THE EFFECTS OF GOVERNMENTAL ENERGY EFFICIENCY ACTIVITIES ON ELECTRICITY CONSUMPTION – AN ECONOMETRIC ANALYSIS

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ABSTRACT

Energy efficiency (EE) programs are generally considered an effective policy for controlling electricity demand growth, greenhouse gas emissions, and for lowering the cost of electric power for individuals and society. Evaluating these programs is difficult, and the results of such evaluations have proven controversial. Nevertheless, to abate energy consumption and greenhouse gas emissions, policy makers have continued to view EE as the most cost effective policy option available.

The governmental sector plays an important and central role in the promotion and development of EE programs, with the ability to regulate, promote, analyze, and fund such programs. This paper attempts to quantify the effectiveness of governmental actions in EE activities through the use of econometric modeling of the Canadian provinces from the period of 1999 to 2005.

For the last six years, the Canadian Centre for Energy Efficiency (CCEE) has graded the Canadian provinces on their EE activities. This study uses these grades as a measurement for provincial governmental EE efforts. Through a panel level statistical analysis using electricity consumption, the grades, and various controls over several years, this study attempts to find a correlation between the change in provincial grade and the change in energy consumption. A negative correlation between the two suggests that increased provincial government effort in EE programs reduces electricity consumption. The results of this study point to such a correlation.

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Introduction

Concurrent with the worldwide trend, electricity demand in Canada is growing at a rapid pace. Between 1990 and 2003, demand grew by 22 percent. This is attributed to larger homes, more electronic devices, industrial production growth, and a booming building sector. (Canadian Gas Association, 4) Electricity demand is expected to continue to grow under a business as usual scenario.

Such a growth in demand creates negative societal externalities from the power generation sector including increased greenhouse gas emissions, higher energy prices, and the need for costly new capacity and transmission infrastructure. Energy efficiency (EE) programs can be implemented to alleviate these externalities. By 2025, with the effective implementation of EE programs, Canada has the potential to reduce its demand growth by 16% to 56%. (Canadian Gas Association, 1) History suggests that the Canadian federal and provincial governments will implement a large portion of any future EE programs.

In Canada the public sector is a major player in the formulation of EE programs. The federal government alone spends around $155 million per year on such programs. (Improving Energy Performance, 10) Even though it invests heavily in EE, it 'relies strongly' on provincial and territorial governments for the implementation of energy efficiency standards and other initiatives (Winfield, 6). Therefore both governmental levels are important actors in energy efficiency program dissemination and success. Through an econometric analysis, this research attempts to assess the impact of recent governmental energy efficiency program activities on energy demand. We find that the current governmental EE actions have had significant effect on the electricity demand in the provinces, although a more robust data set could further validate this analysis.

Energy Efficiency Discussion

Energy efficiency takes many shapes and sizes. Its definition can be encompassed in a multitude of programs, the most common being appliance standards, financial legislative programs, information and voluntary programs, and the management of government energy use. (Gillingham, 162) Energy efficiency programs have been implemented by the sectors of society that have a vested interest in energy - governmental departments, non-profit advocacy groups, private businesses, and utility companies. This study uses the terminology from the cited work of Amulya Reddy (3), "Energy-efficiency improvements is used here in this extended sense to include any measure that results in the delivery of an energy service with a reduction of energy consumption."

Measuring the effectiveness of energy efficiency programs is necessary to justify their costs. Measuring such programs can be done in a variety of ways, including engineering models and statistical analysis. Each has its advantages and disadvantages, but in macro-scale evaluations, an engineering analysis may be unrealistic due to the amount of variables. Statistical analysis provides a possible answer, but recently has been an object of intense critique.

The evaluation of energy efficiency programs at a macro scale is a difficult task. As one study states: "The task of measuring, modeling, and ultimately influencing the path of technological development is fraught with complexity and uncertainty—as are the technologies themselves." (Jaffe, 1) In large comparative analyses, the complexity and uncertainty are due to data availability and correct model specification. It can also be extremely difficult to measure energy efficiency over time or between countries or sectors. (Herring, 4) Not all studies hold such a critical view. For example, one study found that 99.4% of energy efficiency impacts are statistically observable "after accounting for economic and weather effects." (Palifomak, 59)

There are various studies that call into question the effectiveness of energy efficiency programs. They argue that the effect of improving the energy efficiency is synonymous to lowering energy's price making it more affordable, ultimately leading to greater use. This market failure of energy efficiency programs has been termed the 'rebound effect'. (Herring, 10) In order to control for this effect, it is important to control for price effects in statistical studies. This study controls for price and other factors which are believed to influence the demand for electricity.

This study adds to the current body of energy efficiency evaluation research by estimating Canadian provincial and federal governmental energy efficiency program impacts. This econometric analysis is the first of its kind using Canadian data and is the first to quantify the effectiveness the Canadian governmental energy efficiency programs using the energy efficiency scorecard created by the Canadian Centre for Energy Efficiency.

Analytical Framework:

This study uses a panel level statistical model to determine the effects of Canadian provincial and federal government energy efficiency efforts on provincial electricity consumption. Other recent studies have used a similar econometric analysis to evaluate energy efficiency efforts, including Berry (2008) and Horowitz (2007). Like these studies, our study holds constant various factors that affect energy consumption in order to isolate the effectiveness of the Canadian governmental energy efficiency activities.

Traditionally, a generalized least squares (GLS) model has been used for such panel analyses, to correct for autocorrelation in the time series. However, this data set has more panels than time series, which rules out

GLS. (Beck, 637) Instead, this analysis uses a Prais-Winsten regression model with panel corrected standard errors (PCSE). A PCSE model provides similar estimates and is more efficient. (Beck, 637) PCSE also produces consistent estimates. (Forrest, 256)

As a panel model, it is highly suspect that the model will exhibit panel heteroskedasticity, panel autocorrelation, and contemporaneous errors. (Blackwell, 202) The statistical program STATA has various routines which tests for these errors. Panel level heteroskedasticity is tested for using the modified Wald test. Autocorrelation is detected using the Wooldrige test for autocorrelation in panel data. Contemporaneous errors are tested for using Breusch-Pagan Lagrange Modifier test for independence. These errors were tested for and, if necessary, corrected for in the modeling process.

This study considered data from the provinces of Alberta, British Columbia, Manitoba, Ontario, Quebec, and Saskatchewan. The other four Canadian provinces were dropped because of the unavailability of the data for one or more of the parameters in the model. This is not particularly troublesome because the six mentioned territories account for much of the Canadian population and should therefore be sufficient to represent the country as a whole.[i] A first difference model using a natural logarithm transformation was considered appropriate because a regular model would correlate the natural growth of the variables and would bias the model. Other studies have also advocated using first difference models. Paifomak and Lave (1996) state in their article, "Because of the inherent long-term trends in economic time series, the best way to understand the structure of an economic relationship is to explain changes in variables, not their full levels."

Our model is represented as:

*lnTCEit = b1*PEESit + b2*FEESt + b3*lnAPEPit +b4*lnPGDPit + b5*lnUTEE + b6*lnPGS + b7*lnACDit + b8*lnAHDit + e*

where *i* represents the territory, and *t* represents the year, and *ln* before the variable represents a natural log transformation (i.e. first difference change by year)

TCE = Provincial Total Consumed Electricity

PEES = Provincial Energy Efficiency Score

FEES = Federal Energy Efficiency Score

APEP = Average Provincial Electricity Price

PGDP = Provincial Gross Domestic Product

UTEE = Total Provincial Utility Expenditures in Energy Efficiency Programs

PNGS = Provincial Natural Gas Sales by Thousands of Cubic Meters

ACD = Average Monthly Total Cooling Days per Capita

AHD = Average Monthly Total Cooling Days per Capita

Data

- Total consumed electricity is the total electricity generated in the province, plus the total receipts (electricity received from other states or countries), minus the total deliveries (energy sent to other provinces or countries). This number provides an accurate measure of the total electricity consumed in the province during the period. This data was provided by Statistics Canada. (Table 127-0001)
- Provincial and federal government energy efficiency effort scores were collected from the annual Canadian Energy Efficiency Centre report, *National Energy Efficiency Report Card: Report Card on Government Activities*. The energy efficiency criteria considered in giving the provincial grade are: Programs and Public Outreach, NGO/NPO Partnerships, Public/Private partnerships, Energy Efficiency Act, Building Codes, Energy Business Plan, House-keeping (In-House Programs), Regulation of Energy Markets, Access to Government Information, Related Policy Developments, Performance. Evaluation Activities. The centre has given grades to each of the Canadian provinces, from 1999 to 2005.[ii] The grades given were a measurement of the annual effectiveness in the governmental provincial energy efficiency effort. (Canadian Energy Efficiency Alliance) Provinces with higher grades should expect to see less electricity demand, *ceteris paribus.*

- Average annual provincial electricity price was calculated using data from the annual Quebec Hydro report: *Comparison of Electricity Prices in Major North American Cities* (Hydro-Québec). The average residential, commercial, and industrial prices were weighted by the average energy consumption of the province using energy usage statistics from Statistics Canada Comprehensive Energy Use Database - Query System (Natural Resources Canada). This calculation assumes that there are no major deviations between the utility prices mentioned in the report and the rest of the province. Provinces with higher electricity prices should expect to exhibit less electricity demand, holding all other factors constant.
- Annual provincial gross domestic product (GDP) at basic prices was acquired from Statistics Canada (Table 379-0025). An increase in GDP is expected to create a higher demand for electricity.
- Annual provincial utility energy efficiency expenditures were calculated using data from various utilities around Canada. Taking into account the specific utility's percentage of provincial population served, total utility energy efficiency expenditures were estimated. Utility energy efficiency expenditures are expected to bring down electricity consumption. (BC Hydro, Hydro-Québec, Le Riche, Pilek, Tollefson, Toronto-Hydro)
- Provincial natural gas sales by cubic meter were acquired from Statistics Canada. In many applications, natural gas is a substitute for electricity and therefore should be negatively related to electricity consumption. (Table 129-0003) Natural gas sales by unit were substituted for natural gas prices, which were unavailable.
- Heating and cooling days data was acquired from the Canadian National Climate Archive. (Environment Canada) The data was weighted by population. (Table 051-0001) It is suspected that both heating and cooling are positively correlated with electricity consumption, although each may have a different impact on consumption.

Data Caveats

This study collected its data from a myriad of sources. The energy efficiency effort scores were collected from the National Energy Efficiency Report Card, which has a few shortcomings. The report card does not give an in depth explanation of the grading methodology. It also 'evolves' its grading on a yearly basis. For example, the last report card states, "As such, the Year Six Report Card incorporates a more in-depth review of partnership roles in the delivery of public outreach and action-based programs." This changing rubric distorts the ability of the model to accurately reflect the effect of the provincial and federal government efforts on a year-to-year basis, which may ultimately bias the model.

There is data in the model that was imputed through linear forecasting. This included the year 2003 in the scorecard, four data points in the energy pricing data, and two points in the utility prices calculations. Such imputation was deemed necessary because of the need to conserve degrees of freedom. It is recognized that such data imputation may bias the model, making it overly efficient.

It was burdensome to calculate energy prices. Without data from a centralized agency, average provincial price was assumed based on the utility data that was available. This makes the assumption that the variance in electricity prices varies little from the available utility data. This is not as much of a concern for a province like Quebec, since the available energy prices were representative for about 94% of its population. This assumption is more difficult to validate for the other provinces in which the surveyed utilities served a lesser percentage of the total provincial population.

The same problem arose for the calculation of energy efficiency expenditures. There is a lack of a central data clearinghouse for such energy data in Canada. Therefore we had to contact the utilities directly. Constrained by time and resources, we were only able to contact the utilities mentioned in the Comparison of Electricity Prices in Major North American Cities report. Then, based on their ratio of utility customers to total provincial population, estimated energy efficiency expenditures were calculated for the province. This assumes that the observed utility's expenditures were representative of the aggregate utilities expenditures throughout the entire province. If it is not representative, then the model displays a bias.

Results

The study finds a relatively strong correlation between provincial governmental energy efficiency efforts and a decline in provincial energy usage in Canada. This was concluded by running two models. (See Table 1) The reasoning behind two models is because of an ambiguity inherent in the scorecard measurement. Due to the wording of the scorecard, it was indeterminate whether the scorecard measured a change in provincial energy efficiency activities or their cumulative yearly performance.[iii] Model 1 interpreted the grades as a change in energy efficiency efforts, and therefore made no transformation. Model 2 assumed cumulative yearly performance grading, and therefore measured the change in scorecard grades using a natural logarithm transformation. In Model 2, there were two less degrees of observations because we did not want to convert the failing grade (a score of 0) to a natural log, which would result in an infinity and a bias in the model.

Both models suggest a negative correlation between Canadian provincial governmental energy efficiency activities and the aggregate provincial consumption of energy. Provincial activity is significant in both models at a 90% confidence level, with a z score of -2.09 (Model 1) and -1.67 (Model 2). The federal energy efficiency activity score is highly insignificant in both models, with a z score of 0.37 (Model 1) and -0.01 (Model 2).

A caveat in the results relates to this insignificance. It is assumed that because of the cross-sectional invariance of the parameter and the small variation in the federal grades themselves that the model cannot effectively capture the influence of the Canadian federal government activities. The insignificance warrants further study that includes a more robust data set representing federal governmental energy efficiency activities.

All of the other parameters were significant and conformed to theory as delimited in the previous section. Provincial GDP and average monthly heating days were positively correlated with electricity usage. Provincial natural gas sales, electricity prices, and total utility energy efficiency expenditures were negatively correlated. In one model, cooling days was significantly negatively correlated with electricity usage, which was counter to theory.

The model results presented are consistent with other studies using similar methods.

Table #1	Model 1	Model 2
Dependent Variable	LN change in Total Electricity Consumed	LN change in Total Electricity Consumed
Constant	7.006641 (9.90)*	6.970253 (6.37)*
Provincial Energy Efficiency Score**	-.0291301 (-2.09)*	-.0590122 (-1.67)*
Federal Energy Efficiency Score**	0.0098898 (0.37)	-.0021498 (-0.01)
Provincial GPD	0.9764239 (14.06)*	0.9728691 (11.67)*
Total Provincial Utility Expenditures in DSM programs	-.0689888 (-10.53)*	-.0683277 (-8.10)*
Provincial Natural Gas Sales (Thousands of Cubic Meters)	-.649957 (-11.69)*	-.6421945 (-9.83)*
Average Monthly Total Heating Days / Population	.7339904 (11.45)*	.7348718 (8.51)*
Average Monthly Total Cooling Days / Population	-.0325045 (-1.98)*	-.0331866 (-1.64)
Average Provincial Electricity Price	-.9003761 (-10.83)*	-.8851494 (-9.06)*
Number of Observations	41	39***
R Squared	**	**
(Table 1 Source: author's calculations.) Z-scores in parentheses. *Indicates significant at the 10% level. **R^2 was not provided because of the nature of the panel data. (Blackwell, 205) ***As mentioned, there are two less observations in this model because of natural log of 0 problems.		

Conclusion

This study suggests a negative correlation between Canadian provincial government activities in energy efficiency and aggregate provincial energy consumption. It furthers the argument that energy efficiency programs have a significant negative effect on electricity consumption. However, the various caveats in the data, in addition to the insignificance of the federal energy efficiency scores, leave some questions to be further investigated. With more detailed utility energy efficiency expenditures, federal energy efficiency activities, electricity prices, and a more transparent scorecard, this study could more effectively assess the relationship between energy efficiency programs and electricity consumption. Also, with a scorecard that better described the breakdown of the provincial and federal grades, additional studies could be conducted defining which types of energy efficiency programs are most effective for reducing electricity consumption.

This study adds to the growing body of literature suggesting that the macro investment in energy efficiency programs does lead to electricity demand reduction, although it is important to add that other analyses, including cost-benefit analyses, may be needed to determine if energy efficiency programs have a positive net impact on society.

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[i] According to the author's calculation using data from Statistics Canada, the six territories mentioned include 92.5% of the Canadian population.

[ii] For unknown reasons, the year 2003 was not graded. Due to the need to include as many of degrees of freedom as possible, the year 2003 was inferred using a linear regression.

[iii] The authors of the scorecard were unavailable for comment.