Impact of Energy Prices and Energy Efficiency Activities on Sales of ENERGY STAR® Appliances in California

K. H. Tiedemann, BC Hydro, Vancouver, BC

Abstract

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, but on the other hand, econometric techniques, such as the interrupted time-series model, can potentially deal with confounding market effects in a comprehensive and credible manner. This study develops and applies the interrupted time-series model to measure market transformation in the California markets for refrigerators, clothes washers and dishwashers using quarterly sales data for the period 1998-2003. This study has three main conclusions. First, an increase in electricity price increases the sales of ENERGY STAR qualifying refrigerators, clothes washers and dishwashers. Second, additional energy efficiency activities launched following the 2001 California energy crisis increased the sales of ENERGY STAR refrigerators, clothes washers and dishwashers. Third, the combined first year reductions in energy consumption for the three appliances were 12.03 GWh in 2002 and 24.06 GWh in 2003 using ordinary least squares regression models, and 11.87 GWh in 2002 and 23.74 GWh in 2003, using maximum likelihood regression models.

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/comparison groups may not be possible if the treatment group is potentially the whole population. This means that new methods of measuring the impacts of 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 spillover 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.

Several previous studies have used econometric methods to analyze the impact of market transformation programs. Nadel et al. (2003) provided a comprehensive overview of market transformation activities in the United States. Duke and Kammen (1999) found that accounting for interaction between the demand response and production response for electronic ballasts increases the consumer benefit-cost ratio. Horowitz (2001) found that coordinated national electronic ballast programs were more cost effective than local efforts. Horowitz and Haeri (1990) 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 (1995) found that insulation levels in new residential housing appropriately reflect energy prices. Tiedemann (2004) applied an econometric approach similar to that used here to an analysis of the China Green Lights program, and he found that the program had statistically significant positive impacts on sales of more efficient and negative impacts on sales of less efficient lighting products. While building on these studies, this paper attempts to provide a comprehensive approach to market analysis by examining the impact of economic activity, price and energy efficiency activities on sales of ENERGY STAR and non-ENERGY STAR qualifying product.

A number of papers have examined the impact of the ENERGY STAR program using marketing and engineering rather than econometric methods. Titus and Feldman (2003) define the analytical and data requirements for tracking the effectiveness of energy-efficient appliance programs, and they apply their model to the Wisconsin Focus on Energy CFL Program and to the Efficiency Vermont appliance program. Rosenberg (2003) uses cross-section state data to estimate the determinants of ENERGY STAR market share for the four appliances included in the present study. Webber, Brown and Koomey (2000) provide a comprehensive set of both historical energy savings and forecast savings due to ENERGY STAR. They explore the magnitude and allocation of ENERGY STAR savings in detail, but they do not examine the determinants of sales of ENERGY STAR and non-ENERGY STAR products, which is the focus of this paper. Wenzel et al. (1997) provide a detailed sourcebook on energy use in the residential sector, and they include detailed estimates of energy consumption by end use. Meyers et al. (2003) estimate historical and forecast impacts of ENERGY STAR sales on energy use and carbon emissions, and they estimate that ENERGY STAR products saved 740 petajoules of energy and 13 million metric tons of carbon emissions through 1999. Mauldin et al (2005) examine determinants of prices for ENERGY STAR and non-ENERGY STAR room air conditioners.

An outline of this paper is as follows. The next section briefly describes market and regulatory developments in the California market for major appliances. This is followed by an outline of the data sources, the statistical model, the approach of the study and the hypotheses to be tested. Following sections examine the results of the market analysis and regression modeling for refrigerators, clothes washers and dishwashers. The final section provides the conclusions.

Market and Regulatory Developments

Energy efficiency standards and labeling in the United States were established under the National Appliance Energy Conservation Act (NAECA) 1987 for a wide range of products. These included major household appliances such as refrigerators, clothes washers and dishwashers. In general, the energy efficiency standards were aimed at ensuring that all products offered for sales met minimum levels of energy efficiency to protect both consumers and manufacturers. The labeling requirements were put in place to assist consumers in making informed choices and ensure that performance claims were both correct and justified.

ENERGY STAR and a wide range of government and utility energy efficiency programs were particularly prominent in California, and were estimated to have reduced electricity demand in California by almost 10,000 MW by the late 1990s [California Energy Commission (1999)]. But following initial discussions on electricity market deregulation, the major California utilities reduced their budgets for energy conservation by more than one-half, thus reducing the potential impact of DSM on the electricity load [Environmental Working Group (2000)]. On January 17-18, 2001, blackouts affected several hundred thousand customers with Governor Davis declaring a state of emergency on January 17, 2001. Further blackouts on March 19-20, 2001 affected a further 1.5 million customers. The State Government moved rapidly to implement a number of energy efficiency and energy conservation programs in order to avoid further blackouts, including, perhaps most prominently, the Governor's 20/20 Rebate Program, which provided a 20% rebate on electricity bills for customers able to reduce their energy use by 20% during the June through September billing period [LBL (2001)]. Energy efficient appliances, including in particular those qualifying for ENERGY STAR, received additional promotion including: (1) market-pull activities to increase supply of ENERGY STAR qualifying appliances and (2) market-push activities to increase demand, including rebates, consumer education and promotions through radio, television, print and point of sale advertising.

Data, Hypothesis and Approach

We model sales of ENERGY STAR appliances as a function of the price of electricity and DSM activity. For this study, we use quarterly information on California appliance sales taken from Itron (2006). This source provides detailed information on estimated quarterly sales of refrigerators, clothes washers and dishwashers for the period 1988:1 through 2005:4. Information for 2004 and 2005 was not used because of major changes made to the ENERGY STAR standards effective January 1, 2004. The nominal average residential price of electricity was taken from the California Energy Commission (2007) and was deflated by the California consumer price index (CPI) taken from the California Department of Finance (2007). The ramping up of appliance-related DSM activity was modeled as a linear spline that takes the value 0 from 1998:1 through 2001:4 and then takes the value 0.25 for 2002:1 and increases by 0.25 per quarter through 2003:4, so that it takes the value 2.0 in the last quarter covered by the analysis. This spline can be though of a dummy variable that increases in magnitude, rather than remaining constant, to reflect ramping up of DSM activity, with an implicit lag to account for the fact that wholesalers and retailers order white goods many months in advance of anticipated sales. In summary, the regression model used is given by Equations (1).

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

In these equations, $quantity_{it}$ is residential sales in California for appliance (i) at time (t), $price_t$ is the unit price of electricity for residential customers at time (t), $dummy_t$ is the spline defined above, and ε_{1t} is the error term for the equation at time (t). This model is sometimes referred to as a regression discontinuity model because the dummy variable creates a jump or a discontinuity in the regression. Equation (1) says that demand in year (t) is a linear function of electricity price, a preference variable, which represents a shift in consumer demand as a result of DSM marketing activity, and an error term. The error term is modeled first as a normal variable in which the errors are independent over time and second as a first-order autoregressive scheme in which the current period error is a function of the previous period error plus an additional current period shock that has the normal distribution.

We assume that consumers base purchase decisions, at least in part, on the assessment of some financial criteria such as pay-back period or life cycle costs. Because comprehensive information on customer costs and benefits is not available, we apply a modified analysis in which consumers consider the cost of electricity in making purchase decisions on energy using products. An increase in the price of electricity shifts purchases towards more energy efficient products, while a decrease in the price of electricity shifts purchases towards less energy efficient products. This then gives us Hypothesis 1.

Hypothesis 1: An increase in electricity price increases sales of ENERGY STAR refrigerators, clothes washers and dishwashers.

Barriers to increased sales of energy efficient products include inadequate consumer and trade ally awareness and knowledge of the features, benefits and cost effectiveness of energy efficient products. DSM marketing efforts are aimed, in part, at overcoming these barriers and thereby increasing demand for more energy efficient products. This then gives us Hypothesis 2.

Hypothesis 2: An increase in DSM marketing increases sales of ENERGY STAR refrigerators, clothes washers and dishwashers.

We model the impact of changes in sale of ENERGY STAR appliances on energy use using simple algorithms as shown in Equation (2).

$$(2) \qquad \Delta\, energy\ consumption = \Delta\, quantity \cdot (consumption\ of\ ES\ model - consumption\ of\ standard\ model)$$

In these equations, Δ energy consumption is the reduction in energy consumption due to increased sales of the appliance, Δ quantity is the change in sales of the appliance, and consumption of the typical

Energy Star compliant model and the typical standard model of the appliance are based on information using the energy use calculators formerly maintained at the Energy Star website [EPA(2006)].

Refrigerators

Table 1 presents the results of the regression modeling for refrigerators. Column (1) shows the results for the ordinary least squares (OLS) regressions, and Column (2) shows the results for the maximum likelihood (ML) regressions, with the standard error for each regression coefficient below the regression coefficient. For Equation (1), the coefficients on electricity price and DSM trend have the expected signs and are statistically significant. A one cent increase in electricity price increases the number of ENERGY STAR refrigerators sold by 13,646 for equation (1) and 13,533 for Equation (2). An additional year of post-2001 DSM activity increases the number of ENERGY STAR refrigerators sold by 47,671 for Equation (1) and 49,042 for Equation (2).

Table 1. Refrigerator Regression Models (1998:1-2003:4)

Variable/statistic	OLS Regressions (units) (1)	ML Regressions (units) (2)
Constant	-31,920 (75,790)	-30,642 (71,210)
Electricity price	13,646* (6,632)	13,533* (6,232)
DSM trend	47,671* (16,320)	49,042* (15,550)
Adjusted R-squared	0.62	0.65
Durbin-Watson statistic	1.91 (0.04)	2.08 (-0.04)
Sample size	24 quarters	24 quarters

Note. Standard errors for coefficients and the estimated auto-correlation coefficient are shown in parentheses, and an asterisk mean that coefficient is significant at the 10% level.

Table 2 provides calculated energy savings due to additional sales of ENERGY STAR refrigerators. Estimated energy savings for an ENERGY STAR qualifying 23 cubic foot automatic defrost refrigerator with top-mounted freezer is 104 kWh per year. Estimated first year savings are 4.96 GWh for the OLS model and 5.10 GWh for the ML model, while estimated second year savings are 9.92 GWh for the OLS model and 10.20 GWh for the ML model.

Table 2. Refrigerator Sales and Energy Savings Results

Year	OLS Results			Maximum Likelihood Results		
	Additional units sold	Savings per unit	First year GWh savings	Additional units sold	kWh Savings per unit	First year GWh savings
2002	47,671	104	4.96	49,042	104	5.10
2003	95,342	104	9.92	98,084	104	10.20

Clothes Washers

Table 3 presents the results of the regression modeling for clothes washers. Column (1) shows the results for the ordinary least squares (OLS) regressions, and Column (2) shows the results for the maximum likelihood (ML) regressions, with the standard error for each regression coefficient below the regression coefficient. For Equation (1), the coefficients on electricity price and DSM trend have the expected signs and are statistically significant. A one cent increase in electricity price increases the number of ENERGY STAR refrigerators sold by 1,812 for equation (1) and 1,789 for Equation (2). An additional year of post-2001 DSM activity increases the number of ENERGY STAR refrigerators sold by 13,333 for Equation (1) and 13,327 for Equation (2).

Table 3. Clothes Washers Regression Models (1998:1-2003:4)

Variable/statistic	OLS Regressions (units) (1)	ML Regressions (units) (2)
Constant	84,589* (35,980)	84,840* (35,490)
Electricity price	1,812* (910)	1,789* (892)
DSM trend	13,333* (7,749)	13,327* (7,669)
Adjusted R-squared	0.22	0.26
Durbin-Watson statistic	1.93 (0.03)	2.03 (-0.02)
Sample size	24 quarters	24 quarters

Note. Standard errors for coefficients and the estimated auto-correlation coefficient are shown in parentheses, and an asterisk mean that coefficient is significant at the 10% level.

Table 4 provides calculated energy savings due to additional sales of ENERGY STAR clothes washers. Estimated energy savings for an ENERGY STAR qualifying clothes washer with eight loads per week is 286 kWh per year. Estimated first year savings are 3.81 GWh for the OLS model and 3.81 GWh for the ML model, while estimated second year savings are 7.62 GWh for the OLS model and 7.62 GWh for the ML model.

Table 4. Clothes Washer Sales and Energy Savings Results

Year	OLS Results			Maximum Likelihood Results		
	Additional units sold	Savings per unit	First year GWh savings	Additional units sold	kWh Savings per unit	First year GWh savings
2002	13,333	286	3.81	13,327	286	3.81
2003	26,666	286	7.62	26,654	286	7.62

Dishwashers

Table 5 presents the results of the regression modeling for dishwashers. Column (1) shows the results for the ordinary least squares (OLS) regressions, and Column (2) shows the results for the maximum likelihood (ML) regressions, with the standard error for each regression coefficient below the regression coefficient. For Equation (1), the coefficients on electricity price and DSM trend have the expected signs and are statistically significant. A one cent increase in electricity price increases the number of ENERGY STAR refrigerators sold by 23,374 for equation (1) and 24,409 for Equation (2). An additional year of post-2001 DSM activity increases the number of ENERGY STAR refrigerators sold by 45,229 for Equation (1) and 41,139 for Equation (2).

Table 5. Dishwasher Regression Models (1998:1-2003:4)

Variable/statistic	OLS Regressions (units) (1)	ML Regressions (units) (2)
Constant	-212,171* (38,690)	-223,882* (53,070)
Electricity price	23,374* (3,386)	24,409* (4,636)
DSM trend	45,229* (8,333)	41,139* (10,070)
Adjusted R-squared	0.91	0.26
Durbin-Watson statistic	0.98 (0.51)	0.92 (0.22)
Sample size	24 quarters	24 quarters

Note. Standard errors for coefficients and the estimated auto-correlation coefficient are shown in parentheses, and an asterisk mean that coefficient is significant at the 10% level.

Table 2 provides calculated energy savings due to additional sales of ENERGY STAR refrigerators. Estimated energy savings for an ENERGY STAR dishwasher with energy factor of 0.52 compared to a non-ENERGY STAR qualifying dishwasher with energy factor of 0.63 with both used for four loads per week is 72 kWh per year. Estimated first year savings are 3.26 GWh for the OLS model and 2.96 GWh for the ML model, while estimated second year savings are 6.51 GWh for the OLS model and 5.92 GWh for the ML model.

Table 6. Dishwasher Sales and Energy Savings Results

Year	OLS Results			Maximum Likelihood Results		
	Additional units sold	Savings per unit	First year GWh savings	Additional units sold	kWh Savings per unit	First year GWh savings
2002	45,229	72	3.26	41,139	72	2.96
2003	90,458	72	6.51	82,278	72	5.92

Conclusions

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, but on the other hand, econometric techniques, such as the interrupted time-series model, can potentially deal with confounding market effects in a comprehensive and credible manner. This study develops and applies the interrupted time-series model to measure market transformation in the California markets for refrigerators, clothes washers and dishwashers using quarterly sales data for the period 1998-2003. This study has three main conclusions. First, an increase in electricity price increases the sales of ENERGY STAR qualifying refrigerators, clothes washers and dishwashers. Second, additional energy efficiency activities launched following the 2001 California energy crisis increased the sales of ENERGY STAR refrigerators, clothes washers and dishwashers. Third, the combined first year reductions in energy consumption for the three appliances were 12.03 GWh in 2002 and 24.06 GWh in 2003 using ordinary least squares regression models, and 11.87 GWh in 2002 and 23.74 GWh in 2003, using maximum likelihood regression models.

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