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ECONOMICS OF APPLIANCE EFFICIENCY

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ABSTRACT
This paper presents and applies an econometric approach to the identification and estimation of market models for refrigerators, clothes washers, dishwashers and room air conditioners. The main study results are follows. First, an increase in GDP increases the sales of both more efficient and less efficient refrigerators, clothes washers, dishwashers, and room air conditioners. Second, an increase in electricity price increases sales of Energy Star® refrigerators, clothes washers, dishwashers, and room air conditioners. Third, additional energy conservation activities launched following the 2001 California and Pacific Northwest energy crisis increased the sales of Energy Star refrigerators, clothes washers, dishwashers, and room air conditioners, thus further helping to transform these markets.

KEY WORDS
Identification and estimation, refrigerators, clothes washers, dishwashers air conditioners, market analysis and modelling.

1. Introduction

Market transformation programs create new challenges and opportunities for program evaluators. On the one hand, traditional evaluation techniques such as use of pre/post comparisons with treatment and control groups may not be possible if the treatment group is potentially the whole population. This means that new methods of measuring the impacts of demand side management (DSM) programs may need to be developed. On the other hand, econometric techniques, such as the interrupted time-series model, can potentially deal with confounding market effects including free riders and spill-over in a comprehensive and credible manner. This means that it may be possible to avoid subjective, and potentially unreliable, survey based approaches to measuring market transformation. This paper develops and applies the interrupted time-series model to measure market transformation in the U.S. markets for screw-type lighting and refrigerators.

Several previous studies have used econometric methods to analyze the impact of market transformation programs. Duke and Kammen [1] found that accounting for interaction between the demand response and production response for electronic ballasts increases the consumer benefit cost ratio. Horowitz [2] found that coordinated national electronic ballast programs were more cost effective than local efforts. Horowitz and Haeri [3] found that the cost of energy efficiency investments was fully capitalized in housing prices and that purchasing an energy efficient house was cost effective. Jaffe and Stavins [4] found that insulation levels in new residential housing appropriately reflect energy prices.

2. Market and Policy Developments

Through the late 1980's a number of utilities began to offer demand side management (DSM) programs in response to changes in the incentive mechanisms they were offered by Public Utility Commissions. The intent of these mechanisms was to put supply-side and demand-side options on an equal footing given evidence that it was sometimes more cost effective, at the margin, to change-out current technologies for new ones than to increase energy system capacity to handle ever larger energy loads. The development of integrated resource planning formalized the insights of DSM planners, provided a consistent framework in which the range of relevant energy supply options could be fairly compared, and led to the development of market-based policy initiatives to address energy efficiency concerns.

Although the utility DSM initiatives laid the groundwork for future activity, the launch of the modern era in energy conservation in the United States can perhaps most appropriately be linked to the launch of the Green Lights Program in 1991. The Environmental Protection Agency (EPA) Green Lights initiative was a voluntary partnership between the government and the private sector aimed at promoting energy efficient lighting in commercial and industrial establishments. Program emphasis was initially on electronic ballasts, T8 fluorescent tubes, CFLs and lighting controls. The Green Lights Program focused attention on gaining senior management support for voluntary initiatives to upgrade lighting in existing buildings.

The voluntary Energy Star program was introduced by the EPA in 1992. The focus of that program was to promote the sales of best in class products, typically those with energy efficiency about ten percent better than the market average, through testing, labeling and promotional activity. The first qualifying products were personal computers and monitors, but a number of products were subsequently added. These included refrigerators, clothes washers and room air conditions in 1996 and dishwashers in 1997.

A number of major developments occurred in 2001, and the econometric modelling in this study can be thought of as testing for the joint impact of these developments. These developments included: first, the Change a Light, Save the World promotion; second, the California energy crisis, and, third, the Pacific Northwest drought induced hydro power shortage. The Change a Light, Change the World program serves as a framework for the coordination of national, regional and local activities aimed at promoting coordinated public messages on the benefits of Energy Star qualifying lighting products. The California Energy Crisis was a direct fall-out of attempts to deregulate the California energy market which led to an electricity demand and supply gap. The Pacific Northwest drought led to substantial curtailments of electricity production, which affected not just the Pacific Northwest but California and the Southwestern United States more broadly.

A major result of these developments was a renewed and stronger emphasis on energy conservation. These developments included: market-pull activities to increase supply of energy efficiency appliances and lighting, including partnerships with retailers and manufacturers to influence price and product offerings; market-push activities to increase demand, including rebates, consumer education and promotions through radio, television, print and point of sale advertising; and time-of-use rates to shift peak and reduce consumption.

3. Method

This paper uses market analysis to understand the impact of energy conservation policy developments on sales of energy efficient appliances. The basic approach is straightforward: first, publicly available information is used to build a database of sales and drivers of sales; second, econometric models are used to estimate the determinants of sales; and, third, the regression results are used to estimate the individual impacts of prices, GDP and energy conservation policies on sales.

It is convenient to view a appliance market in isolation and abstract from linkages to other markets or from general equilibrium effects. Consider the following simple two-equation model, where (1) is the demand curve for a standard product, say a standard refrigerator, and (2) is the demand curve for an efficient product, say an Energy Star-qualifying refrigerator, where the standard and efficient products comprise the whole market. In these equations, $quantity_{it}$ is the residential and small commercial demand for product i in year t, $price_t$ is the average price of electricity in year t, GDP_t is the gross domestic product in year t (as a proxy for income), $dummy_t$ is a dummy variable that takes on the value 0 for the years up to the energy crisis (1997 through 2001) and the value 1 for the post-crisis years (2001-2004), ε_{it} is and error term and the symbols α, β, γ, and δ are parameters.

$$(1)\ quantity_{1t} = \alpha_1 + \beta_1\, price_t + \gamma_1\, GDP_t + \delta_1\, dummy_t + \varepsilon_{1t}$$

$$(2)\ quantity_{2t} = \alpha_2 + \beta_2\, price_t + \gamma_2\, GDP_t + \delta_2\, dummy_t + \varepsilon_{2t}$$

Equation (1) represents the demand for the first product in year t and says that demand for the first product is a linear function of the electricity price, gross domestic product and a preference variable which reflects a shift in consumer demand as a result of marketing and related activity. It would be desirable to include the prices of the first product and the second product as arguments on the right hand side of equation (1), but these are not available. Next, using the estimated parameters from the regressions, we take first differences of (1) and (2) in order to decompose the change in sales in a given year into price-related, GDP-related and DSM-related components. Noting that the first difference of a constant is zero and the first difference of the dummy variable is 1, we have (3) and (4) as follows.

$$(3)\ \Delta quantity_{1t} = \beta_1\, \Delta price_t + \gamma_1\, \Delta GDP_t + \delta_1$$

$$(4)\ \Delta quantity_{2t} = \beta_2\, \Delta price_t + \gamma_2\, \Delta GDP_t + \delta_2$$

4. Refrigerators

Model (1) shows the impact of gross domestic product and electricity price on sales of Energy Star refrigerators in thousands of units. Model (2) shows the impact of gross domestic product, electricity price and the demand side management dummy variable on sales of Energy Star refrigerators in thousands of units. Model (3) shows the impact of gross domestic product (GDP) and electricity price (price) on sales of non-Energy Star refrigerators in thousands of units. Model (4) shows the impact of gross domestic product, electricity price and the demand side management dummy variable on sales of non-Energy Star refrigerators in thousands of units. The explanatory power of the regressions is very good, most coefficients have the expected signs, and most coefficients are significant at the 10% level or above. Table 4 uses the regression results to provide an analysis of the changes in gross domestic product, residential electricity prices and demand side management on annual sales of Energy Star refrigerators. The price effect is an increase in sales of 0.2 million units in 2002, 0.6 million units in 2003 and 1.0 million units in 2004. The GDP effect is an increase in sales of 0.1 million units in 2002, 0.2 million units in 2003 and 0.4 million units in 2004. The DSM effect is an increase in sales of 1.1 million units in each of 2002, 2003 and 2004. The total effect is an increase in sales of 1.4 million units in 2002, 1.8 million units in 2003 and 2.4 million units in 2004.

Table 1. Refrigerator Sales Regressions (000)

	Energy Star refrigerators		Non-Energy Star refrigerators	
	(1)	(2)	(3)	(4)
Constant	-29,767 (4,919)	-18,957 (7,238)	-3,314 (3,188)	-2,317 (3,994)
GDP	0.0011 (0.00020)	0.00088 (0.00018)	0.0012 (0.00017)	0.0011 (0.00018)
Electricity	2,593 (682)	1,552 (819)	162 (438)	66 (490)
DSM dummy	-	1,065 (607)	-	98 (301)
R-squared	0.87	0.90	0.88	0.85
F	24.0 (0.00)	22.6 (0.01)	25.5 (0.00)	13.7 (0.01)
Durbin-Watson	1.62 (0.19)	2.85 (-0.43)	2.08 (-0.04)	2.25 (-0.13)

Table 2. Energy Star Refrigerator Sales Analysis

	2001	2002	2003	2004
Price (cents)	8.34	8.46	8.70	8.97
Price change (cents)	-	0.12	0.36	0.63
Price effect (000)	-	186	559	978
GDP ($B)	989100	10049	10321	10756
GDP change ($B)	-	158	272	435
GDP effect (000)	-	139	240	393
DSM effect (000)	-	1065	1065	1065
Total effect (000)	-	1390	1864	2438

Table 3. Clothes Washers Sales Regressions (000)

	Energy Star clothes washers		Non-Energy Star clothes washers	
	(5)	(6)	(7)	(8)
Constant	-14,658 (2,162)	-7,381 (2,971)	9,751 (2,903)	1,754 (3,392)
GDP	0.00078 (0.000087)	0.00063 (0.00010)	0.00088 (0.00014)	0.0010 (0.00015)
Electricity	958 (320)	257 (362)	-1,406 (461)	-636 (419)
DSM dummy	-	717 (256)	-	-788 (253)
R-squared	0.87	0.94	0.56	0.76
F	14.2 (0.00)	37.7 (0.00)	5.5 (0.05)	8.2 (0.03)
Durbin-Watson	1.43 (0.29)	2.73 (-0.40)	1.75 (-0.16)	2.81 (-0.42)

Table 4. Energy Star Clothes Washers Sales Analysis

	2001	2002	2003	2004
Price (cents)	8.34	8.46	8.70	8.97
Price change (cents)	-	0.12	0.36	0.63
Price effect (000)	-	31	93	162
GDP ($B)	989100	10049	10321	10756
GDP change ($B)	-	158	272	435
GDP effect (000)	-	100	171	274
DSM effect (000)	-	717	717	717
Total effect (000)	-	848	981	1,153

5. Clothes Washers

Model (9) shows the impact of gross domestic product and electricity price on sales of Energy Star clothes washers in thousands of units. Model (10) shows the impact of gross domestic product, electricity price and the demand side management dummy variable on sales of Energy Star clothes washers in thousands of units. Model (11) shows the impact of gross domestic product (GDP) and electricity price (price) on sales of non-Energy Star clothes washers in thousands of units. Model (12) shows the impact of gross domestic product, electricity price and the demand side management dummy variable on sales of non-Energy Star clothes washers in thousands of units. The explanatory power of the regressions is very good, most coefficients have the expected signs, and most coefficients are significant at the 10% level or above. Table 6 uses the regression results to provide an analysis of the changes in gross domestic product, residential electricity prices and demand side management on annual sales of Energy Star clothes washers. The price effect is an increase in sales of 31 thousand million units in 2002, 93 thousand units in 2003 and 162 thousand units in 2004. The GDP effect is an increase in sales of 0.1 million units in 2002, 0.2 million units in 2003 and 0.3 million units in 2004. The DSM effect is an increase in sales of 0.7 million units in each of 2002, 2003 and 2004. The total effect is an increase in sales of 0.8 million units in 2002, 1.0 million units in 2003 and 1.2 million units in 2004.

6. Room Air Conditioners

Model (13) shows the impact of gross domestic product and electricity price on sales of Energy Star room air conditioners in thousands of units. Model (14) shows the impact of gross domestic product, electricity price and the demand side management dummy variable on sales of Energy Star room air conditioners in thousands of units. Model (15) shows the impact of gross domestic product (GDP) and electricity price (price) on sales of non-Energy Star room air conditioners in thousands of units. Model (16) shows the impact of gross domestic product, electricity price and the demand side management dummy variable on sales of non-Energy Star room air conditioners in thousands of units. The explanatory power of the regressions is very good, most coefficients have the expected signs, and most coefficients are significant at the 10% level or above. Table 8 uses the regression results to provide an analysis of the changes in gross domestic product, residential electricity prices and demand side management on annual sales of Energy Star room air conditioners. The price effect is an increase in sales of 19 thousand units in 2002, 58 thousand units in 2003 and 101 thousand units in 2004. The GDP effect is an increase in sales of 0.1 million units in 2002, 0.2 million units in 2003 and 0.3 million units in 2004. The DSM effect is an increase in sales of 2.4 million units in each of 2002, 2003 and 2004. The total effect is an increase in sales of 2.6 million units in 2002, 2.7 million units in 2003 and 2.9 million units in 2004.

Table 5. Room Air Conditioner Sales Regressions (000)

	Energy Star room air conditioners		Non-Energy Star room air conditioners	
	(9)	(10)	(11)	(12)
Constant	-27,539 (5,662)	-6,640 (1,664)	24,224 (6,361)	7,883 (8,514)
GDP	0.0017 (0.00040)	0.00065 (0.000088)	0.0061 (0.00046)	0.0014 (0.00022)
Electricity	1,523 (1,031)	161 (197)	-3,086 (1,151)	-2,0330 (968)
DSM dummy	-	2,438 (129)	-	-1,091 (808)
R-squared	0.70	0.99	0.09	0.44
F	9.0 (0.02)	450.1 (0.00)	1.4 (0.34)	13.6 (0.02)
Durbin-Watson	2.04 (-0.02)	2.25 (-0.12)	2.72 (-0.36)	2.76 (-0.38)

Table 6. Room Air Conditioners Sales Analysis

	2001	2002	2003	2004
Price (cents)	8.34	8.46	8.70	8.97
Price change (cents)	-	0.12	0.36	0.63
Price effect (000)	-	19	58	101
GDP ($B)	989100	10049	10321	10756
GDP change ($B)	-	158	272	435
GDP effect (000)	-	103	177	283
DSM effect (000)	-	2,438	2,438	2,438
Total effect (000)	-	2,560	2,673	2,882

7. Dishwashers

Model (17) shows the impact of gross domestic product and electricity price on sales of Energy Star dishwashers in thousands of units. Model (18) shows the impact of gross domestic product, electricity price and the demand side management dummy variable on sales of Energy Star dishwashers in thousands of units. Model (19) shows the impact of gross domestic product (GDP) and electricity price (price) on sales of non-Energy Star dishwashers in thousands of units. Model (20) shows the impact of gross domestic product, electricity price and the demand side management dummy variable on sales of non-Energy Star dishwashers in thousands of units. The explanatory power of the regressions is very good, most coefficients have the expected signs, and most coefficients are significant at the 10% level or above. Table 10 uses the regression results to provide an analysis of the changes in gross domestic product, residential electricity prices and demand side management on annual sales of Energy Star dishwashers. The price effect is an increase in sales of 0.3 million units in 2002, 1.0 million units in 2003 and 1.7 million units in 2004. The GDP effect is an increase in sales of 0.1 million units in 2002, 0.2 million units in 2003 and 0.3 million units in 2004. The DSM effect is an increase in sales of 0.5 million units in each of 2002, 2003 and 2004. The total effect is an increase in sales of 1.0million units in 2002, 1.7 million units in 2003 and 2.5 million units in 2004.

Table 7. Dishwasher Sales Regressions (000)

	Energy Star dishwashers		Non-Energy Star dishwashers	
	(13)	(14)	(15)	(16)
Constant	-33,529 (11,970)	-29,165 (14,330)	27,390 (11,110)	27,486 (13,420)
GDP	0.0010 (0.00032)	0.00080 (0.00037)	0.00017 (0.00027)	0.00017 (0.00031)
Electricity	2,967 (1,304)	2,683 (1,428)	-2,935 (1,142)	-2,940 (1,310)
DSM dummy	-	508 (874)	-	11 (1,310)
R-squared	0.55	0.46	0.17	0.12
F	5.30 (0.06)	3.06 (0.06)	1.8 (0.26)	0.94 (0.50)
Durbin-Watson	2.60 (-0.30)	2.51 (-0.25)	2.64 (-0.32)	2.64 (-0.32)

Table 8. Energy Star Dishwasher Sales Analysis

	2001	2002	2003	2004
Price (cents)	8.34	8.46	8.70	8.97
Price change (cents)	-	0.12	0.36	0.63
Price effect (000)	-	322	966	1,690
GDP ($B)	989100	10049	10321	10756
GDP change ($B)	-	158	272	435
GDP effect (000)	-	126	218	348
DSM effect (000)	-	508	508	508
Total effect (000)	-	956	1,692	2,546

8. Conclusion

The main study results are follows. First, an increase in GDP increases the sales of both more efficient and less efficient refrigerators, clothes washers, dishwashers, room air conditioners. Second, an increase in electricity price increases sales of Energy Star® refrigerators, clothes washers, dishwashers, room air conditioners. Third, additional energy conservation activities launched following the 2001 California and Pacific Northwest energy crisis increased the sales of Energy Star refrigerators, clothes washers, dishwashers, room air conditioners, thus further helping to transform these markets.

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