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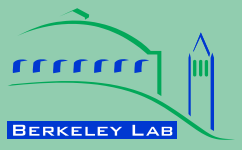

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Retrospective Evaluation of Appliance Price Trends

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Disclaimer

1. Introduction

Between 1980 and 2000, the Department of Energy (DOE) announced and implemented minimum efficiency standards for a variety of residential appliances, including room air conditioners (RAC), central air conditioners (CAC), refrigerators and clothes washers. Accompanying each announcement, DOE issued a technical support document (TSD) for the rulemaking. As part of these studies, DOE contractors forecasted the retail price increases that would result in a market of more energy efficient, and, presumably, more costly equipment. This estimate was generally performed using an engineering approach, that is, by assessing the materials and labor costs to manufacturers associated with implementing energy efficiency technology. Inflation-adjusted prices were assumed constant over time, and uniform retail markups were applied. The TSD price estimates are integral in assessing the cost impact to the consumer, the payback period and the national impacts of higher appliance standards. Life cycle cost and payback period are calculated based on estimates of incremental costs related to efficiency improvement. Standards tend to be set at the highest cost-effective level. Therefore, the potential effect of an overestimation in cost increases is implementation of a standard that is not as stringent as it might be.

This paper provides a retrospective evaluation to assess the validity of DOE estimates of the consumer cost of efficiency standards against actual retail price data. Two sources were used to represent retail price data. For room and central air conditioners, we relied on models advertised in the Sears Roebuck and Company Catalog published between 1967 and 1993. These data were collected and compiled into a database by Dr. Richard G. Newell as part of his Ph.D. dissertation (Newell and Richard, 1997). In the case of refrigerators and clothes washers, we collected price data from ratings reports published in *Consumer Reports* magazine issued from the early 1970s until the present. We recognize that the Sears data represent prices from a single manufacturer, which we assume to be typical of the industry as a whole with regard to overall price trends and relative price of efficiency. *Consumer Reports* data are broader in terms of manufactures, but features models selected with some presumably subjective criteria. Nevertheless, we believe the data form a sufficiently representative sample of the market to reveal the main price and efficiency trends.[1]

In the following sections, we explore general trends in energy efficiency and retail price of the appliances. We then directly compare prices to predictions made in the TSD. Distinct patterns are evident in the data. Most clearly, the retail data indicate that inflation-adjusted prices of all four appliance types are decreasing over time. Second and most significantly for the evaluation of proposed standards, we find that five of the six TSDs we studied overestimated the relative price of efficiency, most dramatically in the case of RAC. We discuss possible explanations for the divergence of predicted and actual retail prices. The main possibilities, we argue, are overall and "efficiency-directed" technological change and declining price-cost margins and economies of scale associated with higher efficiency appliances. A simple econometric model of a hedonic price equation is used to test each of these explanations. Regression results show evidence of each of these forces in decreasing energy efficient appliance prices.

2. Impacts of appliance efficiency standards

Federal appliance minimum efficiency standards remove models below a certain baseline from the market. Generally, DOE conducts an engineering-economic study to assess the current appliance market and the existing efficiency technologies. Economic analysis includes consumer life cycle cost and national net present value estimates of several possible efficiency levels. The results of this study are published as a TSD that accompanies the Notice of Proposed Rulemaking (NOPR) and the Notice of Final Rulemaking (NOFR) prescribing the standard level. Manufacturers generally have several years between the NOFR and the standard implementation date and can begin test marketing high-efficiency products well before the implementation date of the standard. Upon implementation, the manufacture of less-efficient designs is prohibited.

2.1. Efficiency data

In the case of both room and central air conditioners, efficiency ratings were listed directly in the Sears Catalog for every model. The efficiency metric for RAC is the energy efficiency ratio (EER), measured in Btu/h/W which represents the cooling-capacity output for a given power input. EER ranges from about 5 to about 10.5 in the RAC data. The efficiency indicator for CAC is SEER. SEER is defined similarly to EER but based on seasonally adjusted cooling loads. The efficiency range in the CAC data is from about 5.5 to 11.5 SEER.

Since refrigerators operate year round, they can be rated simply in terms of total annual energy consumption, in kilowatt-hours. Federal efficiency standards are volume dependent,[2] allowing larger-capacity refrigerators to use more energy than smaller ones. Efficiency in our sample ranges from 0.015 to 0.05 $(ft^3/kWh)^{-1}$. Capacity and consumption data were taken from the Association of Home Appliance Manufacturers (AHAM) certified directory where available[3] (AHAM, 1978–2001).

Clothes washer efficiency data were not available from *Consumer Reports*. Total energy consumption per cycle, including water heating energy was taken from manufacturer reports collected by Natural Resources Canada and the Federal Trade Commission, and ranges from 0.2 to 1.6 $(kWh/cycle)^{-1}$.

Efficiency data for all years available are plotted in Figure 1. The data show a trend towards higher efficiency for all of the appliances, although this shift can be either gradual or abrupt. Clearly, efficiency standards had a significant effect on the appliance market. Perhaps most striking are the cases of room and central air conditioning. Standards for these products, along with those for several other appliances were legislated as part of the National Appliance Energy Conservation Act (NAECA) in 1986–1987, although implementation dates for these standards were set for 1990 and 1992, respectively. The Sears Catalog shows that nearly all RAC models below 7.5 EER and CAC units below 9.0 SEER were eliminated by 1986. This illustrates a case in which appliance efficiency standards seem to have an abrupt effect on efficiency but not necessarily in the scheduled implementation year. In the case of refrigerators and clothes washers, a transformation to a more energy efficient market is also evident, although more gradual.

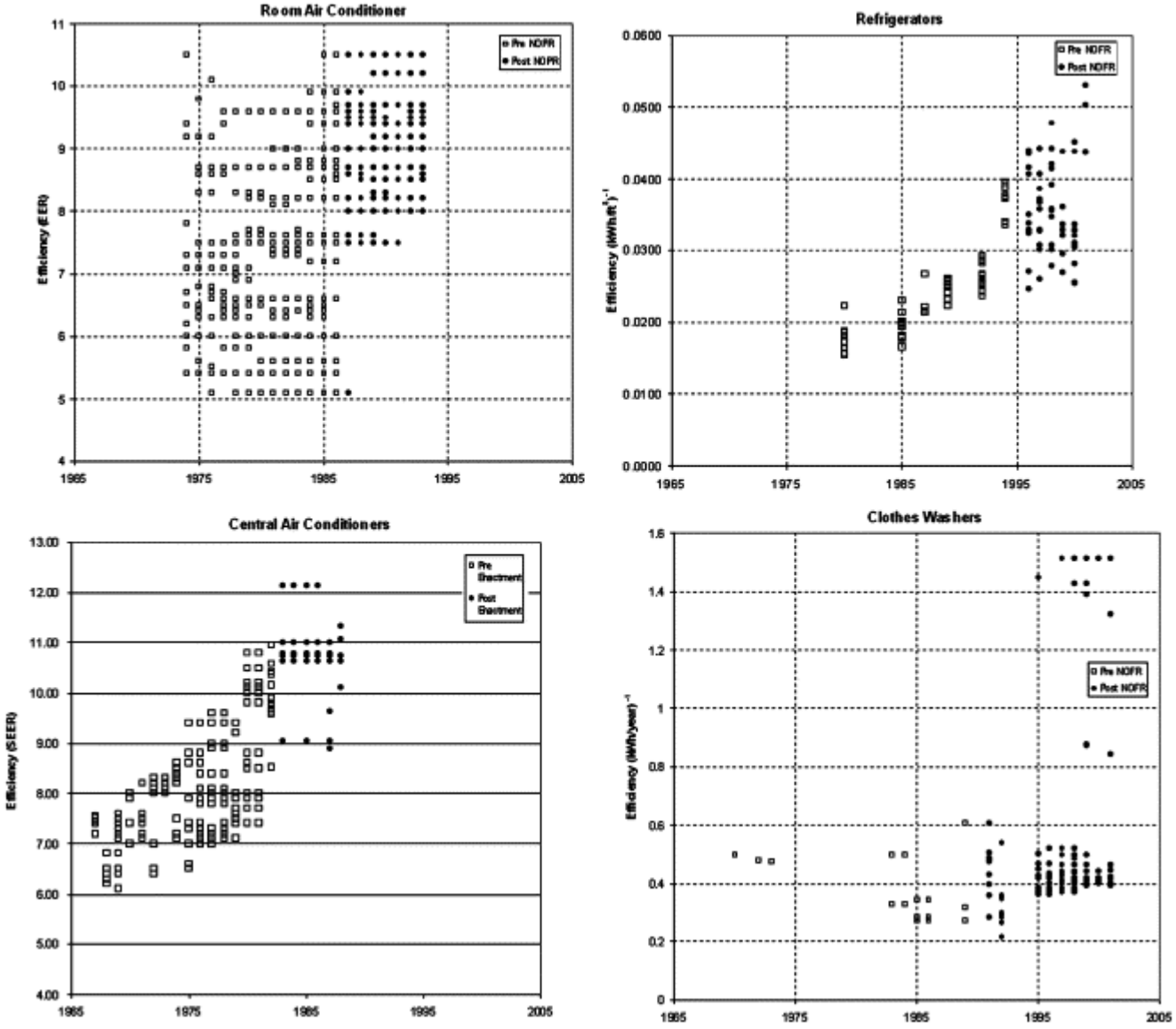

Figure 1 Impact of Federal Efficiency Standards on Appliance Market

Source: RAC and CAC: (Newell and Richard, 1997). Refrigerators: (Consumer Reports Magazine, 1975–2001), Refrigerators: (AHAM, 1978–2001), Clothes Washers: (Natural Resources Canada, 1981–2001).

3. TSD appliance price forecasts

Analysis of expected impacts from possible appliance efficiency standards requires an estimate of the retail price of appliances to the consumer and an estimate of the incremental increase in price caused by appliance efficiency improvements. One approach to forecasting retail prices is to conduct an engineering analysis of the manufacturing cost associated with different efficiency design enhancements (Turiel et

al., 1997). As a part of this analysis, markups are added to the manufacturing cost to obtain the predicted retail price of the appliance.

Table 1 presents the TSD forecasts of appliance prices, normalized to 2001 dollars using the Bureau of Labor Statistics' consumer price index for all items. For air-conditioning equipment, standards were applied according to the capacity of the unit. Refrigerators and room air conditioning were the subject of two rulemakings so that data from two TSDs are shown.

Table 1 TSD prediction of appliance prices

Room air conditioner				**Central air conditioners**		**Refrigerators**				**Clothes washers**	
1982 TSD		**1990 TSD**		**1982 TSD**		**1989 TSD**		**1995 TSD**		**1990 TSD**	
EER	Price $2001	EER	Price $2001	SEER	Price $2001	$(kWh/ft^3)^{-1}$	Price $2001	$(kWh/ft^3)^{-1}$	Price $2001	$(kWh/cycle)^{-1}$	Price $2001
Small—8 kBtu				*Small<39 kBtu*		*Top-mounted freezer-Auto defrost*					
6.4	802	8.5	550	7.1	2036	0.0188	813	0.026	701	0.312	624
6.9	829	9.4	559	7.9	2321	0.0192	814	0.0293	724	0.374	624
8.8	842	9.7	568	8.5	2490	0.0205	819	0.0306	733	0.426	624
9.3	912	9.9	579	9.9	2791	0.0229	830	0.0318	741	0.433	642
9.7	983	10.3	651	10	3009	0.0236	843	0.0335	755	0.448	674
				10.4	3599	0.0246	872	0.0337	756	0.450	689
Cost of efficiency ($/EER)				Cost of Eff. ($/SEER)		0.255	900	0.0367	782	1.114	734
55		56		474		0.0261	915	0.0376	788	1.150	922
Medium—14 kBtu				Large>39 kBtu		0.0312	1023	0.0384	795	1.156	937
7.7	1145	9.3	674	7.1	3652	0.0354	1186	0.041	815		
9.1	1216	9.7	689	7.9	4132	0.0367	1238	0.0417	823		
8.8	1409	9.9	695	8.5	4243			0.0428	838		
10.2	1474	10.1	706					0.0431	845		
		11	786								
Cost of efficiency ($/EER)				Cost of Eff. ($/SEER)		Cost of efficiency ($\times(kWh/ft^3)$)				Cost of Eff. ($\times(kWh/cycle))	
132		66		422		23716		8421		371	
Large—20 kBtu											
6.7	1521	9	835								
7.2	1660	9.7	861								

The first noticeable pattern in the table is that prices rise as units increase in efficiency, due to the added costs of efficiency technology. Secondly, the price to increase efficiency is inferred from price differences reported in the TSDs. We define “cost of efficiency” in the table as the change in price per average change in efficiency over the efficiency range listed for each appliance category in the TSDs. For both RAC and refrigerators, this measure decreased in going from the earlier to the later TSDs.

4. Accuracy of the TSD appliance price forecasts

Although the TSDs forecast prices to increase in response to efficiency gains, market price trends reveal a different pattern. Between 1970 and 2000, room air conditioner, refrigerator and clothes washer prices decline and central air conditioner prices vacillate around a flat or slightly declining trend line (Figure 2). The discrepancy between TSD forecast price and market price is revealed in two ways: (1) by comparing the TSD forecast price with the subsequent market price of a given appliance and (2) by comparing the TSD forecast price to increase efficiency with the subsequent market price to increase efficiency.

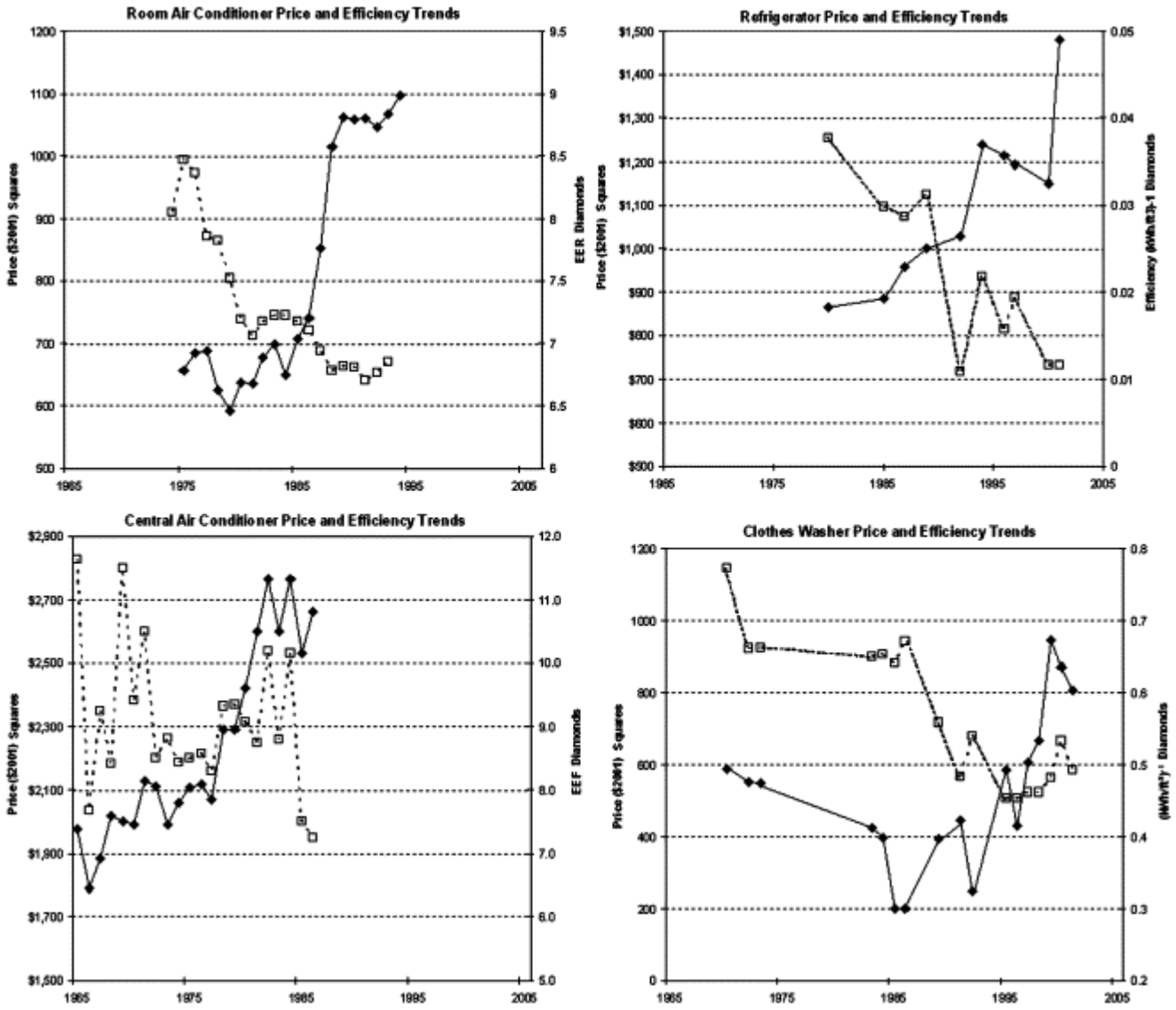

Figure 2 Appliance Price and Efficiency Trends.

Source: RAC and CAC: (Newell and Richard, 1997). Refrigerators: (Consumer Reports Magazine, 1975–2001), Refrigerators: (AHAM, 1978–2001), Clothes Washers: (Natural Resources Canada, 1981–2001).

The first comparison—between TSD forecast price and the subsequent market price—suggests that the TSDs provide upper bound estimates of appliance prices. Table 2 shows that some TSDs (1982 room air and central air conditioner and the 1990 clothes washer) significantly overestimate market prices and others (1990 room air TSD) tend to underestimate market prices.

Table 2 Predicted and observed market prices

	Predicted(1982 TSD)		1982–1987 DATA		Predicted (1990 TSD)		1990–1993 DATA	
	Nearest efficiency	Price	Average efficiency	Average price	Nearest efficiency	Price	Average efficiency	Average price
	EER	2001$	EER	2001$	EER	2001$	EER	2001$
Room air conditioners								
Small (8 kBtu)	6.9	829	7.0	544	8.5	550	8.8	514
Medium (14 kBtu)	7.7	1145	8.1	817	9.3	674	9.3	707
Large (20 kBtu)	8.1	1677	8.0	1151	9.0	835	8.7	998

	Predicted (1982 TSD)		1982–1988 DATA	
	Nearest efficiency	Price	Average efficiency	Average price
	SEER	2001$	SEER	2001$
Central air conditioner				
Small (<39 kBtu)	9.9	2791	9.9	2075
Large (>39 kBtu)	10.0	4402	9.4	2694

	Predicted (1989 TSD)		1989–1994 DATA		Predicted (1995 TSD)		1991–2001 DATA	
	Nearest efficiency	Price	Average efficiency	Average price	Nearest efficiency	Price	Average efficiency	Average price
	(kWh/ft3)−1	2001$	(kWh/ft3)−1	2001$	(kWh/ft3)−1	2001$	(kWh/ft3)−1	2001$
Refrigerators								
Top mounted AutoDefrost	0.026	915	0.027	799	0.031	1023	0.033	795

	Predicted (1990 TSD)		1991–2001 DATA	
	Nearest efficiency	Price	Average efficiency	Average price
	(kWh/cycle)−1	2001$	(kWh/cycle)−1	2001$
Clothes washers				
Standard clothes washers 115 v, Capacity 2.6 cu.ft	0.45	689	0.52	567

The comparison between forecast TSD with observed market price to increase efficiency is more problematic. The TSDs forecast that any rise in appliance efficiency should be accompanied by an increase in price. In the market, however, appliance prices decreased and appliance efficiencies increased. This contradiction points to a process of technological change, where production costs in general, and for high-efficiency products in particular, are decreasing over time. In the following section, we suggest a model to parameterize technological change and discuss other market factors that might contribute to a decline in prices. This model permits an assessment of TSD forecasts of the price to increase efficiency, holding technology constant.

5. Explanations of declining appliance prices and TSD forecast inaccuracy

We now turn to evaluating four sources of declining appliance prices: "overall" technological change, "efficiency-directed" technological change, declining markups and economies of scale in production of higher efficiency units. We quantify the amount of price decline that can be attributed to these sources.

5.1. Overall technological change

One explanation of the forecast inaccuracy is overall, or neutral, technological change. Technological change reflects the ability to get more output with the same inputs. Overall technological change refers to an equiproportionate lowering of costs across all factors of production, such as labor, materials, capital and energy. It may result from improvements in input quality or production processes (Denison, 1972; Griliches, 1986; Srivastava and Heady, 1973). Overall technological change helps explain a trend of falling prices at a time of rapidly increasing room air, central air and refrigerator appliance efficiency (Figure 2). By not accurately accounting for increasing productivity, the TSD price predictions for these appliances were likely to be outdated within a few years of being published.

Overall technological change may be attributed to an increase in capitalization that occurred in the appliance, or white goods, industry between 1970 and 1990 which lowered labor requirements and increased productivity of all four appliances covered in this paper.[4] and [5] At the same time, there has been rapid productivity growth in the wholesale trade sector between 1987 and 1997 that outpaced productivity growth in manufacturing and other sectors in the economy except mining (Triplett and Bosworth, 2001).

To develop an empirical test for overall technological change, we estimate a simple hedonic price model:

$$P_i=\alpha+\beta 1^{*} size_i+\beta 2^{*} feature_i+\beta 3^{*} eff_i+\beta 4^{*} date_i+e_i$$

where P is the price of the given model, *size* is the capacity of the model, expressed as kBtu for RAC and CAC and as ft^3 for refrigerators and *eff* is the efficiency rating of the model. The variable *feature* represents an optional product feature−variable fan speed for

air conditioners, glass shelves or ice makers for refrigerators, *date* is a year variable, α, $\beta 1$, $\beta 2$, $\beta 3$, and $\beta 4$ are coefficients to be estimated, e_i is the error term and *i* are appliance model indices (Rosen, 1974).

The parameters are estimated econometrically using the ordinary least squares regression technique. The focus of this model is on the coefficient associated with the time variable, *date*. After controlling for appliance features, the time trend captures other influences on price. A negative sign on this coefficient indicates appliance prices are falling.

5.2. Efficiency-directed technological change

In contrast to overall technological change, efficiency-directed technological change reduces the relative cost of the high efficiency appliances. In the context of energy efficient appliances, Newell et al. (1999) developed an hedonic supply model and found evidence of both overall technological change and efficiency-directed technological change in household appliances. Greening et al. (1997) also use a hedonic framework to estimate the price of appliances as a function of energy-efficiency levels. Here, we compare the regression results of the hedonic model in the two time periods available for room air conditioning and refrigerator appliances. Significant differences in the coefficient on the efficiency feature, *eff*, between the two time periods would indicate a shift in the price charged for increasing efficiency by one unit.

5.3. Regression results for identifying technological change

The high *R*-squared for each regression, except for refrigerators 1980–90, clothes washers 1980–2000 and medium RAC 1987–1993, shows a good overall fit for the models as specified (Table 3). The coefficient estimates for the independent variables show the change in price for a change in the independent variable. As expected, size, speed (for RAC) and EER/SEER increase production cost and thus price, as the estimates are positive and highly significant statistically. The larger and more efficient the appliance, the higher the product cost and retail price.

Table 3. Regression results for technological change and appliance price

Room air conditioners					**Central air conditioners**			**Refrigerators**					**Clothes washers**		
	1974–1987		**1987–1993**			**1967–1988**			**1980–1990**		**1991–2001**			**1980–2001**	
Small (<8 kBtu)					Small (*<39 kBtu)*			*Top mounted freezer-Autodefrost*							
	Coeff.	*t*(162)	Coeff.	*t*(92)		Coeff.	*t*(117)		Coeff.	*t*(54)	Coeff.	*t*(95)		Coeff.	*t*(129)
Intercept	778.2	9.1	134.8	0.5	Intercept	−1016.0	−7.5	Intercept	100257.89	5.59	24528.8	3.1	Intercept	41813	9.00
Size	50.4	15.1	59.6	5.9	Size	44.3	14.4	Size	−17.06	−0.88	39.1	11.7	Eff.	294.3	6.52
Speed	67.3	12.1	72.7	6.3	SEER	302.8	19.7	Glass	124.27	3.27	3.3	0.1	Date	−20.7	−8.90
EER	31.6	9.2	8.7	1.1	Date	−65.0	−15.0	Ice	246.06	2.36					R^2=.44
Date	−10.9	−10.5	−2.7	−0.9				Efficiency	18734.52	1.92	7134.8	4.3			
								Date	−50.04	−5.55	−12.5	−3.2			
		R^2=.87		R^2=.64			R^2=.76			R^2=.40		R^2=.69			
Medium (>8 kBtu; <14 kBtu)					Large (*>39 kBtu)*										
	Coeff.	*t*(76)	Coeff.	*t*(57)		Coeff.	*t*(59)								
Intercept	1810.0	9.4	758.7	1.9	Intercept	−1246.0	−3.7								
Size	37.3	7.5	28.5	5.5	Size	42.1	8.2								
Speed	67.2	3.0	65.9	2.8	SEER	385.0	10.1								
EER	57.8	7.9	41.1	2.9	Date	−89.9	−11.0								
Date	−25.1	−12.5	−10.4	−2.6											
		R^2=.75		R^2=.44			R^2=.73								
Large (>14 kBtu)															
	Coeff.	*t*(101)	Coeff.	*t*(41)											
Intercept	1493.0	12.2	2241.9	5.4											
Size	38.4	32.8	37.8	13.4											
Speed	155.3	7.9	N.A.	N.A.											
EER	61.1	9.5	51.8	2.8											
Date	−25.0	−15.9	−27.3	−5.1											
		R^2=.94		R^2=.87											

The results give evidence that overall technological change was occurring in these time periods that lowered the production cost and sales price of appliances. The coefficient on the trend variables are negative and highly significant (at the 5% level or higher), except for small RAC 1987–1993. In annual percent terms calculated at mean prices, the decline in appliance prices ranges between 2% and 3% per year for small and medium RAC in the early (1974–1987) period, falling to between 0.5% and 1.5%, respectively, in the later (1987–1993) period. Refrigerator prices were declining 5.3% prior to 1990, falling to 2.3% after 1990. Central air conditioner prices fell approximately 2.7% between 1967

and 1988, the only period for which we have data.[6] Finally, clothes washer prices decreased an average of 4.1% between 1980 and 2001.[7]

Comparing the coefficient estimates on EER for RAC and refrigerators in the two time periods show that technological changes directed at reducing energy consumption also occurred during this period. The marked decline in the incremental price of efficiency between periods suggests a degree of directed technological change in the refrigerator and room air-conditioner appliances.

5.4. Declining markups and economies of scale in production of higher-efficiency units

Technological change apparently contributed to a steady decline in appliance prices and price of efficiency, but our conversations with appliance engineers suggest that these changes were relatively constant.[8] Additional variables are needed to explain the rapid increases in efficiency that occurred off and on between 1980 and 2000 with little or no change in appliance price (Figure 2). Two variables that may help explain rapid efficiency run-ups without a price increase are declines in retail price-cost markups and economies of scale in production of higher-efficiency units.

5.5. Declining markups

Markups are defined in this paper as the ratio of the consumer retail price of an appliance to its manufactured cost. TSDs assume appliance markups to be constant across models and efficiency levels. For example, the 1982 TSD (US Department of Energy, 1982) assumed the markup on small- and medium-size RAC and central air conditioners to be 2.0 for all efficiency levels, indicating that the retail price is twice the manufactured cost across all efficiency levels and in market conditions.[9]

There are several reasons to doubt the TSD assumption that appliance markups are constant across efficiency levels. These reasons include increasing competition in appliance markets and elimination of inefficient appliances. In the US, extensive distributor surveys indicate that competition is causing a decline in wholesale profit margins (Business News Publishing Company, 2001). Retail appliance markets around the world are facing similar competitive pressure. For example, in the Japanese market, “the prices of home electric appliances have been dropping for a long time…due primarily to…fierce rivalry at the retail level… It is said that if a new product…can be sold at the same price or even lower than the previous year's model, the old product's price goes down in an instant” (Takeuchi, 1997).

With technological improvements, productivity growth and competitive pressures along the production and distribution chain, it seems unlikely that markups will remain fixed as higher efficiency models become baseline models and are sold at higher volumes by more companies. Which effect dominates, the rising cost of manufacturing to produce more efficient appliances or the market changes that tend to lower retail price, is an empirical question to be explored below. However, a likely result of both these trends, we argue, is a decline in the retail price to manufacturing cost ratio.

5.6. Economies of scale in production

Economies of scale in production are also likely to temper any increase in production costs attributed to rising efficiency levels. During the last two decades new standards and changing consumer preferences have eliminated many low-efficiency appliances from the market (Figure 1). As a consequence, there has been a pronounced rise in the market share and production quantity of higher efficiency appliances.[10]

Increasing market share and sales volume are associated with a decline in the average cost of production in the appliance and many other industries (Hirsch, 1952). Conversations with industry experts have emphasized the importance of economies of scale in appliance manufacturing and, in particular, the importance of economies of scale to lower the production cost of the more popular baseline air conditioners and refrigerator models that are increasing in efficiency over time.[11]

5.7. Regression analysis to evaluate markups and economies of scale

These considerations lead us to expect that rapid increases in the average appliance efficiency in the past, due to standards and other market factors, will tend to be associated with relatively small price increases.[12] One way to formulate this expectation into a testable hypothesis is to compare the changes in average efficiency over time to changes in the price per unit of efficiency. Large increases in average efficiency due to standards rulemaking, for example, would be associated with a drop in the dollar price per unit of efficiency. In other words, we expect a negative relationship between the incremental price to increase efficiency (as defined above) and changes in average appliance efficiency.

An econometric analysis evaluates the hypothesis that there is a negative relationship between appliance efficiency and the incremental price of efficiency. We first derive a relationship between retail price and appliance efficiency which is consistent with our assumptions that markups for a product of given efficiency level drops over time while manufacturing cost increases with price. Next, a regression analysis is performed to evaluate this relationship. We specify a hedonic appliance price equation similar to the equations reported in Table 3, while adding two new variables—a “change in average efficiency” variable, measured as the difference between average efficiency of models in year t and year $t-1$, and a market share variable for central air conditioners.[13]

The change in efficiency variable, *Delta EER/SEER/Eff* measures the change in average appliance efficiency experienced in each year covered by the retail price data.[14] According to the relationship described above, a negative coefficient on this variable indicates that appliance price is negatively correlated with changes in average appliance efficiency.

We are able to test the hypothesis of economies of scale with market share data by efficiency level for central air conditioners. The market share variable represents a proxy for volume of models sold by efficiency level. It therefore explicitly captures economies of scale, which lower costs of production. Past studies indicate that both leading firm efficiency and market shares of different technologies affect prices over time and should

be taken into account in energy models (Decanio and Laitner, 1995). We incorporate this data into our regression analysis for CAC to test for these effects. A negative coefficient would indicate that increasing market share reduces the cost of supplying central air conditioners, and therefore, the price.

Price is regressed on the independent variables in the hedonic equation using ordinary least squares. In contrast to previous regressions, we group all size classes of appliances together. Again, the overall fit of the model specifications is very good, as evidenced by the R^2 ratios. The change in efficiency (*Delta EER/SEER/Eff)* for the three appliances analyzed in this section shows the expected sign. The negative and significant (at the 1% level or higher) coefficient estimate on the *Delta EER/SEER/Eff* variables is consistent with the hypothesis that increases in appliance costs due to rising energy efficiency are associated with less than proportional increases in price. Even as average efficiency levels are rising, improvements in energy efficiency in the market for appliances lead to declines in product cost. The variable, *Date*, representing the time trend remains negative in all three equations, suggesting overall technological improvements that also decrease price over time. In the CAC regression equation, market share by efficiency level is negative and significant, indicating that as volume sold increases, price decreases.

Adding the additional variables does not affect the sign or relative magnitudes of the coefficient estimates of the other variables, as reported in Table 4. The results suggest that scale economies and declining markups help explain the rapid decline in the price of higher efficiency appliances noted in this paper.[15]

Table 4. Regression results for fixed markup and economies of scale hypotheses

Room air efficiency			**Central air efficiency**		
1974–1993 data			**1976–1988 data**		
	Coefficient	*t*(542)		Coefficient	*t*(176)
Intercept	1457.5	28.9	Intercept	6576.0	14.1
Size	36.2	77.5	Size	46.7	27.8
Speed	73.9	13.1	Market share	−485.7	−3.3
EER	41.1	13.9	SEER	324.5	11.7
Date	−19.2	−28.2	Date	−107.0	−13.5
Delta EER	−44.1	−2.7	Delta SEER	−61.8	−2.2
		R^2=.95			R^2=.88
Refrigerator efficiency			Clothes washer efficiency		
1980–2001 data			1985–2001 data		
	Coefficient	*t*(141)		Coefficient	*t*(141)
Intercept	79686.6	13.5	Intercept	36837.8	5.0
Size	39.8	10.9	Efficiency	318.5	6.9
Glass	105.7	5.2	Date	−18.2	−4.9
Ice	56.4	3.0	Delta eff.	228.6	−2.6
Efficiency	8091.3	3.8			
Date	−40.1	−13.4			
Delta eff.	−6209.7	−2.5			
		R^2=.75			R^2=.36

These results suggest that the accuracy of TSD forecasts may be improved by lowering the markup on incremental costs to increase efficiency. Currently, the TSDs assume that markups are fixed and that a dollar increase in manufacturing cost often leads to a two or three dollar increase in retail price. The results in this section suggest that markups, and more specifically markups on incremental manufacturing costs, decline when there is a rise in average appliance efficiency. TSD forecasts may be improved by applying a lower markup on incremental costs when there is an increase in average efficiency due to standards or other changes in appliance markets.[16]

6. Comparison of TSD and regression estimates of incremental efficiency price

A comparison of TSD and regression estimates of the price to increase efficiency strongly suggests that the TSD overestimated the price to increase efficiency for every appliance considered in this paper. The price overestimate is most pronounced for room air and central air conditioners but it is also evident for refrigerators and clothes washers (Table 5). Below is a discussion of the estimates of the price to increase efficiency derived from the TSD and the hedonic model regression analysis.[17]

Table 5 TSD estimate of the price to increase efficiency

EER range	**1982 TSD**	**1974–1986 regression**	**EER range**	**1990 TSD**	**1987–1933 regression**
	$/EER	**$/EER**		**$/EER**	**$/EER**
Room air					
Small 8 kBtu*			Small 8 kBtu*		
6.4–9.7	55	32	8.5–10.3	56	9
Medium-14 kBtu*			Medium-14 kBtu*		
7.7–10.2	132	58	9.3–11	66	41
Large-20 kBtu*			Large-20 kBtu*		
6.7–9.3	278	61	9–10.7	37	52
SEER range	1982 TSD	1967–1988 Regression			
	$/SEER	$/SEER			
Central air					
Small (<39 kBtu)*					
7.1–10.4	474	303			
Large-(>39 kBtu)					
7.1–10.4	422	385			
Efficiency range	1982 TSD	1980–1990 regression	Efficiency range	1995 TSD	1991–2001 regression
$/(kWh/ft^3)$^{-1}$	$/(kWh/ft^3)$^{-1}$	$/(kWh/ft^3)$^{-1}$	$/(kWh/ft^3)$^{-1}$	$/(kWh/ft^3)$^{-1}$	$/(kWh/ft^3)$^{-1}$
Refrigerators					
0.019–0.036	23716	18735	0.026–0.043	8421	7135
Efficiency range	1990 TSD	1980–2001 regression			
(kWh/cycle)$^{-1}$	$/(kWh/cycle)$^{-1}$	$/(kWh/cycle)$^{-1}$			
*Clothes washers**					
0.31–1.16	371	294			

* For these appliance categories, the TSD price exceeds the market price at the 90% confidence level.

6.1. Room air conditioners

The 1982 TSD predicts that a unit efficiency increase of small, medium and large appliances would raise prices $55, $132 and $272 dollars, respectively.

The regression analysis reveals the market price of efficiency to range from one-third to two-thirds of the TSD forecast price. A one-unit increase in the EER of a small, medium and large room air appliance is estimated to increase price an average of $32, $58 and $66 dollars.

The 1990 TSD predicts the price of efficiency to be $56 for small appliances, $66 for medium appliances and $37 for large appliances. The regression analysis suggests that the market price of efficiency fell to $9 for small appliances and $41 for medium sized appliances. The regression analysis suggests that the 1987–1993 price of efficiency was $52, higher than the 1990 TSD prediction. However, there was little data on large RAC available in the 1990 TSD.

6.2. Central air conditioners

Using the range of efficiency levels considered by the 1982 TSD, the only TSD to coincide with the Sears data for central air conditioning, the regression analysis indicates that the incremental price of efficiency in the market is less than the incremental price estimated in the TSD. The TSD forecasts the price of efficiency to be $474 for smaller units and $422 for larger units. The regression analysis suggests the market price of efficiency to be about $303 for smaller units and $385 for larger units.

6.3. Refrigerators

The analysis suggests that the refrigerator TSDs overestimate the market price of efficiency by a smaller margin than the room air and central air TSDs. The 1982 TSD forecast the price of efficiency to be $23,716. The regression analysis suggests a market price of efficiency of $18,735, about 20% lower. The 1995 TSD forecast price of efficiency ($8421) is also somewhat above the regression or market price of efficiency ($7135).

6.4. Clothes washers

Clothes washer TSD forecast the price of efficiency to be $371. The regression analysis indicates that the market price to increase efficiency was about 25% lower, at $294.

7. Conclusions

This analysis presents an overview of the behavior of retail prices for energy-efficient appliances over time, using newly available data. A comparison of price trends as compared to TSD predictions shows that the TSDs generally overestimated prices to consumers of higher-efficiency products, and, therefore, the costs to consumers and manufacturers of implementing energy standards. While higher-efficiency models are

generally more expensive than the baseline models, real prices for all models are falling over time. The regression analysis suggests several possible reasons for this trend, including overall technological change and technological change directed at producing more efficient appliances for lower cost, and lower markups charged to the customer. The analysis suggests that our current methods for forecasting post-standard equipment prices may insufficiently represent real-world industry trends. It points to a clear need to collect more real price data to clarify price response to standards and to incorporate market dynamics more realistically into the standards setting analyses to generate price trends more accurately.

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9. Endnotes

[1] Specific models are not identified in the appliance data set, so that it is not possible to identify changes in prices over time for specific model numbers.
[2] Refrigerator consumption is given by *adjusted volume*/*annual consumption*, where *adjusted volume*, is defined as *fresh food volume*+1.63×*freezer volume*.
[3] In the case that a listing in the AHAM directory was not found, the consumption estimate from *Consumer Reports* was used, and adjusted volume was estimated based on total refrigerator capacity.
[4] John Pietsch, Appliance Engineering Consultant. Personal communication.
[5] Bill Beard. Beard Engineering, Inc. Personal communication.
[6] Our empirical approach to testing for technological change is a simpler version of the model specified in Newell et al. (1999). That study added time-period dummy variables to indicate that efficiency standards had been implemented. Regression results indicated that both overall and directional technological change occurred in central air and room air-conditioners and water heaters but that standards did not have an effect in overall technological change and only induced energy-efficiency improvements during the period that standards were being implemented for room air conditioners.
[7] The limited variation in the coefficient associated with size in the regressions reported in Table 3 suggests that, for most appliances, price is a roughly linear function of size. We did not divide the refrigerator and clothes washer observations into separate size categories because our data set of these appliances was too small.
[8] Bill Beard. Beard Engineering, Inc. Joseph Pietsch. Engineering Consultant. Personal communication.
[9] The refrigerator TSDs show slightly higher appliance markups on higher-efficiency units.
[10] Air-Conditioning and Refrigeration Institute.
[11] Joseph Pietsch, P.E. Engineering consultant for HVAC energy systems.
[12] "Relatively small" price increases compared to observed cross-sectional price differentials between high- and low-efficiency appliances at any one time.
[13] The market share data by efficiency category, from the Air-Conditioning and Refrigeration Institute, was only available for central air conditioners.
[14] The Delta EER (Delta SEER, Delta Eff) variable is defined as the change in average efficiency (from previous to current period) across all units in any given year of the analysis.
[15] In Table 4, we have assumed that price is a linear function of size in order to focus on the impact of changes in appliance efficiency with a larger data set.
[16] The marginal markups may be lower if some costs of distribution are unaffected by the energy efficiency of the appliances.
[17] We performed a means comparison test of the hypothesis that the TSD forecast price of incremental changes in efficiency is larger than the market price, as measured from our regression analysis. This test indicates that the TSD price exceeds the market price in seven of 11 cases at the 90% confidence level. In four other cases, the TSD price exceeds the market price, but the difference is not significant at the 90% confidence level.