Empirical Analysis on Response of Natural Gas Demand to Price for Residential Sector

by

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CONTENTS

ACKNOWLEDGEMENTS……………..…………………………………………...ii

1. INTRODUCTION... 1

2. LITERATURE REVIEW 3

3. THEORY AND METHOD 11
3.1 ECONOMIC THEORY AND STANDARD ECONOMETRIC APPROACH 11
3.2 ESTIMATION MODEL 13

4. DATA 16
4.1 NATURAL GAS QUANTITY 16
4.2 PRICE OF NATURAL GAS 16
4.3 PRICE OF ELECTRICITY 17
4.4 INCOME.. 19
4.5 WEATHER 19
4.6 SEASONALITY 20

5. ANALYSIS AND RESULTS 21
5.1 MODEL FOR CANADA 25
5.2 MODEL FOR ALBERTA AND ONTARIO 27
5.2.1 MODEL FOR ALBERTA 28
5.2.2 MODEL FOR ONTARIO.. 30
5.2.3 COMPARISION OF COEFFICIENT ESTIMATES 35

6. CONCLUSIONS 36

REFERENCES.. 38

APPENDIX 41

1. INTRODUCTION

The demand for energy is rapidly increasing worldwide and natural gas is becoming the most important energy source in the 21th century. Natural gas as an abundant and relatively clean energy source has attracted established and new producers to explore and produce in a major way. Unlike solar, wind and tides, natural gas is still not renewable; therefore the availability of natural gas for the far future is unclear. Although conventional gas production in Canada is declining and the abundant unconventional gas (ie. shale gas by hydraulic fracturing) is becoming popular, the future energy scarcity problem still exists. Natural gas is used extensively in residential, commercial, industrial and power generation applications. Natural gas is primarily used as a source of space heating, water heating, clothes drying and in cooking applications in the residential sector. Deregulation of natural gas affects the retail price in residential sector. In addition, when more stringent environmental regulations on emissions are developed, the new energy policies often involve increase the cost of energy to consumers. Since producers of a carbon intensive good such as energy will pass the additional costs onto the consumers depending on elasticity of demand and supply. It is important to understand the responsiveness of households to changes in energy costs in order to determine the effectiveness of the policies. For these reasons, I am interested in analyzing how Canadian households' demand for natural gas is affected by the changes in price of natural gas and the price of electricity. In this paper, I analyze the residential natural gas demand using a double log static model. I estimate the price elasticities of the residential demand for natural gas at the national level and in two selected provinces using monthly time series data spanning over the period of January 1981 to December 2002. I find that residential natural gas demand is inelastic with respect to changes in the natural gas price. Especially in Alberta, demand for natural gas is not much responsive to changes in the natural gas price. Residential natural gas demand decreases by 0.36% with the electricity price rises by 1% in Ontario.

Canada is the world's fifth largest producer of natural gas with production of 13.9 billion cubic feet per day (Canadian Association of Petroleum Producers, 2014). Consumption of natural gas in Canada has increased considerably during the last 50 years. Due to the long and cold winter, home heating is essential to all Canadian households. Almost 80% of all residential natural gas use was for space and water heating in 2009 (Natural Resource Canada, 2012). In 2011, 36.1% of households in Canada use electricity as the principal heating energy source and 50.2% of households use natural gas as the principal heating energy source (Natural Resources Canada, 2014). From Figure 1 in Appendix, it can be seen that both numbers have been increasing over the past decade. There are three main reasons: firstly, there is an increase in availability of natural gas; secondly, the cost of natural gas prices is lower relative to oil; thirdly, the advancement of technology, expands the use of natural gas in many heating appliances, such as: natural gas furnace, natural gas water heater and natural gas fireplace.

In Canada, Alberta accounts for 69% of natural gas produced (Alberta Energy, 2014), and half of the natural gas production is consumed in Alberta. Natural gas is the primary energy source for households in Alberta, accounting for 77% of their total energy use (Statistics Canada, 2012). On average, each household consumes 110GJ of natural gas in Alberta. From Figure 2 in Appendix, it can be seen that the percentage of households using natural gas as the principal heating source is around 90.7% in 2011, and the percentage of households using electricity as the principal heating source is low, only 4.2%. Natural gas accounts for 58% of household energy use in Ontario, and natural gas consumption per household is 81GJ (Statistics Canada, 2012). Figure 3 in Appendix shows that 68.2% of households use natural gas as the principal heating source in 2011, and only 13.2% of households use electricity as the principal heating source. More than half of Canada's population live in the central part of the country; therefore Ontario is the biggest consumer of natural gas in Canada. These statistics show the importance of natural gas in Alberta and Ontario. I also provide a comparison of natural gas consumption in the above two provinces to compare with national level natural gas consumption.

The reminder of this paper is structured as follows. Section 2 reviews and compares existing literature on residential natural gas price elasticity estimate. Section 3 presents the method and model. Section 4 introduces the data used in the empirical analysis. Section 5 presents my models and analyzes empirical results. Section 6 concludes the discussion and suggestions for future research in this field.

2. PREVIOUS LITERATURE

How much the energy price affects the demand for energy consumption in residential sector has been studied by numbers of scholars. Many existing studies have shown a wide range of price elasticity of residential natural gas demand.

Since electricity and natural gas share many similar characteristics, modelling demand for natural gas can be similar to that for electricity. Espey and Espey (2004) conduct a meta-analysis of residential electricity demand elasticities from many previous studies, and they reveal that the differences in elasticity estimates may come from the demand functional form, the types of data, the time and location of the study, and the estimation technique.

Bohi (1981) surveys some early works on price elasticity of residential natural gas demand, and he also finds the price elasticity of natural gas varies widely from study to study. He concludes that residential natural gas demand is less elastic than residential electricity demand. Bohi and Zimmerman (1984) update the study with another review of studies on energy demand. They survey eight more recent studies on natural gas consumption. They find that the consensus estimates of price elasticities for natural gas consumption is -0.2 in the short run and -0.3in the long run. Also they note that natural gas demand is more elastic in the long run due to the end-use of natural gas being limited to space and water heating. However, the authors fail to use regression analysis to evaluate different studies on energy demand quantitatively. Instead of using statistical test, they just categorize and summarize those studies on energy demand qualitatively.

A more recent study conducted by Bernstein and Madlener (2011) estimates price elasticities of residential natural gas demand in twelve OECD countries uses time series data from 1980 to 2008. They analyze residential natural gas demand as a function of real residential natural gas price, real net disposable income, and heating degree-days (HDD). On average, the long run price elasticity is -0.51, which is higher than the short run price elasticity of -0.24; the long run coefficient on HDD is 1.3, which is also higher than the short run (Bernstein & Madlener, 2011). They conclude that the magnitude of the long run elasticities is approximately twice as large as the magnitude of the magnitude of the short run elasticities.

On the other hand, the electricity cross-price elasticity of natural gas demand in many previous studies is often found to be small in magnitude and statistically insignificant. Some previous studies show that the electricity cross-price elasticity is positive and thus establishes natural gas and electricity as substitutes. For instance, Alberini, Gans and Velez-Lopez (2011) estimate the cross-price elasticity from multi-year cross-section data of households in 50 metropolitan areas in the United States from 1997 to 2007; they find the electricity cross-price elasticity of residential natural gas demand is 0.15 with city-specific effect. Dagher (2011) shows a similar result, the long run electricity cross-price elasticity is 0.1515 in Colorado using time series data from 1994 to 2006. In contrast, other studies show the negative electricity cross-price elasticity, indicating natural gas and electricity as complements. For example, Garcia-Cerutti (2000) estimates the electricity cross-price elasticity of residential energy demand by using panel data at the county level in California from years 1983 to 1997. His results show that the mean electricity cross-price elasticity of natural gas demand is -0.068 and not statistically significant. He explains the weak cross price effect is due to limited switching between natural gas and electricity as natural gas is limited to space and water heating. A Canadian study conducted by Maruejols and Ryan (2009) shows the cross-price elasticity is around -0.2 in most provinces, and the authors suggest the electricity cross-price elasticity of residential natural gas demand become less elastic after period 2000 as electricity price rises.

Usually, the models used to analyze the effect of price on energy demand have control variables for household income. According to Bohi's (1981) survey from cross-section estimations, income is not an important determinant of residential natural gas demand. On the other hand, some studies indicate income is statistically significant. Bernstein and Griffin (2006) show income in the current year is statistically significant at the national level, thus income can affect residential natural gas consumption. The study conducted by Alberini, Gans and Velez-Lopez (2011) using mixed panel data shows the income elasticity of electricity demand is low but statistically significant. The income elasticity of natural gas is relatively low as well but not significant at any level of significance. Their results suggest that households will tend to choose more energy-efficient appliances when income increases. There are many choices of energy-efficient appliances for electricity since electricity has more end-use: heating, lighting, cloth drying, refrigerating and etc. By contrast, the predominant end use of natural gas is space heating (Berndt & Watkins, 1977) and households do not have many choices of natural gas energy-efficient heating appliances[1], thus residential natural gas demand is not as responsive to changes in income.

Many studies have indicated that price elasticity varies widely when data are selected at different levels of analysis. Bernstein and Griffin (2006) examine the relationship between energy demand and energy prices using different levels of data, including the national level, regional level, state level and utility level. From their panel data analysis of residential natural gas consumption from 1997 to 2004, they conclude that there are significant differences in price elasticities of residential energy demand between different regions and states in America. Both the value of energy uses and the costs of substitutes in a specific geographic area contribute to variations in the price elasticity. In addition, they show the price elasticities are quite inelastic at all levels. At

[1] For natural gas, there are natural gas high-efficiency furnace, high-efficiency natural gas water heaters, fireplaces or boilers

the national level, the short-run natural gas price elasticity is -0.12, the long run is -0.36, the short run income elasticity is 0.24 and the coefficient on the climate is 0.27; at the regional level, the natural gas price elasticity in short run varies from -0.03 to -0.18 through West South Central region to Pacific Coast (Bernstein & Griffin, 2006). At the state level, differences in natural gas price elasticities in many states are not statistically significant.

Not many studies have examined the demand for natural gas in residential sector in Canada. Berndt and Watkins (1977) estimate natural gas demand in both residential and commercial market sectors in two provinces, Ontario and British Columbia. From a two separate equations approach, the short run price elasticity is -0.15 and the income elasticity is 0.04; the long run price elasticity is -0.686 and the income elasticity is 0.133. Their results indicate that the absolute values of all elasticities are low; in other words, the demand for natural gas is inelastic. However, the demand is more elastic in the long run as the absolute value of the long run price elasticity is greater than the absolute value of the short run elasticity.

Maruejols and Ryan (2009) is one of the few studies that analyze the impact of price on natural gas consumption for residential sector in all Canadian provinces. Time series data from 1960 to 2007 are used to estimate the price elasticity and income elasticity for the Atlantic Provinces and all other provinces individually. The average own price elasticity of natural gas demand is about -0.5 (Maruejols &Ryan, 2009). The authors explain that because Canadian households use natural gas as the main heating source, thus the demand of natural gas is less elastic than electricity demand. Moreover, their estimation results show the price elasticity varies across provinces: the own price elasticity of natural gas demand ranges from -0.2 to -0.5 in Alberta, the own price elasticity is around -0.7 to -0.9 in Ontario (Maruejols &Ryan, 2009). This implies natural gas demand in Ontario is more elastic than that in Alberta. Bernard, Bolduc and Yameogo (2011) conclude natural gas and electricity are substitutes from a cross-section study on household electricity and natural gas demand in Quebec from 1989 to 2002. They show the cross-price elasticity is 0.606.

Overall, most of previous studies find residential natural gas demand is negatively related to its own price and the natural gas demand is inelastic in residential sector. They also reveal that the long run price elasticity is greater than the short run price elasticity due to the limited end-use of natural gas.

Next, I briefly review some previous literature on estimating demand curves. In a competitive market, basic principles of supply and demand determine the price and quantity sold. Canadian natural gas market is highly competitive, thus natural gas price is determined by both the demand and supply curves, at the level where the demand and supply curves intersect. Suppose demand and supply equation are in linear form

$$\text{Demand: } q_t^d = \alpha + \beta P_t + \varepsilon_t$$

$$\text{Supply: } q_t^s = \gamma + \theta P_t + u_t$$

Markets are assume to clear, thus q_t^s = q_t^d = Q. By solving the above two equations for price and quantity, we are able to obtain:

$$\text{Price: } P_t = \frac{(\alpha + \varepsilon_t - \gamma - u_t)}{\theta - \beta}$$

Quantity: $Q = \frac{(\alpha+\varepsilon_t)\theta-(\gamma+u_t)\beta}{\theta-\beta}$

Working (1927) questions that whether it is possible to deduce statistically the theoretical demand function when we know only the observations corresponding to the intersections of unknown demand and supply curves at different points in time. Data used in estimating demand curve contain observations of price and quantity sold at various time. Each observation on price and quantity corresponds to a specific point on an unknown demand curve and the supply curve. The statistical problem is identifying a demand curve generated by these observations. The author shows that the demand curve derived from these observations is a general demand curve. The demand curve is constructed by plotting quantity demanded in a certain time period versus its corresponding price in that period. By repeating this procedure for other time periods, a curve can be draw, which will fit as nearly as possible all the plotted points.

Economists are interested in estimating the elasticities of demand and supply for a variety of products. The first theoretic demand curve is proposed by Verri in 1771, a hyperbolic demand curve, and Cournot defines a more general demand schedule Q = f (P) in 1938 which is popularized by Marshall (Dahl, 2007). In early studies on demand analysis, the effect of income on quantity demand is not formally considered. With the advance in statistics, more economic studies start to incorporate regression analysis. Benini (1907) uses the method of multiple regression and includes the own price and cross-price in demand equation.

Schultz (1938) incorporates both the theoretical work and empirical analysis of income and price on quantity demanded in estimating demand curves. He statistically estimates demand and supply functions for various products in all the multi-market complexity of Walras's general equilibrium system. He finds the demand function by calculating least squares from time series data for some agricultural product. He shows that different functions obtained depend on whether price or quantity is the dependent variable. Schultz points out that if we use quantity as the dependent variable and fit the curve by minimizing the sum of the squares of the residuals of quantity, we are assuming that a deviation only occurs in quantity and no deviation in independent variables; if we use price as the dependent variable and fit the curve by minimizing the sum of the squares of the residuals, we are assuming that a deviation only occurs in price. Because the quantity data is often less accurate, Schultz suggests that using quantity as dependent variables in demand equation is more likely to obtain better approximation to true demand. He deduces the demand functions for beef, veal and pork in two forms and I simplified them into the following two equations:

$$Q = \beta_0 + \beta_1 P_t + \beta_2 Y_t \qquad (1)$$

$$Q = A P_t^{\alpha 1} Y_t^{\alpha 2} \qquad (2)$$

Equation (1) is linear demand function. Equation (2) can be linearized by taking logarithms of both sides.

A study conducted by Stone (1954) tests a linear in logs demand function and then he uses Slutsky decomposition of demand elasticities and homogeneity restrictions to obtain the estimated demand equation.

$$logQ_i = \alpha + \beta \log(Y) + {}_{j=1}^{N}\Sigma \beta_{ij} P_i \qquad (3)$$

where Q is the quantity demanded for good i, Y is the real income, P_i is the price of good i, Later, economists use calculus and optimization to formally derive the demand equation (Hicks, 1939). Consumer demand curves are derived from maximizing utility subject to a budget constraint.

However, all statistical analysis of supply or demand have the general problem of identification. In a special case, if we are aware of that the demand relationship between price and quantity was stable and the supply curve shifts from one unit of observation to another, the set of points will lie along the theoretical demand curve. However, statistical analysis should be based on observations which reflect shifts in both curves. Bohi (1981) reasons that the identification problem arises because two or more variables are causally interdependent in the same equation, thus their values are determined simultaneously. For example, quantity and price are simultaneously determined in a demand equation because price affects quantity demanded and quantity demanded also affects the price.

3. THEORY AND METHOD

In this section, I present information that I used in producing my model. Before I describe the model, I first provide an overview of the economic theory.

3.1 Economic Theory and Standard Econometric approach

Municipalities, utility companies and policy makers are interested in understanding how households' energy demand changes when the energy price changes. Because a comprehensive understanding of price elasticity can help them to predict future energy demand, to regulate pricing and to design taxation policies (Espey & Espey, 2004). In general, the demand for energy is determined by an equation of the following form (Olsen & Roland, 1988):

$$Q = f(p, y, z) \qquad (4)$$

where

Q is natural gas consumption,

p is a vector of prices

y is the real income

z is a vector of other independent variables which can affect natural gas consumption

The sensitivity of consumers' energy demanded to price change is measured by price elasticity. The price elasticity of demand can be calculated as percentage change in quantity consumed divided by the percentage change in price. Based on economic theory, as the natural gas price increases, the quantity of natural gas demanded will fall while holding all other variables constant. Price elasticity of demand generally has a negative sign. An elastic demand involves a "larger" change in quantity in response to a "small" change in price.

$$\eta = \frac{\%\ change\ in\ quantitity}{\%\ change\ in\ price} = \frac{\frac{\Delta Q}{Q}}{\frac{\Delta p}{p}}$$

Previous studies of energy demand use a variety of models. The basic model used by researchers is a reduced-form, double log, static model (Espey & Espey, 2004). One advantage of using a double log functional form is that the coefficient on the price represents elasticity. That is, that estimated coefficients on the natural gas price and on the electricity price represent natural gas own price elasticity and cross-price elasticity respectively. One limitation of the double log static model is that the coefficients of price and income do not indicate whether they are short-run or long-run (Dagher, 2011). Lin and Prince (2013) suggest that when estimating energy demand with a static model, the fact that behavioural changes in residential sector in response to changes in prices take time to come about are not being captured. As the coefficient estimates on the prices from the static model only take adjustments in a specific short time period into account, the regression estimation may give us short-run or intermediate-run estimates.

Energy demand has been examined by researchers using different forms of data, for example cross sectional, time series and panel data. A meta-analysis of residential electricity demand elasticity conduct by Espey and Espey (2004) show that estimates from time series studies are significantly more elastic than cross-sectional studies. In a number of previous studies on energy demand, two variants of price are most commonly used: marginal price and average price. Theoretically, marginal price is more appropriate since consumers' demand is responsive to marginal price. However, the marginal price is difficult to define and often not available. Thus average price is often used and can be easily calculated: divide total amount of money spend on energy by total spend on energy consumption (Bohi & Zimmerman, 1984; Espey & Espey, 2004).

3.2 Estimation model

In this study, I use the double log static model to empirically analyze the relationship between residential natural gas demand and prices. First of all, I propose that the residential natural gas consumption depends on the price of natural gas, real income, monthly dummy variables, and real price of electricity since electricity is a competitor for natural gas. Although weather is an important determinant of amount of residential natural gas demanded, data for population weighted temperature or heating degree-days (HDD) are not available at the national level. Taking the average of temperatures in all cities is not an appropriate approach, because the temperature varies across Canada. Thus, I did not include the weather variable in the national model. For the provincial model, in addition to the above variables, HDD is included as a regressor in the model since it is easier to calculate weighted HDD within the province. The household appliances stock is not included as a variable in the model because these data are not available in time series form for the period of this study. Therefore, I end up with two models of residential natural gas demand given my data constraints.

Residential natural gas consumption in Canada is estimated by using Model (1):

$$ln(Q_t) = \beta_0 + \beta_1 ln(P_{Nt}) + \beta_2 ln(P_{Et}) + \beta_3 (income_t) + \beta_5 (M1) + \beta_6 (M2) + \beta_7 (M3) + \beta_8 (M4) + \beta_9 ln(M5) + \beta_{10} ln(M6) + \beta_{11} ln(M7) + \beta_{12} ln(M8) + \beta_{13} ln(M9) + \beta_{14} ln(M10) + \beta_{15} ln(M11) + u_t$$

where Q_t is per residential customer natural gas demand in Canada at time t, P_{Nt} is the real price of natural gas in Canada, P_{Et} is the real price of electricity in Canada, Y_t is the real income in Canada, M1 to M11 are the monthly dummy variables and u_t is an error term.

Residential natural gas consumption in two selected provinces is estimated by using Model (2):

$$ln(Q_t) = \beta_0 + \beta_1 ln(P_{Nt}) + \beta_2 ln(P_{Et}) + \beta_3(income_t) + \beta_3(HDD_t) + \beta_5(M1) + \beta_6(M2) + \beta_7(M3) + \beta_8(M4) + \beta_9 ln(M5) + \beta_{10} ln(M6) + \beta_{11} ln(M7) + \beta_{12} ln(M8) + \beta_{13} ln(M9) + \beta_{14} ln(M10) + \beta_{15} ln(M11) + u_t$$

where Q_t is per residential customer natural gas demand in each province at time t, P_{Nt} is the real price of natural gas in each province, P_{Et} is the real price of electricity in each province, Y_t is the real income in each province, HDD_t is the heating degree-days, M1 to M11 are the monthly dummy variables and u_t is an error term.

Since time series data are used in this study, an Augmented Dickey-Fuller test is conducted to check for stationarity, and the null hypothesis is that the series has a unit root. After the stationarity of each variable has been determined, a Breusch-Godfrey test can be used to test for serial correlation. Three steps are needed to construct the Breusch-Godfrey test (Golder, n.d.):

1. Estimate the model by OLS and obtain the residuals, $\widehat{u_t}^2$

2. Regress the residuals, $\widehat{u_t}^2$on all of the independent variables included in the model and as many lags of the residuals as you think appropriate.

3. R^2 from the regression will be distributed as following:

$$(n - p)R^2 \sim \chi_p^2$$

If the chi-square exceeds the critical chi-square value at the 5% level of significance, then we can reject the null hypothesis of no serial correlation. If there is serial correlation, Generalized Least Square (GLS) Prais-Winsten estimation can be used.

4. DATA

Based on the models outlined above, I obtained time-series monthly data from January 1981 to December 2002 for the following: residential natural gas consumption, price of natural gas, price of electricity, average after-tax income and heating degree-days. The monthly data will provide more details than other more aggregated levels of data. The data necessary to perform empirical analysis in this research is acquired through multiple databases and governmental resources (respective resource will be provided in each sub-section). In the following sub-sections, I discuss each of the variables in details.

4.1 Residential natural gas consumption

I obtained data on the dependent variable residential natural gas consumption in Canada and two selected provinces, Alberta and Ontario from CANSIM database on sales of natural gas[2]. The survey defines the residential natural gas sales as gas sold for domestic purposes, such as space heating, water heating, cooking, etc. Hence, in this study, residential natural gas consumption is the total amount of natural gas sales to residential consumers during a month. I calculated natural gas consumption per customer by dividing the total natural gas consumption by number of customers[3].

4.2 price of natural gas

A number of factors influence natural gas prices, such as weather (colder weather will boost the price of natural gas) and the storage level (low storage level will raise the price of natural gas). In Alberta for example residential consumers paid approximately

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[2] Data source: Statistics Canada. Table 129-0003: Sales of natural gas, monthly
[3] CANSIM defines customer based on households that have utility bills

30 percent less than average Canadian in other provinces in 2007 (Alberta Energy, 2014). Natural gas prices are usually higher in fall and winter months. I collected the sales unit price from the CANSIM database on sales of natural gas as well[4]. It is calculated by dividing sales revenue by sales volume. This can be considered as the monthly average price of natural gas. I obtained the Consumer Price Index (CPI) from CANSIM[5], adjusted the price of natural gas in real terms dividing by Canadian CPI (2002=100). Based on economic theory, the coefficient on the price of natural gas is expected be negative, as the price increases, the demand for natural gas is expected to fall holding all other variables constant.

4.3 Price of Electricity

Electricity prices vary across Canada for a variety of reasons. Two important factors are the market structure and the type of generation (Natural Resource Canada, 2014). Alberta has a deregulated electricity market, and electricity prices are market based; on the other hand, Ontario has partially structured electricity market. In other parts of Canada, electricity prices are often set by electricity regulators. Hydroelectric power generation stations provide lower-cost electricity in some provinces in Canada. There are many other factors which play very important roles in pricing of electricity, such as the cost of transmission and of local distribution. Overall, Canadian households do have some of the lowest electricity prices in North America. The lowest electricity prices are usually found in British Columbia, Manitoba and Quebec (National Energy Board, 2013).

[4] Data Source: Statistics Canada. Table 129-0003: Sales of natural gas- Sales unit price (cents per cubic metre), monthly

[5] Data Source: Statistics Canada. Table 326-0020: Consumer Price Index (CPI), 2011 basket, monthly (2002=100 unless otherwise noted)

There are no direct monthly data available for residential electricity prices because of the complicated pricing system. To construct the price of electricity, I collected the electricity price index from CANSIM[6], and I obtained the price of electricity in Canada, Alberta and Ontario in April 2011[7]. By knowing the price of electricity in one period (April 2011) and its correspondent electricity price index, I calculated price for each month from January 1981 to December 2002 using the following equation.

$$p_{e,t} = p_{April,2011} \times \left(\frac{CPI_{e,t}}{CPI_{2011}}\right) \qquad (5)$$

After I constructed electricity prices in Canada, Alberta and Ontario for the study period, I adjusted them in real terms. It can be seen from Figure 1, approximately 50% of households in Canada use natural gas as a heating source in 2011, and 38% of households in Canada use electricity as a heating source. Hence, electricity might be considered as a substitute for natural gas. According to economic theory, the coefficient on the price of electricity is expected to be positive if electricity is substitute for natural gas, and the coefficient on the price of electricity is expected to be negative if electricity and natural gas are complements.

[6] Data Source: Statistics Canada. Table 326-0020: Consumer Price Index (CPI)-electricity, 2011 basket, monthly (2002=100 unless otherwise noted)

[7] Data Source: Hydro Quebec. Comparison of Electricity Prices in Major North American Cities- Rates in effect April 1, 2011. Retrieved from http://www.hydroquebec.com/publications/en/comparison_prices/pdf/comp_2011_en.pdf

4.4 Income

I obtained the average after-tax income from CANSIM[8], however, those data are only available on an annual basis, and there are no monthly data available in any other databases. Another good proxy for income is wage. Unfortunately, data for Canadian wage only cover periods after 1997. Thus I am not able to use this proxy. Instead, I converted average after-tax income into a quarterly basis time series by using EViews based on linear-match last method. This inserts the low observation value into the last period of the high frequency data, and then it performs linear interpolation on the missing values (EViews,n.d.). Then I adopted the method cubic spline interpolation to convert quarterly time series of income into a monthly time series in Stata (Cox, 2009). By using Stata command *mata* to create a cubic spline function, I generated monthly average income from January 1981 to December 2002 for Canada, Alberta and Ontario. The data obtained are not necessarily ideal and the values may end up systematically related to each other by a cubic polynomial (Chen, 2007). I also adjusted monthly income in real terms. Since energy is considered to be a normal good (Uri, 1983), as income increases, residential natural gas consumption is expected to increase holding all other variables constant. Hence, the coefficient on income is expected to be positive.

4.5 Weather

The weather is a very important determinant of amount of natural gas demanded in residential sector. Environment Canada contains historical temperature data for cities in in each province. However, the weather varies a lot across Canada, thus it is not

[8] Data Source: Statistics Canada. Table 202-06031: Average after-tax income, by economic family type, 2011 constant dollars annual (dollars)

appropriate to use average temperature by taking average of sum of temperatures of all cities in a month. Many previous studies use the population weighted temperature in the energy demand model (Hondroyiannis, 2004; Petrick, Rehdanz, &Tol, 2010). However, data on weighted temperature in Canada are not available. Because a large amount of information is missing, I did not include the weather variable in Model 1. I only included weather variable for two selected provinces, Alberta and Ontario (Model 2). Instead of using temperature, I calculated the monthly total heating degree-days (HDD) in major cities in each province to represent variations in weather. HDD for a given day are the number of degrees Celsius that the mean temperature is below 18 ℃, and if the temperature is equal to or greater than 18 ℃, then the number will be zero (Environment Canada, 2014). For Alberta, I picked Calgary and Edmonton as two major cities. For Ontario, I picked three major cities, Toronto, Ottawa and Windsor. From Canada Weather Stats, I obtained monthly heating degree-day in the above cities from 1989 to 2002[9], but the monthly data for HDD are not available before 1989. Through Government of Canada Climate database[10], I collected daily HDD in these cities from 1981 to 1988, and I calculated monthly total HDD in these cities. By combining two sets of data together, I obtained monthly HDD for above major cities from January 1981 to December 2002, and then I calculated monthly average HDDs in Alberta and Ontario by taking the average of major cities in each province. The coefficient on HDD is expected to be positive, because as the weather gets colder which mean higher HDD, the natural gas consumption will increase holding all other variables constant.

4.6 Seasonality

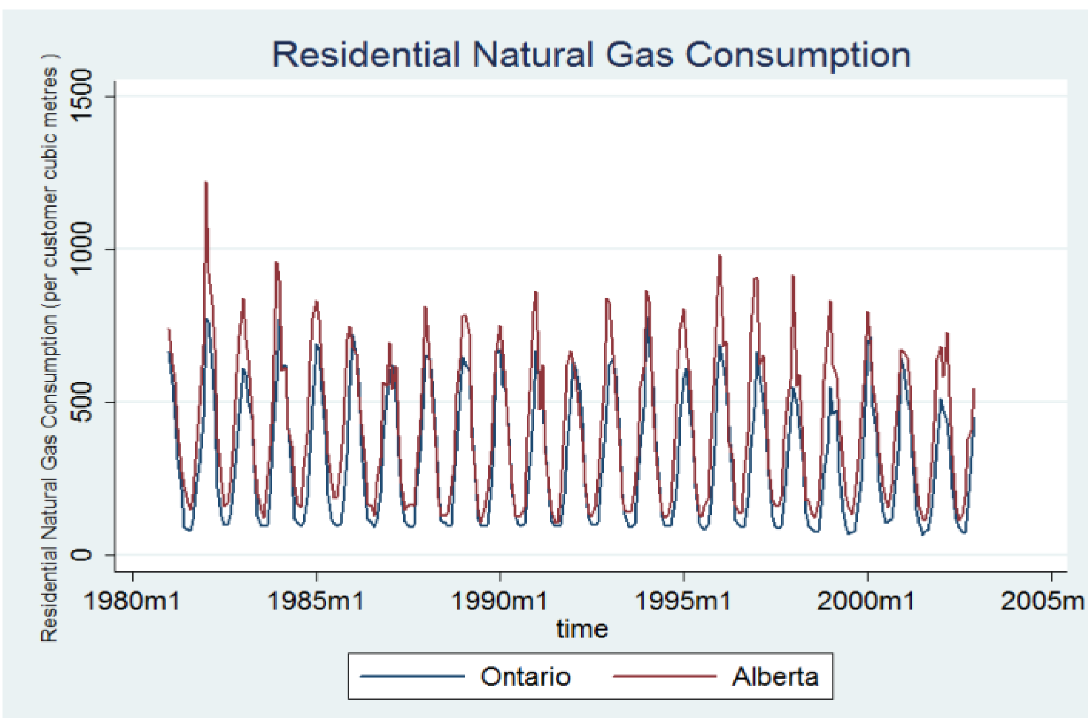
[9] Data Source: Canada Weather Stats. Retrieved from http://www.weatherstats.ca/
[10] Data Source: Government of Canada climate database. Retrieved from http://climate.weather.gc.ca/

I created eleven monthly dummies M1 to M11 to represent 11 months respectively and it is used to justify monthly variations in residential natural gas consumption. I used December as the base month.

5. ANALYSIS AND RESULTS

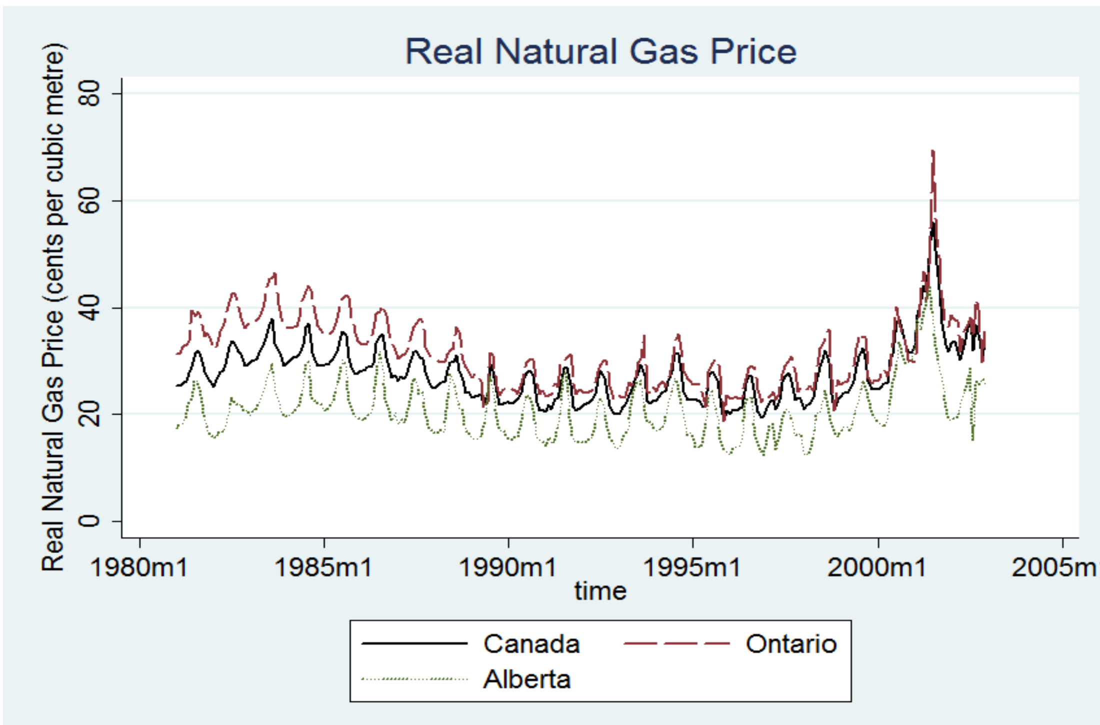
Before estimating the models discussed above, I present some time series plots of the data and summary statistics to illustrate some differences between national level data and that for two provinces. Data on the monthly residential natural gas consumption per customer in Alberta and Ontario are plotted over time in Figure 4. From Figure 4, it can be seen that residential natural gas consumption in Alberta is higher than that in Ontario. Both provinces experience a peak in consumption during winter months. The weather is clearly an important determinant of the amount of natural gas consumption.

Figure 4: Residential Natural Gas Consumption 1981-2002



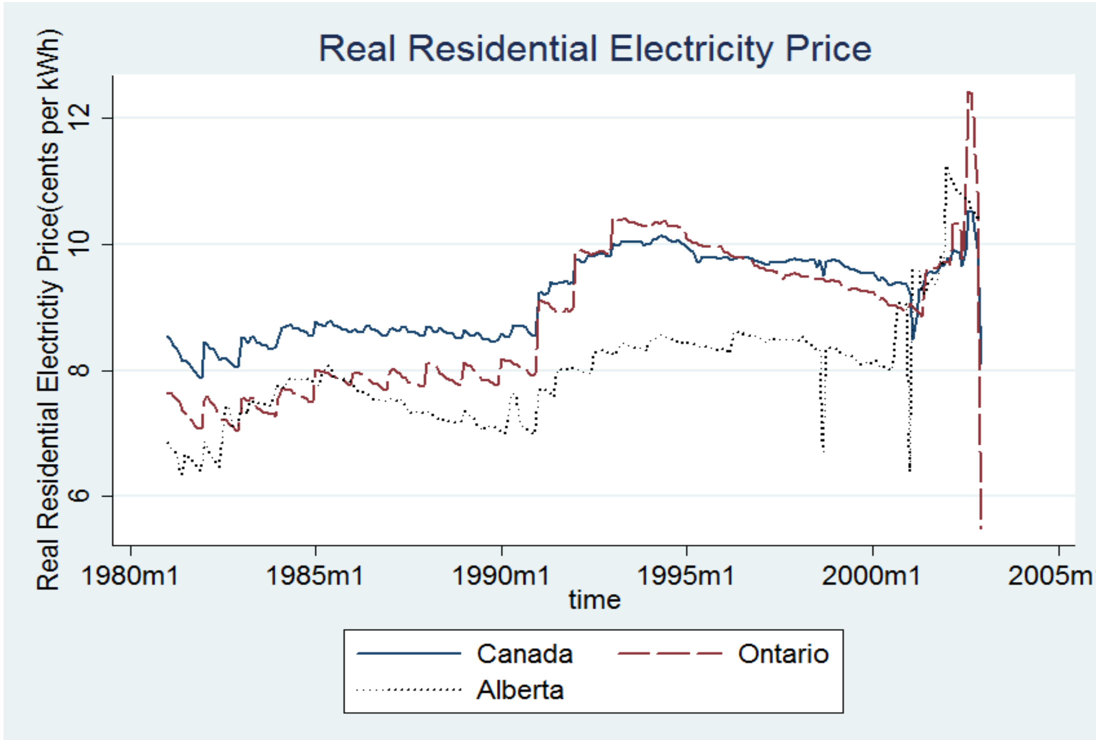
Data on the monthly real residential natural gas prices in Canada and two provinces is plotted over time in Figure 5. From Figure 5, it shows that the natural gas prices fluctuate over time and the natural gas prices in Ontario are always higher than that in Alberta, and the natural gas prices at the national level are between the natural gas prices in two provinces.

Figure 5: Real Natural Gas Price 1981-2002



Data on the monthly real electricity prices in Canada and two provinces are plotted over time in Figure 6. From Figure 6, it can be seen that the electricity prices in Alberta are generally lower than that in Ontario, and the electricity prices are not fluctuating as much as the natural gas prices.

Figure 6: Real Electricity Price 1981-2002



The monthly heating degree-days (HDD) in Alberta and Ontario is plotted in Figure 7, it can be seen that the HDD reaches peaks in the winter months as the temperature decreases. Since Alberta is colder than Ontario, the HDD in Alberta is larger.

Figure 7: Heating degree-days 1981-2002

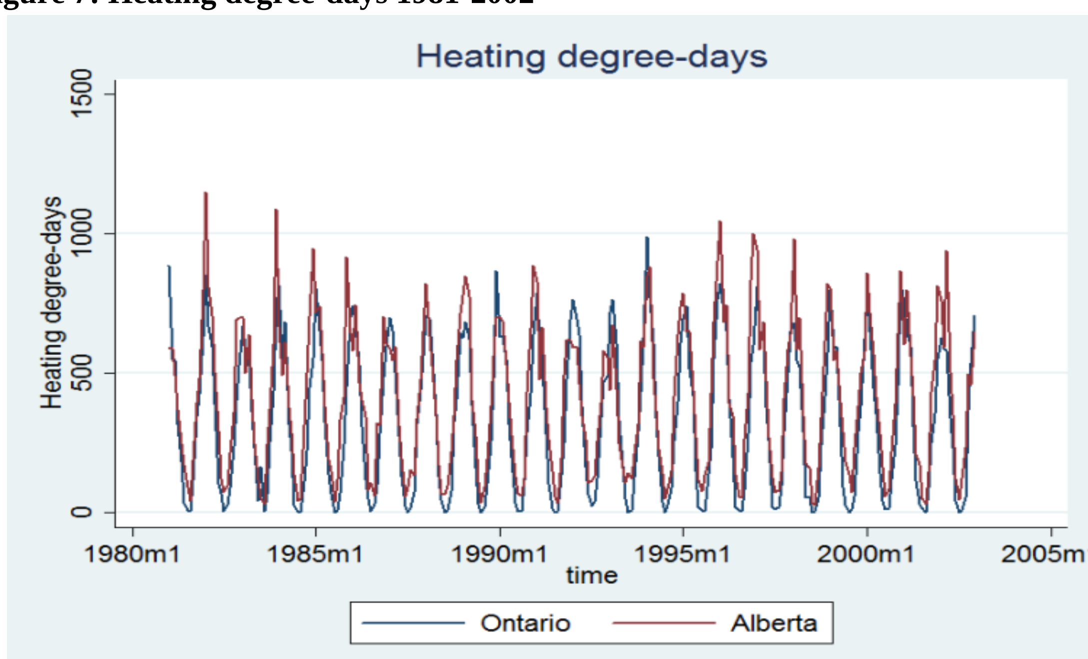


Table 1 presents the average for monthly residential natural gas consumption, the real natural gas price, the real electricity price, the heating degree-days, and annual after-tax income. From Table 1, it can be seen that the average residential natural gas consumption in Alberta is higher than that in Ontario, also higher than the country level. The average real natural gas price in Ontario is higher than that in Alberta, and no doubt explains part of the difference in consumption in two provinces. The average real electricity price is lower in Alberta than Ontario, and the average HDD is higher in Alberta than Ontario. Annual after-tax income in Alberta is the highest among three cases.

Table 1. Average of variables used in the models.

	Average residential natural gas consumption (m^3)	Average natural gas price	Average electricity price	Average heating degree-days	Average income
Canada	326.65	27.77	9.16	N/A	27972
Ontario	317.50	31.65	8.80	334.9	30350
Alberta	422.97	20.81	8.02	412.3	31019

The first step in the empirical analysis involves testing for unit root for all regression variables. Augmented Dickey Fuller (ADF) test is performed on all regression variables to determine whether time series data are stationary or non-stationary. Based on the ADF test results on all regression variables, there is enough evidence to reject null hypothesis that variables is non-stationary at 5% level of significance. Therefore, all regression variable time series are stationary or I(0). The ADF test results are presented in Appendix.

After confirming all variables are stationary, the Breusch-Godfrey test has been conducted in order to test for serial correlation. The basic idea of Breusch Godfrey test is conducting the regression of residuals from OLS the regression on all of the independent variables and on the lagged values of the residuals.

5.1 Models for Canada

The Breusch-Godfrey test result has a chi-square value of 90.89 and the p-value is 0.000. Thus there is enough evidence to reject null hypothesis that there is no serial correlation at 5% level of significance. Hence, serial correlation is present in the model. Because there is no lagged dependent variable is included as a regressor in the model, so I followed the method outlined before. Although OLS is consistent, it is inefficient and the standard errors are not accurate. Therefore, the GLS Prais-Winsten regression estimation results will be more robust than the results from OLS regression estimations results. All coefficient estimates from both regressions are presented in Table 2 (OLS regression estimation results are presented for the purpose of comparison).

From Table 2, it can be seen that the coefficient estimate of the natural gas price is negative, -0.350 and the p-value is 0.000, so there is enough evidence to reject the null hypothesis that natural gas price has no impact on residential natural gas consumption at 5% level of significance. Hence, the natural gas price is statistically significant. As the real natural gas price increases by 1%, the amount of residential natural gas demanded will fall by 0.35% holding all other regressors constant. Bernstein and Griffin (2006) analyze the price elasticity of natural gas demand at national level for United States and they report that the short-term price elasticity is -0.12 and long-term price elasticity is -0.36. My estimate falls between theirs.

However, the coefficient estimate of electricity price which represents the electricity cross-price elasticity is negative and statistically significant. The negative electricity cross-price elasticity implies that electricity and natural gas are complements rather than substitutes. As the real electricity price rises by 1%, the amount of residential natural gas demanded will fall by 0.471% holding all other regressors constant. Since natural gas is primarily used for space or water heating, there is limited switching between electricity and natural gas which may implies the weak electricity cross-price elasticity. There is a prevailing explanation for the negative coefficient. Garcia-Cerrutti (1998) explains that increases in energy price (ie. electricity price) make income share devoted to energy costs larger and provide a strong incentive to use all appliances less intensively at home, and it will result a reduction in total energy consumption . Accordingly, natural gas demand will decrease.

The coefficient estimate of income is 0.162 but not statistically significant. It implies that residential natural gas demand is not very sensitive to the fluctuations in income. In this study, the statistically insignificant result may have resulted from the cubic spline interpolation that I used to convert income data into monthly basis. Stata cannot estimate the coefficient estimate precisely. From Table 2, it can be seen that all monthly dummies are statistically significant except for March, and coefficient estimates of January and February are positive and of the remaining months are negative. The coefficients on monthly dummy variables cannot be explained as elasticities. Instead, the positive coefficients on January and February indicate that residential natural gas consumption is significantly higher than consumption in April through January, and also higher than consumption in December (base month). For instance, in January (M1=1), there will be a 0.23% increase in residential natural gas consumption. The negative coefficients on April to November show that residential natural gas consumption during these months is lower than December (base month). This may sounds contrary to temperatures in November and October in Canada, but the absolute value of coefficient estimates of October, November and March are much smaller than of April to September. Thus, the monthly dummy variables might capture the monthly variations in natural gas consumption that are not captured by the weather.

5.2 Models for Alberta and Ontario

I analyzed the models with data for Alberta and Ontario. The Breusch-Godfrey test has been conducted for Alberta and Ontario in order to test for serial correlation. The Breusch-Godfrey test result for Alberta shows that chi-square value is 101.779 and the p-value is 0.000, so there is enough evidence to reject the null hypothesis that no serial correlation appears at 5% level of significance. Hence, there is serial correlation. The Breusch-Godfrey test result for Ontario shows that chi-square value is 85.422 and the p-value is 0.000, so there is enough evidence to reject the null hypothesis that no serial correlation appears at 5% level of significance. Hence, there is serial correlation in time series for Ontario. Since serial correlation can cause a technical violation of an OLS assumption, GLS Prais-Winstein is used to analyze the model. Regression results for Alberta are presented in Table 3 (OLS regression results are presented for the purpose of comparison), and Regression results for Ontario are presented in Table 4.

5.2.1 Model for Alberta

From Table 3 (Alberta case), it can be seen that the coefficient estimate of natural gas price is negative, -0.256 and the p-value is 0.01, so there is enough evidence to reject the null hypothesis that the natural gas price has no impact on residential natural gas consumption at 5% level of significance. As the real natural gas price increases by 1%, the amount of residential natural gas demanded in Alberta will fall by 0.256% holding all other regressors constant. The natural gas demand in Alberta is inelastic with respect to the natural gas price, and it is more inelastic than natural gas demand at the national level (-0.3495). As I note in previous section, Alberta has a higher percentage of households that use natural gas for space heating and a relatively low natural gas price. Hence, there will be less reduction in residential natural gas consumption when the natural gas price rises. In other words, residents of Alberta are less likely to adjust their consumption of natural gas in response to the natural gas price changes. Maruejols and Ryan (2009) examine provincial natural gas consumption and price relationship in Canada, and they show the own price elasticity ranges from –0.3 to -0.5. My estimate is smaller than theirs, but this may because their data cover from 1960 to 2007, a much longer period.

The electricity cross-price elasticity is negative, -0.010 and not statistically significant. The statistically insignificant cross-price elasticity implies electricity price does not have any impact on residential natural gas consumption. Two factors can be used to explain this: only a small fraction of households use electricity for space heating in Alberta (for instance, only 1.8% of households in 2001 (Natural Resource Canada, 2014)) and there is limited switching between two energy sources. Thus, the electricity price is not going to affect residential natural gas consumption in Alberta.

The coefficient estimate of income is 0.972 and statistically significant. As the real income increases by 1%, the amount of residential natural gas demanded will rise by 0.97% holding all other regressors constant. The positive coefficient implies that energy is a normal good in Alberta. The income elasticity is very close to being elastic, and this implies that residential natural gas demand is very sensitive to the changes in income. One possible explanation for this is that due to the colder weather in Alberta, people will consume more natural gas in space heating when income rises, that is, households are more likely to consume more energy to keep their houses or apartments warmer.

HDD as an important determinant of residential natural gas consumption has a positive coefficient, 0.295 and it is statistically significant. The coefficient estimate of HDD cannot be explained as an elasticity. Instead, we can interpret it as how much percentage of residential natural gas consumption changes when there is an additional heating degree-day in a month. There is 0.295% rise in residential natural gas when there is an additional heating degree-day in a specified month. From Table 3, it can be seen that all monthly dummies are statistically significant except for February, and the coefficient estimate of January is positive and the coefficient estimates of the remaining months are negative. For example, in January (M1=1), there will be a 0.137% increase in residential natural gas consumption. The negative coefficients on February to November show that residential natural gas consumption during these months is lower than December (base month). The absolute value of coefficient estimates of November, February and March are much smaller than those of April to September. It is interesting to note: the negative coefficients in winter months may reflect some factors that HDD failed to capture.

Dagher (2011) suggests that month-to-month variations may come from the influx of tourists during the skiing season.

5.2.2 Model for Ontario

From Table 4 (Ontario Case), it can be seen that the estimate for natural gas price is negative, -0.326 and statistically significant. As the real natural gas price increases by 1%, the amount of residential natural gas demanded in Ontario will fall by 0.326%. Compared with the national level, the natural gas price elasticity in Ontario is a bit more inelastic. There are only few previous studies that focus on residential gas consumption in Ontario. Berndt and Watkins (1977) shows the natural gas price elasticity in Ontario is -0.25 in the short-run and -0.686 in the long-run. My estimate is similar to the previous study.

The cross-price elasticity of natural gas demand is negative -0.360 and statistically significant; it implies that electricity and natural gas are complements rather than substitutes. As the real electricity price rises by 1%, the amount of residential natural gas demanded will fall by 0.36%. The electricity cross-price elasticity in Ontario is more inelastic than that at the national level (-0.471). According to Garcia-Cerrutti's (2000) explanation is that, increases in electricity price cause income the share devoted to energy costs to be higher and households have incentive to reduce all energy use. From Figure 6, it can be seen that electricity price in Ontario is generally lower than that at the national level. This means electricity costs represent a lower share of total energy expenditure in Ontario than that at the national level. As electricity price increases in Ontario, households have incentive to use all appliances less intensively but the reduction in natural gas consumption is less than what it is at the national level. Maruejols &Ryan

(2009) examine the provincial natural gas consumption and price relationship in Canada, and they find the cross-price elasticity is around -0.4 to -0.2 in Ontario. My estimate falls into this range.

The coefficient estimate of income is negative, -0.307 but not statistically significant. One possible explanation for the negative income elasticity is that when income rises, households have more funds available to purchase energy-efficient appliances in order to reduce the natural gas consumption. Since the coefficient estimate is not statistically significant, it implies that changes in income do not have a measurable impact on residential natural gas consumption in Ontario.

The coefficient estimate on HDD is positive, 0.030 and statistically significant. There is 0.03% rise in residential natural gas consumption when there is an additional heating degree-day in a specified month. Table 4 shows that all monthly dummies are statistically significant and the coefficient estimates of January to March are positive and the remaining months are negative. For example, in January (M1=1), there will be a 0.28% rise in residential natural gas consumption in Ontario. This is slightly higher than the increase at the national level. The negative coefficients on April to November indicate that residential natural gas consumption during these months is lower than December (base month).

Table 2:
GLS Prais-Winsten Estimation Results for Residential Natural Gas Consumption in Canada

Variables	OLS	Prais-Winsten
log natural gas price	-0.146***	-0.350***
	(0.0453)	(0.0817)
log electricity price	-0.659***	-0.471**
	(0.0933)	(0.184)
log income	-0.455**	0.162
	(0.210)	(0.434)
M1	0.214***	0.208***
	(0.0287)	(0.0227)
M2	0.0857***	0.0873***
	(0.0287)	(0.0253)
M3	-0.0410	-0.0367
	(0.0287)	(0.0258)
M4	-0.384***	-0.377***
	(0.0288)	(0.0280)
M5	-0.884***	-0.869***
	(0.0290)	(0.0304)
M6	-1.385***	-1.349***
	(0.0300)	(0.0315)
M7	-1.590***	-1.540***
	(0.0310)	(0.0326)
M8	-1.618***	-1.570***
	(0.0309)	(0.0319)
M9	-1.400***	-1.368***
	(0.0297)	(0.0312)
M10	-0.791***	-0.783***
	(0.0288)	(0.0239)
M11	-0.322***	-0.325***
	(0.0287)	(0.0186)
Constant	11.63***	7.213**
	(1.605)	(3.375)
Observations	264	264
Adjusted R-squared	0.981	0.967

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3:
GLS Prais-Winsten Estimation Results for Residential Natural Gas Consumption in Alberta

Variables	OLS	Prais-Winsten
log natural gas price	-0.128***	-0.256**
	(0.0469)	(0.0987)
log electricity price	-0.162**	-0.0105
	(0.0755)	(0.136)
log income	0.815***	0.972**
	(0.157)	(0.405)
log HDD	0.344***	0.295***
	(0.0304)	(0.0253)
M1	0.144***	0.137***
	(0.0377)	(0.0220)
M2	-0.0131	-0.0225
	(0.0378)	(0.0283)
M3	-0.0785**	-0.0884***
	(0.0381)	(0.0299)
M4	-0.295***	-0.322***
	(0.0421)	(0.0374)
M5	-0.579***	-0.608***
	(0.0491)	(0.0448)
M6	-0.749***	-0.793***
	(0.0642)	(0.0586)
M7	-0.712***	-0.777***
	(0.0799)	(0.0697)
M8	-0.736***	-0.804***
	(0.0777)	(0.0734)
M9	-0.723***	-0.754***
	(0.0532)	(0.0507)
M10	-0.442***	-0.458***
	(0.0418)	(0.0331)
M11	-0.170***	-0.175***
	(0.0380)	(0.0220)
Constant	-1.184	-2.004
	(1.167)	(3.041)
Observations	264	264
Adjusted R-squared	0.962	0.944

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4:
GLS Prais-Winsten Estimation Results for Residential Natural Gas Consumption in Ontario

Variables	OLS	Prais-Winsten
log natural gas price	-0.219***	-0.326***
	(0.0463)	(0.0883)
log electricity price	-0.454***	-0.360**
	(0.0652)	(0.151)
log income	-0.343**	-0.307
	(0.170)	(0.352)
log HDD	0.0699***	0.0301**
	(0.0160)	(0.0135)
M1	0.287***	0.283***
	(0.0355)	(0.0273)
M2	0.222***	0.215***
	(0.0354)	(0.0301)
M3	0.0971***	0.0884***
	(0.0355)	(0.0313)
M4	-0.192***	-0.221***
	(0.0369)	(0.0358)
M5	-0.707***	-0.765***
	(0.0423)	(0.0413)
M6	-1.175***	-1.277***
	(0.0583)	(0.0510)
M7	-1.223***	-1.395***
	(0.0856)	(0.0733)
M8	-1.315***	-1.459***
	(0.0756)	(0.0609)
M9	-1.385***	-1.444***
	(0.0483)	(0.0421)
M10	-0.832***	-0.863***
	(0.0380)	(0.0326)
M11	-0.370***	-0.390***
	(0.0358)	(0.0257)
Constant	10.06***	10.20***
	(1.288)	(2.656)
Observations	264	264
Adjusted R-squared	0.975	0.956

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.2.3 Comparison of coefficient estimates for three cases

Table 5: Summary of Coefficient Estimates from Three Regression Results

	Natural gas price	Electricity price	Income	heating degree-days
Alberta	-0.256	-0.010*	0.972	0.295
Ontario	-0.326	-0.360	-0.307*	0.030
Canada	-0.350	-0.471	0.162*	N/A

***** Variable is not statistically significant

Comparing the two sets of provincial results, it is clear that the magnitude of the coefficient estimate of natural gas price in Alberta is smaller than that in Ontario. That is, residential natural gas demand is inelastic in both provinces, and residential natural gas demand in Alberta is more inelastic than that in Ontario. As the natural gas price increase by 1%, the residential natural gas consumption in Alberta will fall by 0.256%, which less than the reduction in Ontario, 0.07%. This may be because that Alberta is much colder, and has cheaper natural gas price and a higher percentage of households are using natural gas as a heating source than Ontario. Overall, residential natural gas demand is inelastic at the national level and in two provinces with respect to its own price. The electricity cross price elasticity is negative in all three cases, but not statistically significant in Alberta. Thus, electricity price does not have a measurable impact on residential natural gas consumption in Alberta. The natural gas demand is inelastic with respect to electricity in both Canada and Ontario, and the negative coefficient implies natural gas and electricity are complements in Ontario and Canada. The coefficient on income variable is positive and statistically significant in Alberta only, and the elasticity is just below unity. The coefficient estimate of HDD is positive and statically significant in both Alberta and Ontario, but the magnitude of the coefficient estimate of HDD is larger in Alberta. Since a higher percentage of households use natural gas for heating in Alberta and natural gas prices are lower in Alberta, households' natural gas quantities demanded are more responsive to weather in Alberta. Weather will affect the residential natural gas consumption in Alberta more than that in Ontario.

6. CONCLUSIONS

Based on the double log static model, I estimated the demand elasticity for residential natural gas consumption with respect to its own price, electricity prices and household income using monthly time series Canadian aggregate data and provincial data for Alberta and Ontario spanning over the period of January 1981 to December 2002. The results show that natural gas demand per customer is inelastic with respect to the natural gas prices for all three cases (from -0.350 to 0.256) and with respect to electricity prices at the national level and in Ontario. The negative cross-price elasticities of natural gas demand in Ontario and Canada indicate natural gas and electricity as complements. It also shows residential natural gas demand is inelastic with respect to HDD in Alberta and Ontario. My estimated price elasticities of natural gas demand in this paper are comparable to those obtained by Maruejols and Ryan (2009) and Berndt and Watkins (1977).

Households respond differently to changes in prices based on the province where they are locate, this indicates that residential natural gas demand does not have the same elasticity in each province. Interpretation and explanation of estimates from estimation on natural gas demand responses to price changes using Canada as a homogeneous whole is limited. The Prairies province such as Alberta has the highest per capita natural gas consumption and they exhibit more inelastic demand for natural gas than Ontario. The natural gas demand for Alberta is less sensitive to the change in natural gas price and more sensitive to the change in weather than that for Ontario.

Aggregate time series data are used in this study. However, there are some drawbacks of using time series data to model residential natural gas demand, and the most important one is that the analysis is not able to reflect variations in individual consumers' characteristics. There are some potential improvements for this and future studies on analyzing elasticities of natural gas demand. For example, lack of monthly household income data may result in an imprecise estimation on the coefficient of the income variable. When new data become available, frequent re-estimation of responsiveness of household natural gas demand to changes in price is essential. As regulatory agencies and policy makers concern how effective energy policies that are being considered to address environmental concerns, frequently updated estimation of elasticity of demand will provide a clear picture of the effectiveness of energy policies which involve changing price of energy to influence the way energy is used.

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APPENDIX

Figure 1: Shares of Households Principal Heating Energy Source in Canada 1990-2011

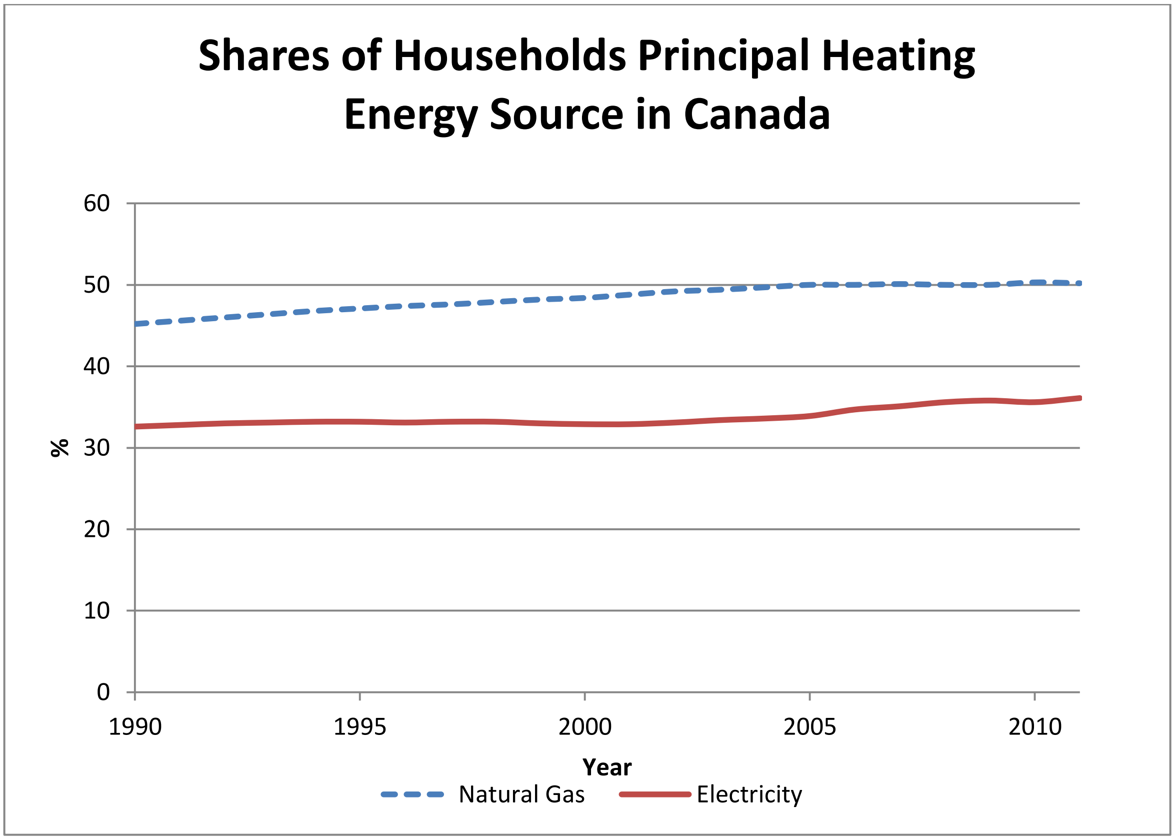

Figure 2: Shares of Households Principal Heating Energy Source in Alberta 1990-2011

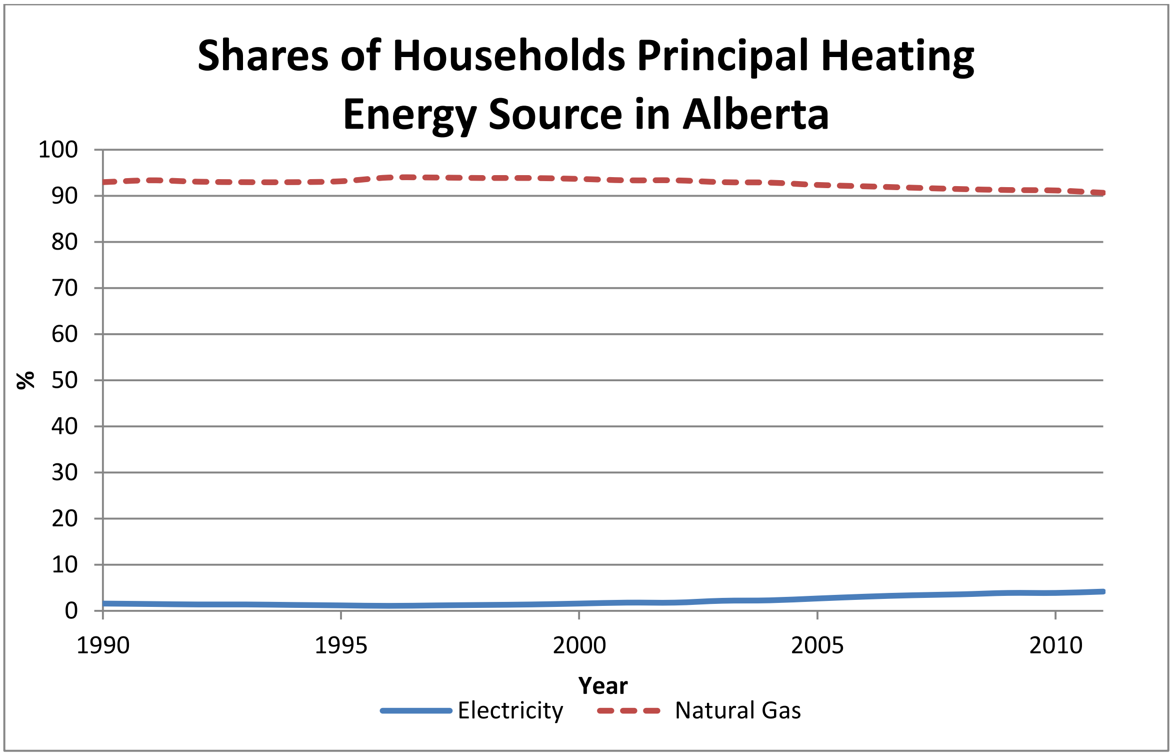

Figure 3: Shares of Households Principal Heating Energy Source in Ontario 1990-2011

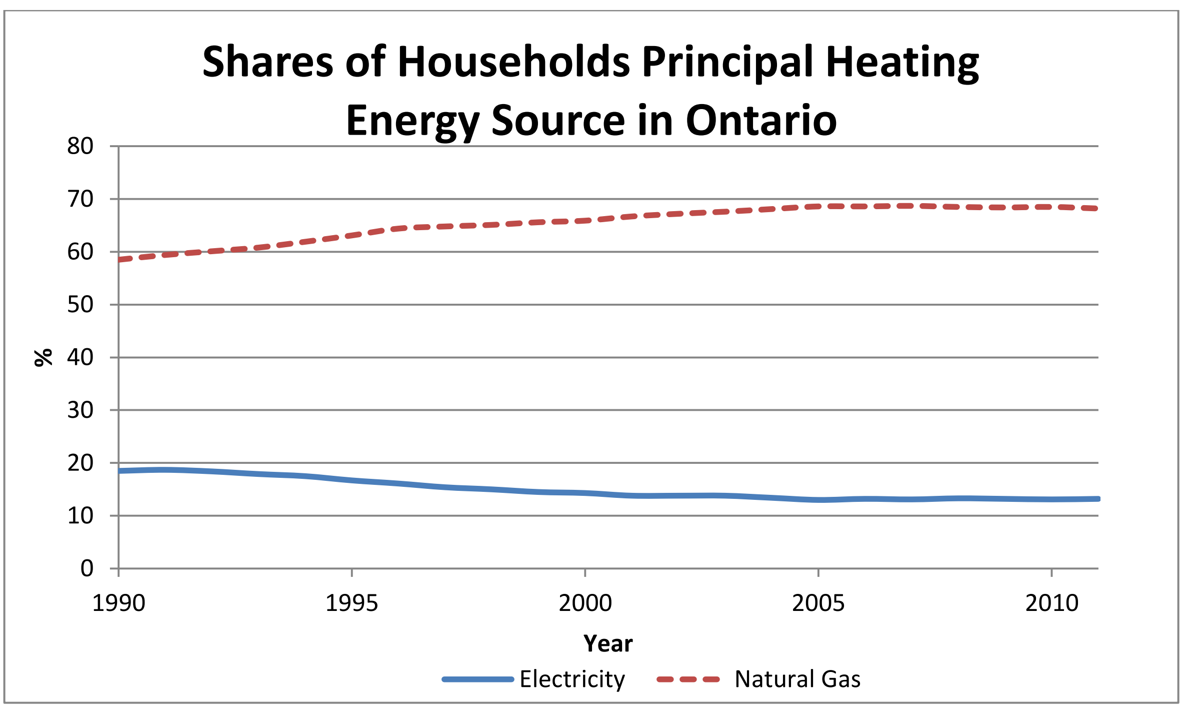

Table 1: Augmented Dicky Fuller Test results

	Canada		Alberta		Ontario	
	Test statistic	p-value	Test statistic	p-value	Test statistic	p-value
log natural gas consumption	-10.5	0.000	-11.147	0.00	-8.19	0.00
Log natural gas price	-8.006	0.000	-3.878	0.002	-7.24	0.00
log electricity price	-3.161	0.022	-3.407	0.05	-2.91	0.041
log income	3.5	0.009	-4.297	0.0004	-3.60	0.0057
log HDD	N/A-	N/A	-12.758	0.00	-11.04	0.00