Transforming U.S. lighting and appliance markets

K. H. Tiedemann
BC Hydro
Canada
ken.tiedemann@bchydro.com

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Abstract
This paper reviews the results of a detailed assessment of US screw-type lamp and refrigerator markets. The study approach was as follows. First, information from annual surveys of sales of lighting products and refrigerators was used to build a database of product sales and drivers of product sales by efficiency type. Second, ordinary least squares regression analysis was used to model the impact of gross domestic product, electricity prices and demand side management on product sales for energy efficient and standard products. Third, the regression output was combined with the database information to estimate the impact of changes in electricity prices, gross domestic product and demand side marketing activity on sales of energy efficient and standard products.

Introduction
The present study extends the commonly applied conditional demand analysis framework in order to produce both end-use consumption and end-use savings estimates. 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, linear fluorescent lighting, refrigerators, clohes washers and dishwashers.

Several previous studies have used econometric methods to analyze the impact of market transformation programs. 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.

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 and 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 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 cutaiolments of electricty 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 applainces 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.

Method

It is convenient to view a single lamp or 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 type-A incandescent lamps, and (2) is the demand curve for an efficient product, say compact fluorescent lamps, 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, $price_t$ if 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. Equation (2) represents the demand for the second product in year t and says that demand for the second 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 also be desirable to include the prices of the first product and the second product as arguments on the right hand side of equation (2), but these are not available. The information used in the regressions comes from the annual RER/Itron surveys of sales of lighting products, Department of Energy (DOE) information on sales of Energy Star-qualifying and non-qualifying products and Bureau of Economic Analysis (BEA) information on energy prices and GDP.

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.

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

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

Screw-type lamps

Table 1 presents the results of the ordinary least squares regression modelling for screw-type lamps. Coefficient standard errors are shown in parentheses below the coefficients and the significance of a linear regression is shown below the F-test value. Model (1) shows the impact of gross domestic product (GDP in billions of US dollars at 2000 prices) and electricity price (price in US cents) on sales of compact fluorescent lamps 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 compact fluorescent lamps in thousands of units. The DSM dummy variable takes the value

Table 1. Lamp sales regressions (000)

	Compact fluorescent lamps		Incandescent lamps	
	(1)	(2)	(3)	(4)
Constant	-263,133*** (61,690)	-171,970** (72,430)	2,715,190*** (381,700)	2,059,020*** (536,300)
GDP	0.010*** (0.0027)	0.0056** (0.0025)	0.089*** (0.014)	0.12*** (0.014)
Price	21,324** (8,501)	15,396** (7,551)	-274,975*** (55,040)	-232,304*** (56,630)
DSM dummy	-	10,605** (4,950)	-	-76,336** (35,770)
R-squared	0.79	0.85	0.56	0.70
F	13.8 (0.01)	14.6 (0.01)	5.5 (0.06)	6.4 (0.05)
Durbin-Watson	1.60 (0.20)	2.00 (0.01)	1.45 (0.28)	1.07 (0.46)

Note: One, two or three asterisks indicate the coefficient is significant at the 10 %, 5 % or 1 % level respectively.

Table 2. Compact fluorescent lamp sales analysis

	Price (US$)	Price change (US$)	Price effect (000)	GDP (US$ M)	GDP change (US$ M)	GDP effect (000)	DSM effect (000)	Total effect (000)
2001	8.34	-	-	9891000	-	-	-	-
2002	8.46	0.12	1848	10049000	158000	885	10605	13338
2003	8.70	0.36	5543	10321000	272000	1523	10605	17671
2004	8.97	0.63	9699	10756000	435000	2436	10605	22740

Table 3. Incandescent lamp sales analysis

	Price (US$)	Price change (US$)	Price effect (000)	GDP (US$ M)	GDP change (US$ M)	GDP effect (000)	DSM effect (000)	Total effect (000)
2001	8.34	-	-	9891000	-	-	-	-
2002	8.46	0.12	-27877	10049000	158000	18960	-76336	-85253
2003	8.70	0.36	-83629	10321000	272000	32640	-76336	-127325
2004	8.97	0.63	-146352	10756000	435000	52200	-76336	-170488

0 for the years 1997-2001 and the value 1 for the years 2002-2004 as explained above. Model (3) shows the impact of gross domestic product (GDP) and electricity price (price) on sales of incandescent lamps 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 compact fluorescent lamps in thousands of units. The next section uses a similar analysis.

The regression modelling is successful since each equation explains at least 56 % of the variance or more, as given by the adjusted R-squared values, all the coefficients have the expected signs, and they are all statistically significant at the 10 % level or better. An increase in gross domestic product increases sales of compact fluorescent lamps and of incandescent lamps. An increase in the residential price of electricity increases the sales of energy efficient compact fluorescent lamps and reduces the sales of less efficient incandescent lamps. Energy crisis motivated DSM activities increase the sales of compact fluorescent lamps and decrease the sales of incandescent lamps.

Table 2 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 compact fluorescent lamps. The price effect is the product of the price coefficient from equation (2) above times the incremental price change calculated in the third column using the information in the second column of the table. The price effect is an increase in compact fluorescent lamp sales by 1.8 million units in 2002, 5.5 million units in 2003 and 9.7 million units in 2004. The GDP effect is the product of the GDP coefficient from equation (2) times the change in GDP calculated in the sixth column from the information in the fifth column of the table. The GDP effect is an increase of compact fluorescent sales of 0.9 million units in 2002, 1.5 million units in 2003 and 2.4 million units in 2004. The DSM effect is just the coefficient of the DSM term from equation (2). The DSM effect is an increase in sales of compact fluorescent lamps of 10.6 million units in each of 2002, 2003 and 2004. Finally, the total effect is the sum of the price effect plus the GDP effect plus the DSM effect. The total effect is an increase in sales of compact fluorescent lamps of 13.3 million units in 2002, 17.7 million units in 2003 and 22.7 million units in 2004. Note that the same methodology is applied to sales analysis for each of the technologies examined in this paper.

Table 3 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 type-A

Table 4. Refrigerator sales regressions (000)

	Energy Star refrigerators		Non-Energy Star refrigerators	
	(9)	(10)	(11)	(12)
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)
Energy price	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)

Note: One, two or three asterisks indicate the coefficient is significant at the 10%, 5% or 1% level respectively.

Table 5. Energy Star refrigerator sales analysis

	Price (US$)	Price change (US$)	Price effect (000)	GDP (US$ M)	GDP change (US$ M)	GDP effect (000)	DSM effect (000)	Total effect (000)
2001	8.34	-	-	9891000	-	-	-	-
2002	8.46	0.12	186	10049000	158000	139	1065	1390
2003	8.70	0.36	559	10321000	272000	240	1065	1864
2004	8.97	0.63	978	10756000	435000	393	1065	2436

Table 6. Non-Energy Star refrigerator sales analysis

	Price (US$)	Price change (US$)	Price effect (000)	GDP (US$ M)	GDP change (US$ M)	GDP effect (000)	DSM effect (000)	Total effect (000)
2001	8.34	-	-	9891000	-	-	-	-
2002	8.46	0.12	19	10049000	158000	174	66	259
2003	8.70	0.36	58	10321000	272000	299	66	423
2004	8.97	0.63	102	10756000	435000	479	66	647

incandescent lamps. The price effect is a reduction in incandescent lamps sales by 27.9 million units in 2002, 83.6 million units in 2003 and 146.4 million units in 2004. The GDP effect is an increase of incandescent lamp sales of 19.0 million units in 2002, 32.6 million units in 2003 and 52.2 million units in 2004. The DSM effect is a decrease in sales of incandescent lamps of 76.3 million units in each of 2002, 2003 and 2004. The total effect is a decrease in sales of incandescent lamps of 85.2 million units in 2002, 127.3 million units in 2003 and 170.5 million units in 2004.

Refrigerators

Table 4 presents the results of the ordinary least squares regression modelling for refrigerators. Model (9) shows the impact of gross domestic product and electricity price on sales of Energy Star refrigerators 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 refrigerator in thousands of units. Model (11) shows the impact of gross domestic product (GDP) and electricity price (price) on sales of non-Energy Star refrigerators 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 refrigerators tubes 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 5 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 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 non-Energy Star refrigerators. The price effect is an increase sales by 0.02 million units in 2002, 0.06 million units in 2003 and 0.1 million units in 2004. The GDP effect is an increase in sales of 0.2 million units in 2002, 0.3 million units in 2003 and 0.5 million units in 2004. The DSM effect is an increase in sales of 0.07 million units in each of 2002, 2003 and 2004. The total effect is an increase in sales of 0.3 million units in 2002, 0.4 million units in 2003 and 0.6 million units in 2004.

Conclusions

This paper reviews the results of a detailed assessment of U.S. compact fluorescent lamp and refrigerator markets. The study approach was as follows. First, information from annual surveys of sales of lighting products and refrigerators was used to build a database of product sales and drivers of product sales by efficiency type. Second, ordinary least squares regression analysis was used to model the impact of gross domestic product, electricity prices and demand side management on product sales for energy efficient and standard products. Third, the regression output was combined with the database information to estimate the impact of changes in electricity prices, gross domestic product and demand side marketing activity on sales of energy efficient and standard products.

This paper has four main findings as follows. First, an increase in GDP increases the sales of CFLs, incandescent lamps, Energy Star refrigerators and non-Energy Star refrigerators. Second, an increase in electricity price increases sales of more energy-efficient CFLs and Energy Star refrigerators, decreases sales of less energy-efficient incandescent lamps but has an insignificant effect on non-Energy Star refrigerator sales. Third, an increase in DSM marketing increases sales of more energy-efficient CFLs and Energy Star refrigerators, decreases sales of less energy-efficient incandescent lamps but again does not have a significant impact on sales of non-Energy Star refrigerators. Fourth, econometric analysis using interrupted time-series modelling appears to be a viable and useful alternative to traditional survey-based methods of estimating net effects of energy conservation programs.

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