.003)	−0.013 (0.004)	−0.016 (0.003)

[1]F-statistic = 7557.209 $_{(0.0001,\ 25,\ 21857)}$ Adj-R^2 = 0.8963 MSE = 0.1155 DW = 0.753 First Order Autocorrleation = 0.623
Test of First and Second Moment Specification Chi Squared Statistic = 1084.99
[2]F-statistic = 3667.249 $_{(0.0001,\ 24,\ 13948)}$ Adj-R^2 = 0.8632 MSE = 0.1122 DW = 0.815 First Order Autocorrelation = 0.592
Test of First and Second Moment Specification Chi Squared Statistic = 815.19
[3]F-statistic = 7951.045 Adj-R^2 = 0.9046 MSE = 0.1112 DW = 0.690 First Order Autocorrelation = 0.655
Test of First and Second Moment Specification Chi Squared Statistic = 1307.05
Difference between pooled and individual years. 1987 to 1990 F-statistic[25, 7910] = 377.11
1990 to 1993 F-statistic[25, 1765] = 10.42
* Insignificant at 0.050 level. **Insignificant at 0.10 level.

refrigerators had factory-installed ice makers, all glass shelving, and meat storage bins. Several statistical tests indicate that, for the most part, all changes in the distributions of amenities between standard levels were statistically significant. The increasing trend in amenities installed in the higher product classes suggests that the large price coefficients on the product class variables are due to improved amenities. Table 1 indicates that location and type of retail outlet also had an effect on price; prices were higher at department stores and in the northeastern U.S.

Figure 1 presents average energy consumption, real price, and volume for refrigerators meeting the three standard levels (the prices are converted to real dollars based on the time coefficients developed from our 1987/88 to 1993 hedonic model in Table 1). For all refrigerators sold, average electricity consumption decreased 15% for units meeting the 1990 standard and an additional 34% for units meeting the 1993 standard, a net decrease of 44 percent since the imposition of standards. Average real prices for units meeting the 1990 standard were unchanged, and decreased 14% in 1993. Food and freezer volumes were relatively stable up to the 1993 standard level, and decreased afterwards. We normalized relative prices by holding food and freezer volumes constant; this lowered the net reduction in real prices to 8% over the six-year period as the standards changed. This represents a 1.25% average annual decrease, which compares well with the 0.68% to 1.10% average annual decrease in quality-adjusted real prices reported by Gordon.

From the limited period of time for which we have data, the previously observed historical declining trend in real prices for refrigerators does not seem to have been disrupted by the implementation of energy performance standards. It is possible that the standards may have dampened the historical trend in price reduction for particular product classes; however, this dampening, if it occurred, probably was the result of increased levels of amenities rather than the cost of energy efficiency features. Our results do not imply that manufacturers did not incur costs in meeting the energy performance standards; rather, they indicate that manufacturers did not pass those costs on to consumers in the form of higher prices.

IMPACT ON LOW-INCOME HOUSEHOLDS

Methodology

To analyze the penetration of efficient refrigerators into low-income households, we obtained the results from surveys

Table 2. *Comparison of Features for Refrigerators Meeting/Not Meeting the Standards (Percentage of sales with specified feature)*

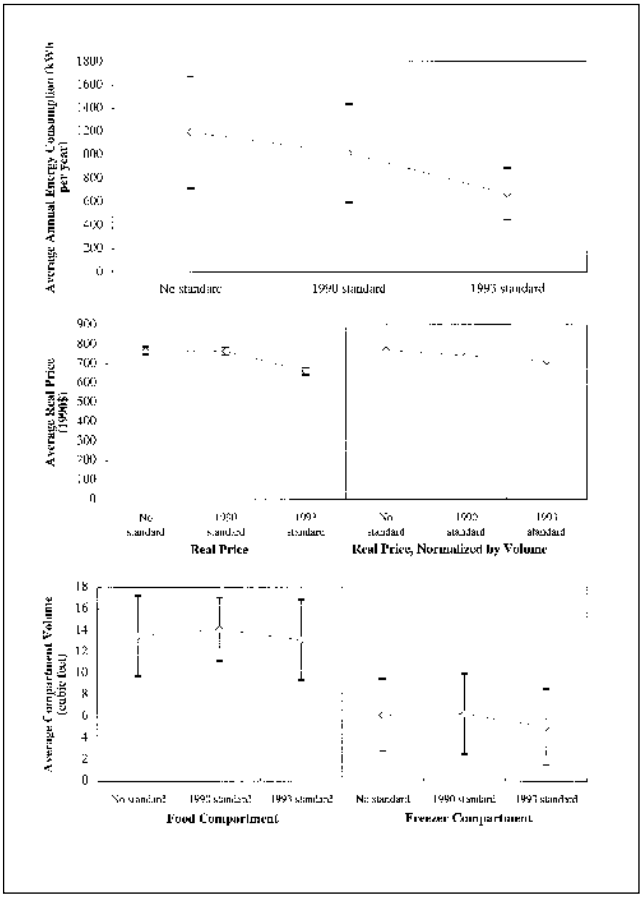
Product Class	Optional Ice Maker	Factory Installed Ice Maker	Wire Shelves Only	Comb. Wire and Glass Shelves	Glass Shelves Only	Veg. Bins Only	Comb. Meat and Veg. Bins
Product class 1: Manual defrost refrigerators and refrigerator/freezers							
Did not meet any level of standard	8.2	3.7	79.1	1.9	19.0	78.9	17.6
Met only 1990 standard	3.1	3.6	87.9	1.8	10.3	86.6	10.7
Met 1993 standard	2.3	2.6	95.5	1.3	3.2	90.4	7.7
Product class 2: Partial auto-defrost refrigerator/freezers							
Did not meet any level of standard	8.4	0.0	89.3	9.7	0.7	86.7	9.9
Met only 1990 standard	5.4	0.0	83.2	5.8	10.8	61.8	36.1
Met 1993 standard	10.1	0.0	86.8	11.9	0.9	83.8	12.0
Product class 3: Top-mount auto-defrost refrigerator/freezers							
Did not meet any level of standard	90.8	4.7	66.2	0.2	33.6	34.3	45.0
Met only 1990 standard	82.2	11.0	39.6	0.6	59.8	17.9	78.0
Met 1993 standard	87.6	8.2	53.3	0.9	45.9	28.7	71.3
Product class 4: Side-mount auto-defrost refrigerator/freezers							
Did not meet any level of standard	86.5	10.9	45.1	11.3	43.6	12.3	80.6
Met only 1990 standard	89.1	8.4	35.8	10.0	54.2	5.9	89.2
Met 1993 standard	86.9	10.2	40.0	13.7	46.3	10.3	83.4
Product class 5: Bottom-mount auto-defrost refrigerator/freezers							
Did not meet any level of standard	86.4	13.6	61.5	4.7	33.9	1.9	97.6
Met only 1990 standard	98.4	0.7	57.4	3.2	39.4	2.3	97.3
Met 1993 standard	99.5	0.4	51.7	3.9	44.3	1.6	98.0
Product class 6: Top-mount auto-defrost refrigerator/freezers with through the door features							
Did not meet any level of standard	53.0	43.2	11.4	46.8	41.8	6.5	86.8
Met only 1990 standard	42.5	54.4	21.8	37.1	41.1	5.3	89.4
Met 1993 standard	51.6	44.3	7.6	50.6	41.8	6.0	86.8
Product class 7: Side-mount auto-defrost refrigerator/freezers with through the door features.							
Did not meet any level of standard	97.1	2.9	0.0	49.3	50.7	6.0	92.5
Met only 1990 standard	3.2	96.8	25.2	0.0	74.8	2.7	96.6
Met 1993 standard	3.3	96.7	39.2	0.0	60.8	7.5	90.6

Percentage of shipments from AHAM (1995) and the representation of those classes in the ELCAP data set for the same period:

AHAM National Sales	**1988**	**1990**	**1993**
Product Class 1	10.2	8.8	11.7
Product Class 2	4.4	2.2	1.9
Product Classes 3 and 6	65.5	68.8	63.3
Product Classes 4, 5 and 7	19.9	20.2	23.1

ELCAP	**1988**	**1990**	**1993**
Product Class 1	7.5	3.0	3.2
Product Class 2	3.3	2.2	0.8
Product Class 3	37.5	34.0	53.3
Product Class 4	18.4	19.2	12.3
Product Class 5	5.0	3.7	2.4
Product Class 6	6.3	6.6	1.8
Product Class 7	21.9	31.5	26.3

Figure 1. *Average values (and 95% confidence intervals) for all refrigerators*



performed by two California utilities, the Pacific Gas and Electric Company (PG&E) and the San Diego Gas and Electric Company (SDG&E). Both of these surveys were ''on-site'' surveys designed to validate each utility's mail-in Residential Appliance Saturation Survey (RASS). The PG&E on-site survey consisted of three individual samples: two samples were drawn from service areas that tended to have average household incomes lower than the service area average, while the third sample was drawn from the entire PG&E service area. The SDG&E on-site survey consisted of a single sample of RASS respondents distributed throughout the SDG&E service area. Model numbers reported in the on-site surveys (read from refrigerator nameplates) were matched with models certified by AHAM using the product directories; certified volume and energy consumption data were then taken from the directories. Although the utilities obtained data for up to three refrigerators in each household, we only analyzed primary refrigerators.

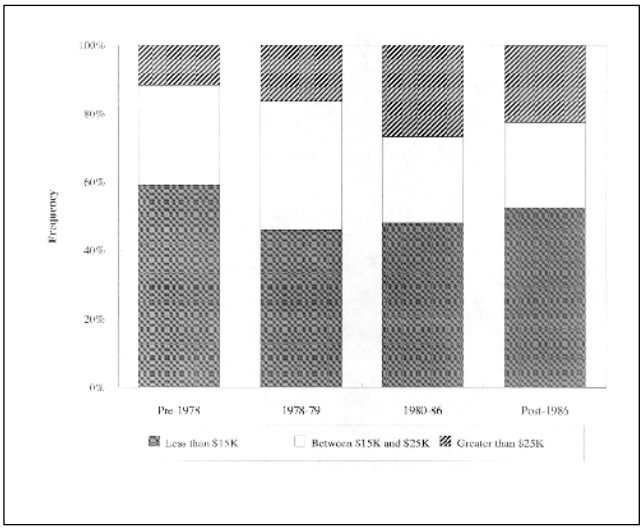
During the analysis of the RASS data we discovered several shortcomings in both surveys. First, household income was not reported in the PG&E service area sample. Since the other two samples in the PG&E survey targeted low-income households, middle- and upper-income households are not well represented. Second, the PG&E survey classified annual household income responses into only three categories: under $15,000, $15,000 to $25,000, and over $25,000. The survey therefore gives little information on middle- and upper-income households. This is in contrast to SDG&E's survey, which had eighteen categories of household income. Third, the inability to match reported refrigerator model numbers to certified models in the AHAM product directories limited the usefulness of both datasets. All of these factors reduced the number of usable observations to only 460 households, representing 34% of total responses.

In order to analyze how standards may have affected refrigerator ownership, we grouped households by the standard level under which their refrigerator was manufactured. We used the first year of appearance in the AHAM directory as a proxy for the first year that model was manufactured. Because California has imposed three levels of standards on refrigerator manufacturers, survey responses were grouped into four time periods corresponding to each standard level, based on the first year that the refrigerator model appears in the certification directories: prior to 1978, 1978 through 1979, 1980 through 1986, and after 1986.[4] We compared the distribution by standard level for the three PG&E income groups to determine whether the standards affected the types of refrigerators installed in low-income households.

Results

Figure 2 shows the distribution of refrigerators by standard level for each income group. Low- and moderate-income households have virtually identical distributions of refrigerators by standard level. These households have a larger share

Figure 2. *Distribution of refrigerators by standard level and household income*



of refrigerators from the period prior to energy standards than high-income households (30% compared to 15%), while high-income households have a larger share of units from 1980–86 (44% compared to 31%). However, all households, regardless of income, have roughly the same share (30%) of the most recent standard level (post–1986). Clearly energy-efficient refrigerator units are being installed in low-income households. These data do not provide enough information to determine who purchased the efficient units (homeowner, landlord, or tenant), or whether the unit was new or used when purchased, however.

CONCLUSION

Our key finding is that the 1990 and 1993 energy performance standards are not associated with statistically significant increases in refrigerator prices; in fact, it appears that the standards did not even alter the downward trend in refrigerator prices documented by others. We have also found that, during the time period these two standard levels were introduced, most amenities were not diminished, and in some instances actually increased (such as factory-installed icemakers and all glass shelving in product class 7). With the increased energy efficiency as a result of the standards, consumers appear to have received higher levels of cold food storage service at lower operating costs, without significant increases in purchase, or ''first,'' costs. These findings are supported by California data indicating that refrigerator efficiency standards do not appear to have inhibited the installation of new, efficient refrigerators in low-income households.

These findings are especially pertinent to concerns that have been raised regarding the impact of federal appliance efficiency policy: namely, that under the policy consumers might be faced with significant increases in first costs; that energy efficiency improvements might be gained at the expense of other features; and that low-income households might be unduly burdened. These effects are not evident from our analyses. To fully understand the effects of energy performance standards, a full cost/benefit analysis should be performed to measure changes in social surplus resulting from the policy, including an investigation of the manner in which manufacturers have responded to the regulation. The primary constraint to such research is the availability of data. In this regard, it is worth re-emphasizing the significance of the retrospective focus of this paper. Whatever the continuing disagreements regarding the justification for policies of this type, reliance solely on prospective, forecasting analysis approaches cannot lead to an understanding of the actual merits or shortcomings of policies as implemented.

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ENDNOTES

1. The federal refrigerator performance standards for 1990 were legislated in the National Appliance Energy Conservation Act (NAECA) of 1987 (P.L. 100-12). Prior to the federal standard, California adopted three levels of standards for refrigerators, effective November 1977, November 1979, and January 1987.

2. The functional form, which follows that of Rasmussen and Zuehlke (1990), is:

   $$\ln(P) = \alpha + \varphi t + \delta' X + 0.5X' \beta X' + \gamma D + \epsilon$$

   where:

   P = selling price of refrigerator
   $\alpha, \varphi, \delta, \beta, \gamma$ = estimated parameters
   t = binary variable representing year of sale
   X = continuous product characteristics (energy consumption, food and freezer compartment volume)
   D = discrete product attributes (product class, type of icemaker, type of shelving, etc.)

   Since each observation in the ELCAP dataset represents an average price for a group of refrigerators, the functional form was estimated with a weighted orthogonal transformation (Gentleman-Givens) using the square root of the number of units sold for each observation reported in the data set as the weighting, a method designed for ill-conditioned data. To correct group-wise heteroscedasticity, the inverse of freezer volume was used to weight each observation within the data set.

3. Several manufacturers are over-represented in the sample of Product Classes 5, 6 and 7 refrigerators, creating a potential bias in the data. We attempted to control for this in the estimation of our hedonic relationship and our other results.

4. No distinction was made between models manufactured under the 1987 California standard and models built under the 1990 federal standard, since the difference in the two standard levels is quite small (3 percent for top-mount, auto-defrost units.)

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