Modeling Program Participation and Choice of Efficiency Level in a New Commercial Construction Program

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ABSTRACT

Determining the impact of a new commercial construction program is complicated by several factors. First, the decision to participate in a program is typically not an all or nothing decision. Instead, participants will often participate in one component of a program but not in others. Second, modeling only the behavior of participants is generally not a viable strategy. Understanding the behavior of non-participants is also essential in understanding program impact. Third, the choice of efficiency level is not independent of the decision to participate in the program. Ignoring this relationship can lead to biased statistical estimates of program impact.

The purpose of this paper is to describe and apply an integrated econometric methodology to deal with these issues. The first issue is dealt with by disaggregating technologies into four relatively homogenous groups (interior lighting, exterior lighting, air conditioning, and fans and pumps) and conducting separate econometric analyses for each group. The second issue is dealt with by using the whole population of new commercial buildings as the sampling frame and choosing samples of both participant and non-participant buildings in an unbiased manner. The third issue is dealt with by modeling the participation and efficiency levels using appropriate probit regression and instrumental variable techniques.

Introduction

In recent years, electric and gas utilities have spent considerable efforts to improve the energy efficiency of new commercial construction. These programs have had a variety of objectives: to deliver energy savings for commercial customers and thereby increase customer loyalty; to avoid the need to finance and build expensive generation and transmission capacity; to reduce peak energy demand; and to meet regulatory requirements. The programs have variously provided information on energy efficient technologies, given design assistance, encouraged voluntary standards and provided financial incentives.

Several papers have discussed various aspects of these programs. Alereza and Chappell (1995) reviewed four new commercial construction programs which used similar methodologies based on whole building simulation models. Three of the studies (San Diego Gas and Electric, BCHydro and Portland General Electric) modeled both participant and non-participant buildings while the fourth (Southern California Edison) used participants only. Carlson et. al. (1997) used DOE-2.1 models to estimate lighting, cooling and other savings for participants in Northeast Utilities' Energy Conscious Construction Program. A net-to-gross factor based on survey data was used to estimate net savings. Davis and Sebold (1995) analyzed Idaho Power Company's Design Excellence Award program using a realization rate approach. This approach integrated engineering and billing information based on a modification to the conventional mixed engineering/statistical approach. Eley et. al. (1998) considered several recent experiments with new building energy performance contracting. They emphasized that careful design of energy performance contracting protocols can achieve solid savings and help overcome a widespread market failure in lack of adoption of cost effective technologies. McCray et. al. (1995) applied survey data to assess baseline construction practices and free ridership for Northeast Utilities' Energy Conscious Construction Program. The survey delved into participant motivations and behaviors and calculated a final free rider estimate as a composite of financial and technical free ridership components.

These papers suggest that determining the impact of new commercial construction programs is complicated by several factors which have sometimes been glossed over in previous work. These factors include the following:

- first, the decision to participate in a program is typically not an all or nothing decision by building developers and architects; instead, participants will often participate in one component of a program (such as energy efficient lighting where the returns are substantial and transparent) but not others (such as high technology glazings where experience and knowledge may be limited);
- second, modeling only the behavior of participants is generally not a viable strategy, at least if econometric techniques are being applied; understanding the behavior of both participants and non-participants is generally necessary to get robust estimates of program impact;
- third, the choice of efficiency level for various end-uses is not independent of the decision to participate in the program or in certain program components; ignoring this relationship can lead to biased statistical estimates of program impact, and estimating the magnitude and sometimes even the sign of the bias can be difficult.

The purpose of this paper is to describe and apply an integrated econometric methodology to deal with these issues. An outline of the paper is as follows. The next section provides a brief description of BCHydro's New Building Design program. The third section summarizes the study approach including the key issues examined. The fourth section reviews the data, sample and engineering analysis. The fifth section explains the participation model. The sixth section similarly explains the efficiency model. The last section is a summary and conclusion.

Program Description

In British Columbia, the commercial and institutional market makes up about one-quarter of electricity sales. The sector offers considerable opportunity for cost-effective energy savings. For example, recent work suggests that up to 30 percent of energy consumption in new commercial and institutional savings could be saved through the application of existing energy efficient technologies, particularly through the application of building system approaches. Conversely, if efficient technologies are not utilized when buildings are constructed, ten to fifteen years could pass before major building systems are updated, thus leading to considerable lost opportunities. BCHydro's response to this situation was to launch the New Building Design Program, a comprehensive whole building design approach to new commercial construction.

During the development stage of the program, in-depth interviews were held with some 50 individuals in the design and construction communities. This work included five key findings. First, energy efficiency was not seen as a critical issue by most respondents and did not add significantly to a building's appeal. Second, building developers and owners assume that consultants design buildings to be as energy efficient as possible given budget constraints. Third, energy efficiency must be achieved without sacrificing tenant comfort and operating convenience. Fourth, barriers to improved energy efficiency include first-cost orientation of developers, priority given to tangible building features, limited knowledge of and commitment to energy efficiency. Fifth, factors which could overcome the barriers include reducing the cost gap between standard and efficient products, providing reliable pay-back information and encouraging an energy conservation ethic.

In response to these considerations, development of the New Building Design program emphasized several features. First, the program offered substantial financial incentives. Financial incentives were generally based on the amount needed to reduce the pay-back period to two years. Second, the program emphasized energy efficient design and the development of an energy efficient ethic over quick but narrow savings. Improved knowledge of energy efficiency was seen as the key to improving design practice, and considerable emphasis was placed on the development of seminars, case studies, technical information and voluntary standards. Third, the program tried to make participation as broad as possible. All commercial and building segments were eligible to participate.

Study Approach

Before examining the details of the methodology below, it is useful to look at more general aspects of the approach used, and to consider how they address the three issues outlined above.

With respect to the first issue of distortions caused by the all-or-nothing approach to participation, a relatively simple solution was used. Discussions with developers, architects and other design professionals, and trade allies suggested that the various electricity saving technologies could be usefully grouped into four main categories: interior lighting; exterior lighting; air conditioning or cooling and HVAC auxiliaries (mainly fans and pumps). Within each of these categories, the factors affecting decision making are similar enough that further disaggregation (such as T8s, electronic ballasts, CFLs, timers for interior lighting) would have limited value. But at the same time, the factors affecting decisions making were different enough across these four categories to mean that further aggregation would lose valuable detail. This suggested that the participation models and efficiency models should be estimated separately for each of these categories. It is perhaps worth noting that penetration of other main categories of energy savings technologies, such as efficient motors, adjustable speed drives on process equipment and building envelope measures, lacked adequate penetration rates to warrant their inclusion in the modeling.

With respect to the second issue, the key point is to understand the determinants of program participation and non-participation. The essence of the problem is to start with appropriate data which means that all new construction projects need to be equally represented (on a probabilistic basis) in the sample. This was achieved by understanding the rate of overall program penetration in the new construction market, and then surveying both participant and non-participant projects in proportion to their share of the new construction population. This meant that valid probit equations could then be used to understand the determinants of participation (by the technology categories outlined above) as a function of building characteristics.

With respect to the third issue of self-selection bias, a number of approaches have been suggested, perhaps the most popular being the use of an inverse Mills ratio as an additional regressor in the efficiency or savings equation(s). This can deal more-or-less with the issue of self-selection in the context in which it was originally developed of segmented labor markets. But its use in the current context is somewhat problematic. A simple approach which provides consistent estimates of program impact is to use the probability of participation from the probit participation equation as an instrument in the efficiency equation.

Data and Sample and Engineering Analysis

As indicated above, it was viewed as critical to understand the share of new construction captured by or participating in the program. Information was collected on the total square footage of new construction in British Columbia from 1990 onwards, using a variety of commercial and official sources (including Canadata and the BC Assessment Authority). Comparison with program records suggested that the program had captured about two-thirds of new construction floor stock, so it was decided to allocate two-thirds of the sample to participants and one-third of the sample to non-participants. Given the budget constraints, the sample was limited to some 99 participant and non-participant buildings.

A comprehensive survey instrument was developed and field tested. Detailed field audits were then undertaken of the 99 buildings in the participant and non-participant samples using trained engineering field staff. Complete data were collected on building geometry, shading, envelope, heating, ventilation, air conditioning, domestic hot water, motors, office equipment, process equipment, operating schedules, occupancy, fuel types and fuel accounts. The site visits also verified the presence of equipment for which incentives had been received.

For each building, a detailed input file was constructed based on site visit data, interview information and, in some cases, end use metering for lighting. This was used to build a DOE-2 baseline model which was calibrated to billed energy use using actual weather and occupancy information. A series of parametric runs was then undertaken assuming typical meterological year data and full occupancy. These included the following. Run A: whole building baseline - this run determined building energy consumption baseline conditions, with the baseline determined by audits of recently built preprogram buildings. Run B: as built structure - this run determined the most likely energy consumption conditions, using the site audit data on the building as actually built. Run C: measure baseline efficiency - this run set rebated measures at the baseline level and all other measures at the as built level. Several types of gross savings were then calculated.

For our purposes, the critical fact is that the calibrated baseline model was then used to calculate consumption and demand on a per square foot basis by main end uses. In this study only demand or watts per square foot is examined. This seems to be the best simple way to examine comparative energy efficiencies at the end use level. It should be noted that of the 99 modeled buildings, six had energy signatures which seemed peculiar, so the overall sample used for the regressions was reduced to 96. Further HVAC auxiliaries and cooling were germane only for the remaining 81 buildings with air conditioning.

Participation Model

The objective of this part of the study was to understand the determinants of the decision to participate or not participate in the program. Since the decision to participate or not is a discrete one, the dependent variable is binary. That is it takes on the value 1 for a participant and 0 for a non-participant. It was noted above that potential participants can decide to participate in one or more aspects of the program so that participation is not an all or nothing decision. For the purposes of this analysis, four distinct participation areas are modeled - energy efficient interior lighting, exterior lighting, HVAC auxiliaries and cooling - with these accounting for well over 90% of program savings. The variables used in the participation model are defined in Table1.

Table 1. Definition of Variables for Participation Model

Name	Definition
PINT	Participating in energy efficient interior lighting=1, otherwise=0
PEXT	Participating in energy efficient exterior lighting=1, otherwise=0
PHVAC	Participating in energy efficient HVAC auxiliaries=1, otherwise=0
PCOOL	Participating in energy efficient cooling=1, otherwise=0
LSIZE	Log of building area in square feet
INST	Institutional building=1, otherwise=0
HIGH	Greater than four stories=1, otherwise=0

Program participation was modeled using probit equations. The results of the participation model are provided in Table 2. For each of the four technology areas, the model works quite well with the significance of the model being one percent or better in each case. The main determinant of participation is building size, with this variable being significant for all four technologies. The impacts of the other variables are mixed. Institutional status and being a high rise building are significant determinants of choosing energy efficient HVAC auxiliaries, but less significant elsewhere.

Table 2. Participation Model

	PINT	PEXT	PHVAC	PCOOL
CONSTANT	-4.614 (-3.618)	-3.999 (-3.168)	-11.511 (-4.558)	-3.420 (-2.776)
LSIZE	.478 (3.682)	.351 (2.820)	1.036 (4.434)	.351 (2.823)
INST	.471 (1.094)	.400 (1.076)	.827 (1.672)	.338 (.772)
HIGH	.698 (1.119)	.168 (.373)	1.629 (2.267)	.890 (1.469)
CHI-SQ.	26.22 (.000)	14.22 (.003)	57.38 (.000)	17.00 (.001)
SAMP. SIZE	93	93	81	81

Note: t-ratios for the coefficients and probabilities for the Chi-squared test are shown in parentheses.

Efficiency Model

The objective of this part of the study was to examine the determinants of energy efficiency level. Efficiency was determined in terms of watts per square foot for that end use. This was viewed as the best common currency since changes in operating schedules could have major and unpredictable impacts on energy consumption, thus potentially masking relative differences in efficiency levels. The additional variables (that is, those variables which have not been previously defined) used in the efficiency model are defined in Table 3.

Table 3. Definition of Variables for Efficiency Model

Name	Definition
DINT	Watts per square foot for interior lighting
DEXT	Watts per square foot for exterior lighting
DHVAC	Watts per square foot for HVAC auxiliaries
DCOOL	Watts per square foot for cooling

Efficiency levels were modeled using instrumental variable procedures. In the instrumental variable regressions, the probability of participating in the program was used as an instrument for the actual participation decision. The results of the efficiency model are given in Table 4. Only the results for the constant terms and the participation variables are given. The model also included a series of 13 sector dummy variables which are omitted to save space. The results are again reasonable and the overall fits are adequate, with all regressions significant at the ten percent level. The key fact is that the coefficients for the participation dummy variables all have the expected negative signs. The coefficients provide the estimated savings from participation . These are respectively: interior lighting .64 watts per square foot; exterior lighting ,.93 watts per square foot; HVAC auxiliaries .38 watts per square foot; and cooling 1.09 watts per square foot.

Table 4. Efficiency Model

	DINT	DEXT	DHVAC	DCOOL
CONSTANT	1.425 (4.959)	.135 (.308)	.390 (1.414)	1.559 (4.135)
PINT	-.638 (-2.148)	--	--	--
PEXT	--	-.927 (-1.127)	--	--
PHVAC	--	--	-.380 (_1.378)	--
PCOOL	--	--	--	-1.092 (-1.824)
F	1.67 (.092)	1.60 (.099)	1.620 (.097)	2.660 (.0030
SAMP. SIZE	93	93	81	81

Note: t-ratios for coefficients and probabilities for the F-statistics are shown in parentheses. The regressions also included thirteen sector dummy variables which are omitted to save space.

Summary and Conclusions

This paper has examined issues pertaining to the modeling and estimation of participation decisions and efficiency level choices in new commercial construction. An integrated econometric methodology to estimate the determinants of program participation and choice of program efficiency level has been proposed and applied to BCHydro's New Building Design program. Substantial savings by participants over non-participant energy intensities have been found for interior lighting, exterior lighting, HVAC auxiliaries and cooling.

Utilities often spend considerable resources in the evaluation of new construction DSM programs. However, the rigor, validity and usefulness of these evaluations is sometimes compromised by an inadequate research design. The proposed methodology should assist in increasing rigor and relevance to this field of evaluation, in a cost effective manner.

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