Modelling Energy Savings and Cost Effectiveness Performance: A Regression Analysis of North American Residential Lighting Programs

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Introduction

- By the mid-1980s, a number of electric utilities in Canada and the United States were offering demand side management (DSM) programs which encouraged their customers to increase energy efficiency and reduce energy consumption
- For the residential sector, lighting programs have been the largest source of energy savings in many jurisdictions , driven initially by energy efficient CFLs and CFL fixtures and more recently by LEDs and LED fixtures
- There is considerable published research on residential energy efficient lighting programs, but there appear to be no published quantitative studies of the impact of marketing variables on energy savings and cost effectiveness

Introduction

- This study helps fill this gap by:

(1) building a database of comparable marketing information for a set of twenty residential energy efficient lighting programs in North America;

(2) estimating program savings and the cost of conserved energy using suitable engineering algorithms for each program; and

(3) using appropriate regression modelling to explore the determinants of program energy savings and the cost of conserved energy

Outline

- Program summaries
- Development of outcome variables
- Regression modelling approach
- Data
- Determinants of energy savings
- Determinants of cost effectiveness
- Conclusions

Program Summaries

- An extensive literature review was undertaken to understand the values of these various parameters used in recent studies, calculate energy savings, and collect additional information to inform the econometric modelling
- Data bases examined included the Social Science Research Network, the Consortium for Energy Efficiency, the California Measurement Advisory Council (CALMAC), International Energy Program Evaluation Conference Proceedings (IEPEC) and Scopus
- Detailed information was found for **twenty residential lighting programs** as discussed below

Program Summaries (1)

Program	Products				Marketing	
	CFLs	CFL fix	LEDs	LED fix	Down	Up
Allegheny	X	-	-	-	X	-
Ameren Il	X	-	-	-	-	X
Avista	X	-	-	-	X	-
BC Hydro	X	X	-	-	X	-
Com Ed	X	X	-	-	X	-
Connecticut	X	X	X	X	X	X
E. Vermont	X	X	X	X	X	X
ET Oregon	X	-	-	-	-	X
Fortis BC	X	-	X	X	X	-
Hydro Quebec	X	X	-	X	X	X

Program Summaries (2)

Program	Products				Marketing	
	CFLs	CFL fix	LEDs	LED fix	Down	Up
Long Island	X	X	-	-	X	X
NV Energy	X	X	-	-	X	-
PacifiCorp	X	X	-	-	X	-
PG&E	X	X	X	X	-	X
Platte River	X	-	-	-	X	-
Potomac	X	-	-	-	X	-
Progress	X	-	-	-	X	-
SMUD	X	X	-	X	X	X
Salt River	X	-	-	-	X	-
SCE	X	X	X	X	-	X

Development of Outcome Variables

- The first outcome variable is net energy savings as given by algorithm (1), where key parameters in this algorithm are the difference in watts between the base and the efficient technology (ΔW), annual hours of use (Hours), the installation rate net of replacements which is often called the in-service rate (Install), the free rider rate (FR), the spillover rate (SO), and the number of rebated measures (No)
- For first-year energy savings net energy savings, the basic algorithm is:

$$\Delta kWh = \Delta W/1000 \cdot Hours \cdot Install \cdot (1 - FR + SO) \cdot No. \quad (1)$$

Development of Outcome Variables

- The second outcome variable is the utility cost of conserved energy where CCE is the utility cost of conserved energy in dollars per kWh, Cost is the utility cost in millions of dollars, GWh is annual energy savings in GWh, i is the discount rate which is assumed to be 5% based on the typical utility cost of capital, and n is the length of life of an energy efficient lamp which is assumed to be six years, given typical stated lifetime of 6,000 hours and typical annual use of about 1,000 hours.

$$CCE = \{Cost/GWh\}\cdot\{[i/[1 - (1 + i)^{-n}]^{-1}\} \qquad (2)$$

Regression Modelling Approach

- We model the impact of the energy efficient lighting programs on energy savings, where ΔGWh is savings for the ith utility in gigawatt hours, α is the constant term, Bud is the annual program budget in millions of U.S. dollars, Bre is a dummy variable which takes the value zero if the program promotes only CFLs and takes on the value one if the program promotes additional energy efficient lighting, Mar is a dummy variable which takes on the the value zero if the program uses only upstream or downstream marketing and takes on the value one if the program uses both upstream and downstream marketing, and ε is an error term

$$\Delta GWh_i = \alpha + \beta_1 Bud_i + \beta_2 Bre_i + \beta_3 Mar_i + \varepsilon_i \qquad (3)$$

Regression Modelling Approach

- Based on the findings of our literature review, our hypotheses on these parameters are as follows.

H11: An increase in the program budget increases energy savings ($\beta_1 > 0$).

H12: An increase in the breadth of the program increases energy savings ($\beta_2 > 0$).

H13: An increase in the depth of the marketing increases energy savings ($\beta_3 > 0$).

Regression Modelling Approach

- We model of the impact of the energy efficient lighting programs on the cost of conserved energy, where ΔCCE is the estimated constant of conserved energy from the utility perspective, α is the constant term, Bud is the annual program budget in millions of U.S. dollars, Bre is a dummy variable which takes the value zero if the program promotes only CFLs and takes on the value one if the program promotes additional energy efficient lighting, Mar is a dummy variable which takes on the value zero if the program uses only upstream or downstream marketing and takes on the value one if the program uses both upstream and downstream marketing, and ε is an error term

$$\Delta CCE_i = \alpha + \beta_1 Bud_i + \beta_2 Bre_i + \beta_3 Mar_i + \varepsilon_i \qquad (4)$$

Regression Modelling Approach

- Based on the findings of our literature review, our hypotheses on these parameters are as follows.

H21: An increase in the program budget increases the cost of conserved energy ($\beta_1 > 0$).

H22: An increase in the breadth of the program decreases the cost of conserved energy ($\beta_2 < 0$).

H23: An increase in the depth of the marketing stream used decreases the cost of conserved energy ($\beta_3 < 0$).

Data

Variable	Metric	Mean	Standard dev.
Savings	GWh/year	98.9	148.7
Budgets	$million/year	11.8	21.1
Cost conserved energy	$/kWh	0.035	0.054
Breadth of offer	0 = CFLs only, 1 = CFLs plus other	0.60	0.50
Depth of marketing	0 = upstream or downstream, 1 = both	0.20	0.41

Determinants of Energy Savings

- Next table shows the results of the regression modelling of the determinants of energy savings, where the dependent variable is energy savings in GWh per year
- The standard errors for the regression coefficients are shown in parentheses below the regression coefficients, and the levels of significance for the F-tests are shown below the F statistics in parentheses
- One asterisk indicates that the regression coefficient is significant at the 10% level, two asterisks indicate that the regression coefficient is significant at the 5% level, and three asterisks indicate that the regression coefficient is significant at the 1% level
- White's method was used because of evidence of heteroscedasticity

Determinants of Energy Savings

- Model 1 includes the program budget and the breadth of the program as independent variables, and it says that a one million dollar increase in program budget increases energy savings by 5.4 GWh per year and having a broader breadth of lighting products increases energy savings by 89.6 GWh per year
- Model 2 includes the program budget and the depth of marketing as independent variables, and it says that a one million dollar increase in program budget increases energy savings by 6.0 GWh per year.
- Model 3 includes the program budget, the breadth of lighting products, and the depth of marketing as the independent variables, and it says that a one million dollar increase in program budget increases energy savings by 5.6 GWh per year and having a wider range of product offerings increases energy savings by 77.3 GWh per year

Determinants of Energy Savings (GWh/y)

	Model 1	Model 2	Model 3
Constant	-18.8 (19.3)	12.5 (8.9)	-20.0 (19.5)
Budget	5.4*** (0.85)	6.0*** (0.99)	5.6*** (0.90)
Breadth of products	89.6*** (35.0)	-	77.3** (33.9)
Depth of marketing	-	76.4 (56.4)	33.6 (58.8)
Adjusted R-squared	0.73	0.68	0.72
F statistic	26.9 (0.00)	21.2 (0.00)	17.5 (0.00)

Determinants of Cost Effectiveness

- Model 4 includes the program budget and the breadth of the program as independent variables, and it says that a one million dollar increase in program budget increases the cost of conserved energy by $0.0084 per kWh and having a broader breadth of lighting products reduces the cost of conserved energy by $0.054 per kWh
- Model 5 includes the program budget and the depth of marketing as independent variables, and it says that a one million dollar increase in program budget increases the cost of conserved energy savings by $0.00060 per kWh
- Model 6 includes the program budget, the breadth of lighting products, and the depth of marketing as the independent variables, and it says that a one million dollar increase in program budget increases the cost of conserved energy by $0.00091 per kWh and having a wider range of product offerings reduces the cost of conserved energy by $0.054 per kWh

Determinants of Cost Effectiveness ($/kWh)

	Model 4	Model 5	Model 6
Constant	0.054** (0.023)	0.031*** (0.013)	0.054*** (0.023)
Budget	0.00085* (0.00046)	0.00060* (0.00056)	0.00091** (0.00046)
Breadth of products	-0.049** (0.025)	-	-0.054** (0.026)
Depth of marketing	-	-0.015 (0.015)	0.015 (0.010)
Adjusted R-squared	0.18	0.01	0.14
F test	3.0 (0.07)	0.71 (0.50)	2.00 (0.15)

Conclusions

- First, utility residential lighting programs vary substantially in terms of the marketing mix
- For the twenty programs for which comprehensive information could be found, average annual budgets were about $11.8, about 60% of program featured other energy efficient lighting products in addition to CFLs, and about 20% of program employed multi-level incentives (both upstream and downstream)
- Product give away was common in the earlier development of residential lighting programs, but it is now significant only in specialized programs targeting hard to reach customers

Conclusions

- Second, standard engineering algorithms were used to estimate energy savings
- Although there are common elements in the estimation and reporting of energy savings, there are also some differences
- To ensure that the basis of comparison was valid across utilities, the algorithms and data used were examined in detail with adjustments made as appropriate
- For the twenty programs examined, average energy savings were 98.9 GWh per year with a standard deviation of 148.7 GWh per year

Conclusions

- Third, cost effectiveness was estimated using the utility cost of conserved energy
- Again although cost reporting across utilizes has similarities, there are some differences, so that basic data was used to consistently estimate the cost of conserved energy
- So again to ensure comparability across utilities, detailed estimates were made using data at the utility level
- For the twenty programs examined, the cost of conserved energy was $0.035 per kWh with a standard deviation of $0.054 per kWh

Conclusions

- Fourth, the determinants of energy savings were estimated using appropriate cross-section regression modelling
- The estimated models had a high degree of explanatory power
- The models confirmed that the size of program budgets and the breadth of the offer were significant determinants of program savings, but disconfirmed an impact of the breadth of the program on energy savings

Conclusions

- Fifth, the determinants of the cost of conserved energy were also estimated using appropriate cross-section regression modelling
- The estimated models had a low degree of explanatory power
- The models confirmed that the size of program budgets and the breadth of the offer were significant determinants of the cost of conserved energy, but disconfirmed an impact of the breadth of the program on cost of conserved energy

Questions?

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