The Likely Effect of Carbon Pricing on Energy Consumption in Canada

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Sustainable Prosperity

BACKGROUND PAPER

Background Report:
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Key Messages

- A carbon price can be imposed through a carbon tax or via an emissions trading system. In theory, carbon pricing shifts consumption away from carbon-intensive products by linking a good's price to its carbon content. As a result, under carbon pricing, the more carbon-intensive a good, the higher its carbon premium. Energy products such as oil and natural gas have high carbon content and will be especially affected by carbon prices.
- The effectiveness of a carbon price in shifting consumption away from carbon-intensive goods depends on consumer responsiveness to price changes. This responsiveness is reflected in a statistic known as the price elasticity of demand.
- New research demonstrates that the price elasticities of demand for energy have been changing over time, especially as real energy prices have fallen.[1] Understanding these trends along with regional variations in the statistics is crucial for predicting the success of policies aimed at reducing carbon emissions via carbon pricing strategies. Policy-makers, as well as climate and economic modellers, require up-to-date information on how carbon prices impact consumer behaviour.
- Natural gas and electricity are what is known as *price inelastic* commodities – i.e., their demand is not highly responsive to changes in price. This holds true for almost all regions and for both the residential and commercial sectors. As a result, higher prices for natural gas and electricity would have a relatively small impact on the quantity of energy consumed.
- Within the residential sector, oil demand has become less responsive to price changes in recent years. However, if the recent high oil prices are maintained, greater reductions in demand may occur over the long-run. As high prices persist, consumers are less likely to view the price level as temporary and will invest more in energy efficient equipment.
- In the industrial sector, increases in electricity and oil prices will have minimal effects on demand. However, the quantity demanded is more responsive to increases in natural gas prices. Natural gas is the dominant fuel in many energy-intensive industries.

The Issue

The effectiveness of a carbon pricing policy to reduce greenhouse gas emissions depends on the behaviour of consumers faced with increased energy prices. New research shows that price elasticities of demand, which reflect responsiveness of energy consumed to changes in price, have evolved in recent years. Energy consumers have become less sensitive to changes in the price of energy products. Understanding the reasons behind these trends and variations is crucial for predicting the success of a policy aimed at reducing emissions by adjusting the price of carbon.[2]

[1] The elasticities presented in this paper are for the short-run. This paper uses the standard economic definition of the short-run, where the current equipment stock is fixed.
[2] This paper does not examine the implications of the energy price elasticities presented for the transportation sector.

The Knowledge Base

Carbon Pricing and Price Elasticity of Demand

The price elasticity of demand is a fundamental concept in economics. The term refers to the change in the quantity demanded of a particular good that is the result of a change in the price of that good.[3] When the price of a good increases, there is a corresponding decrease in the quantity demanded of that good. The price elasticity of demand explains the magnitude of the decrease of quantity demanded that can be attributed to a given increase in price – i.e., the price elasticity of demand is defined mathematically as the percent change in quantity demanded divided by the percent change in price. If the size of the percent decrease in quantity demanded is greater than the percentage change in price then the demand for that good is elastic (much the same way an elastic rubber band is able to expand and contract with ease – so does the demand for the good). If the percentage drop in quantity demanded is less than the percentage change in price then the demand is said to be inelastic.

The main objective of a carbon price is to shift consumption towards lower-carbon goods, thereby reducing carbon dioxide (CO_2) emissions. A carbon price induces this shift by adding a carbon cost for producers of carbon-intensive goods. Depending on the elasticities of demand and supply, producers of carbon-intensive goods are able to pass a portion of the additional costs on to consumers through higher end market prices.

Price elasticities are impacted by various factors, including the availability and price of substitutes, consumer knowledge and responsiveness of demand to changes in income levels. For these reasons, the price elasticity of demand can vary over time and geography. Moreover, there is a difference between short-run and long-run price elasticities. For example, it could take years for demand to fully respond to an increase in electricity prices as consumers gradually shift towards using more energy efficient appliances. This is an important consideration when interpreting short-run elasticity measures (like the ones presented in this paper) – it usually requires significant capital investment to switch between energy sources. Therefore, the quantity demanded of energy products is more likely to respond in the long-term to price changes as consumers change their behaviour and invest in substitutes.

Another contributing factor to the delayed demand response following price increases is the billing cycle. Most utility bills arrive on a bi-monthly basis. As a result, consumers are slow to react to price increases as they may not realize that prices have changed. This was the case during the 2000-2001 spike in Californian electricity prices. Electricity consumption only started to fall significantly in the state a year after the spike began and at a time when prices began falling back to their pre-spike levels.[4] However, several innovations have been introduced to reduce consumers' response time to price changes. These include smart meters and the pre-purchasing of energy products (paying upfront instead of after the fact). Both options provide more information to

[3] Technically this definition applies to own-price elasticities. This paper is focused on own-price elasticities only.
[4] See: Susan L. Pope, 2002. *California Electricity Price Spikes: An update on the facts*. www.hks.harvard.edu/hepg/Papers/Pope_CA.price.spike.update_12-9-02.pdf .

consumers on the pricing of energy products and make them more aware of their consumption habits. They will thus be able to better adapt more quickly to higher prices.

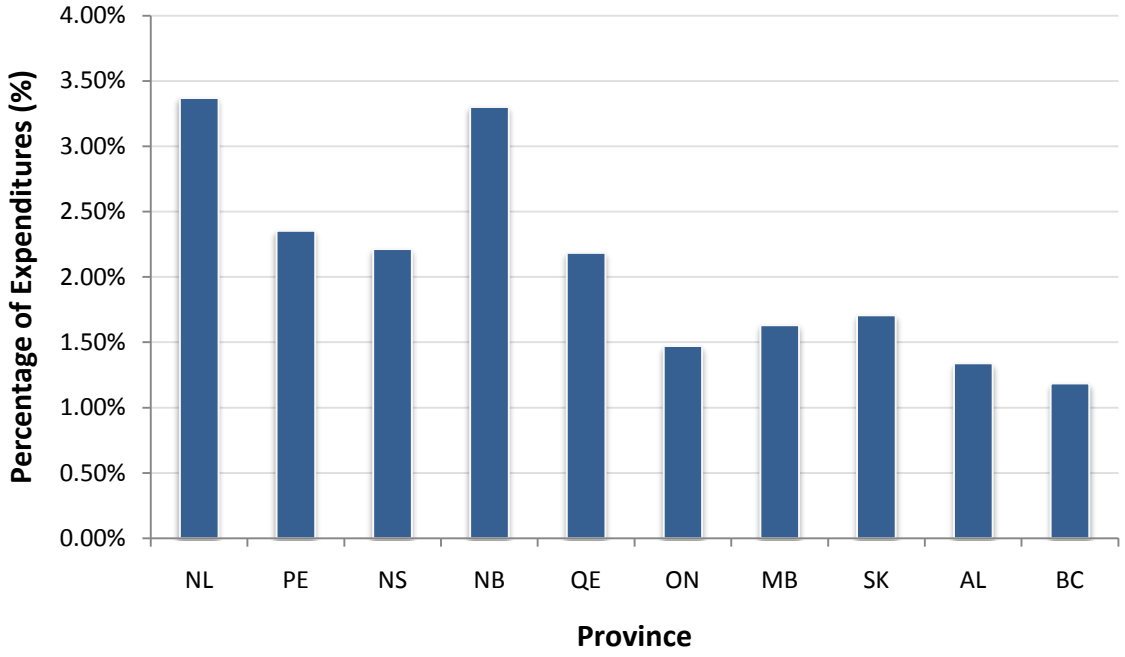
Estimating Price Elasticity of Demand

There are several methods for estimating demand elasticities for carbon-intensive goods such as energy. Each one has its advantages and drawbacks. Price elasticities are typically obtained as mathematical functions of estimated price coefficients in demand equations which are obtained via regression analysis.[5] Yet, energy prices have evolved over recent years, so older price elasticities may not accurately capture new trends. Ideally, price elasticities are estimated holding constant other factors such as income and the price of substitutes. In reality, these factors fluctuate and can have significant impacts on the quantity demanded of a good.

One method to address the challenges of estimating price elasticity over time is to analyze price-elasticities across regions. Different price structures and regulatory regimes among the provinces can have significant impacts on how consumers respond to price changes. For example, a residential consumer in New Brunswick pays a base fee of $21.63 just to have electricity delivered to the home. A customer in Quebec pays only $12.20 a month. In Nova Scotia, customers are charged $6.63 in addition to their base fee for the provincial energy retrofit program. British Columbia's conservation program sees customers pay more per kWh if they use more than 1,350 kWh within a two-month period. Faced with this range of pricing structures, consumers will react differently to price changes since the proportion of their total electricity bill that is comprised of marginal costs (and is therefore adjustable based on the level of consumption) differs based on the region. Moreover, total electricity costs and incomes vary across regions and these variations may produce divergences in the household budget shares allocated to electricity in each province. A consumer who faces a 10% increase in his or her electric bill may wish to reduce consumption more when over 3% of their expenditure is on electricity than a consumer who is faced with the same increase but only allocates 1% of his or her expenditure to electricity. Figure 1 illustrates the differences in expenditure allocated to electricity by province.

[5] See, for example, Ryan, D.L. and Plourde, A. "Empirical Modelling of Energy Demand", Chapter 6 in J. Evans and L.C. Hunt (eds) *International Handbook on the Economics of Energy*, 2009 (Cheltenham, UK: Edward Elgar), for a detailed review of energy demand modeling approaches and how they have evolved.

Figure 1: Average percentage of household expenditures



Source: Statistics Canada. Table 203-0001 - *Survey of household spending (SHS), household spending, summary-level categories, by province, territory and selected metropolitan areas, annual*, CANSIM (database).

Updated Price Elasticity of Demand Estimates

There have been very few recent studies of energy price elasticities for different sectors and different regions in Canada.[6] Researchers at the University of Alberta have recently calculated updated short-run demand elasticity figures, presented in Table 1, using a methodology that overcomes many of the problems with other calculation techniques. The approach allows for substitution between energy sources and for the elasticities to vary over time. They also calculated own- and cross-price elasticities,[7] though only selected own-price elasticities are presented in this paper. Standard errors are used to construct 95% confidence bands for the elasticities (as shown in Figures 2-7 below), so that their statistical significance can be readily ascertained.[8]

Looking at regional and sectoral differences is important, because elasticities vary by energy source and usage, which also vary by region and by sector. Other regional factors such as weather conditions can also influence price responsiveness.

[6] In fact there appear to have been no comprehensive published energy demand elasticities for all sectors or regions in Canada during the past 30 years. The most recent available provincial estimates is for Quebec in 1990, and again in 2002, as well as for the Ontario residential sector in 1989 and again in 1994. For Canada as a whole, at least for the non-transport sector, the most recent estimates appear to be for 1998. More detailed information about existing energy demand studies is contained in Dahl, Carol A. ,2011. *Dahl Energy Demand Database*. Work in Progress, Mineral and Energy Economics Program, Colorado School of Mines.

[7] Own-price elasticity refers to the change in demand for a good that results from a change in price of that good. Cross-price elasticity refers to a change in demand for a good that is due to a change in the price of another good. It is important to note that these other goods could either be substitutes or compliments.

[8] A 95% confidence interval implies that if the same elasticities were repeatedly estimated using different samples from the same population then 19 times out of twenty we would obtain a result that was between this range of values.

Table 1 shows the mean own-price elasticities by region and sector. With the exception of natural gas in the industrial sector, demand for electricity, natural gas and oil are all inelastic. For example, the own-price elasticity of demand for electricity in Saskatchewan equals -0.45. This implies that if there is a 10 percent increase in the price of electricity, it will lead to a decline in the quantity of electricity demanded of 4.5 percent.

Table 1: Estimated Average Own-Price of Demand Energy Elasticities in Recent Years (1960-2006)

Sector/Fuel	B.C.	Alberta	Sask.	Manitoba	Ontario	Quebec	Atlantic
Residential							
Electricity	**-0.53**	**-0.35**	**-0.45**	**-0.57**	**-0.47**	**-0.57**	**-0.60**
Nat. Gas	**-0.67**	**-0.86**	**-0.66**	**-0.76**	**-0.49**	**-0.50**	
Oil	1.37	-0.19	0.91	1.65	-0.38	**-0.75**	**-0.59**
Commercial							
Electricity	**-0.41**	**-0.61**	**-0.56**	**-0.44**	**-0.52**	**-0.49**	**-0.71**
Nat. Gas	**-0.53**	**-0.92**	**-0.73**	**-0.66**	**-0.72**	-0.27	
Oil	**-0.76**	-0.61	0.41	0.38	0.15	-0.35	**-0.98**
Industrial							
Electricity	-0.03	0.02	**-0.42**	0.02	-0.01	-0.04	0.02
Nat. Gas	**-3.68**	**-1.62**	**-3.08**	**-1.62**	**-1.53**	**-1.68**	
Oil	**-0.16**	0.02	**-0.62**	0.02	-0.05	**-0.33**	**0.45**

Source: David Ryan and Noha Abdel Razek

Notes: (1) **Bold** indicates that the elasticity is statistically significantly different from zero at 5% level. Elasticities not bolded are not significantly different from zero. (2) Average elasticities in the residential sector refer to the period 2002-2006, except for oil which refers to the period 2001-2005. (3) In the industrial and commercial sectors, averages are calculated for the period 2003-2007.

Changes in Price Elasticities over Time

Energy demand mean elasticities have changed over time. Figures 2 through 7 show the time-series variation in residential (Figures 2-6) and industrial (Figure 7) elasticities and their 95% confidence bounds.[9]

For residential electricity and natural gas demand (Figures 2, 3 and 5), elasticities demonstrate a general downward trend. This means that demand for these products, though still inelastic, is becoming more elastic (further from zero in absolute value).

Figures 4 and 6 depict the residential demand elasticities for oil in Ontario and the Atlantic region. The elasticity for oil has gotten smaller (in absolute value), implying that oil demand is becoming more inelastic.

Figures 2 and 7 contrast the elasticity of demand for electricity in Ontario for the residential and industrial sectors. Demand for electricity in the industrial sector has almost no price

[9] Whenever either of the confidence bounds is positive, it indicates that an increase in the price of that energy source does not result in a significant decrease in its usage.

responsiveness, whereas it is significant in the residential sector. Industrial users pay lower rates for electricity, and it does not represent a large expenditure, whereas electricity expenses represent a greater budget share for households.

Due to the differential effects of price responsiveness across regions, energy-type and sector, the figures suggest that the effect of carbon pricing will have distinct implications for depending on the context, which is discussed in the context of policy-making in the next section.

This paper presents new price elasticity data which suggests that residential consumers react in a similar fashion as commercial users when faced with changes in the prices for electricity and natural gas. Demand for natural gas in Alberta is more elastic than in other regions, while demand for electricity is more inelastic than other provinces. In Alberta, 95%[10] of households use natural gas for heating. The remaining 5% are likely use electricity or oil due to infrastructure limitations, making those sources more inelastic. Atlantic Canadians are the most responsive to changes in electricity prices. This reflects the fact that they spend a greater share of their expenditure on electricity than other regions.

Insofar as the elasticities have changed through time, consumers have become more responsive to electricity price increases. There are two explanations for this change: higher electricity prices and more efficient household appliances. The demand for oil has become more inelastic over time as oil prices have increased. Oil prices tend to be volatile making it challenging for consumers to identify a permanent price increase. They therefore continue to absorb the increased costs without switching furnace types (an expensive adjustment) because they believe the high prices to be temporary.

In the industrial sector natural gas demand is substantially more elastic than in other sectors. In every region, the quantity demanded falls by a greater magnitude then the percentage increase in price. It is important to remember that the industrial sector is the largest consumer of energy and therefore has the most to gain from substituting to alternative sources of fuel consumption. Many large facilities in the industrial sector would be equipped to switch between gas, oil and electricity in order to maximize efficiency. Therefore, a price increase in natural gas for example, would lead a firm to substitute in another source of energy and thus significantly reduce demand for natural gas. Large firms also tend to have more resources available to monitor efficiency and implement energy saving practices to best lower costs and maximize profitability. This makes them more responsive to changes in energy prices. Interestingly, the results were not the same for oil in the industrial sector.

[10] CANSIM table 203-0003

Figure 2. Residential Elasticity of Demand of Electricity - Ontario

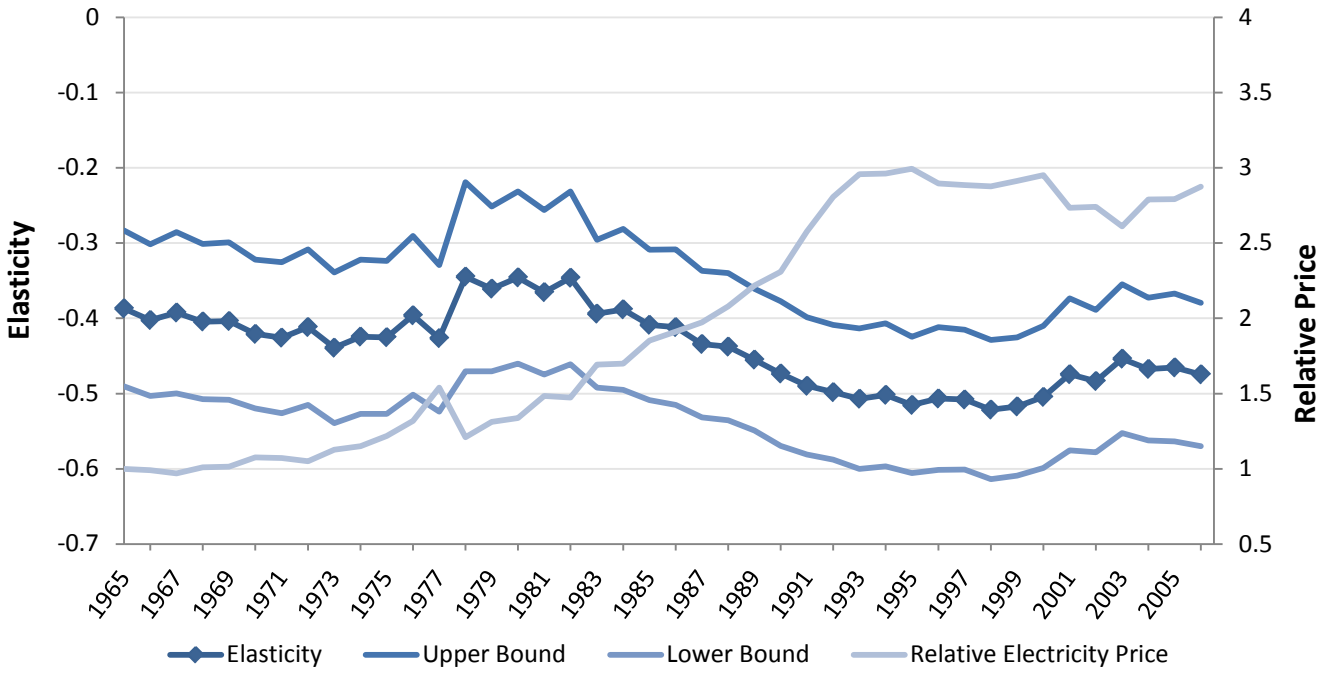


Figure 3. Residential Elasticity of Demand of Natural - Ontario

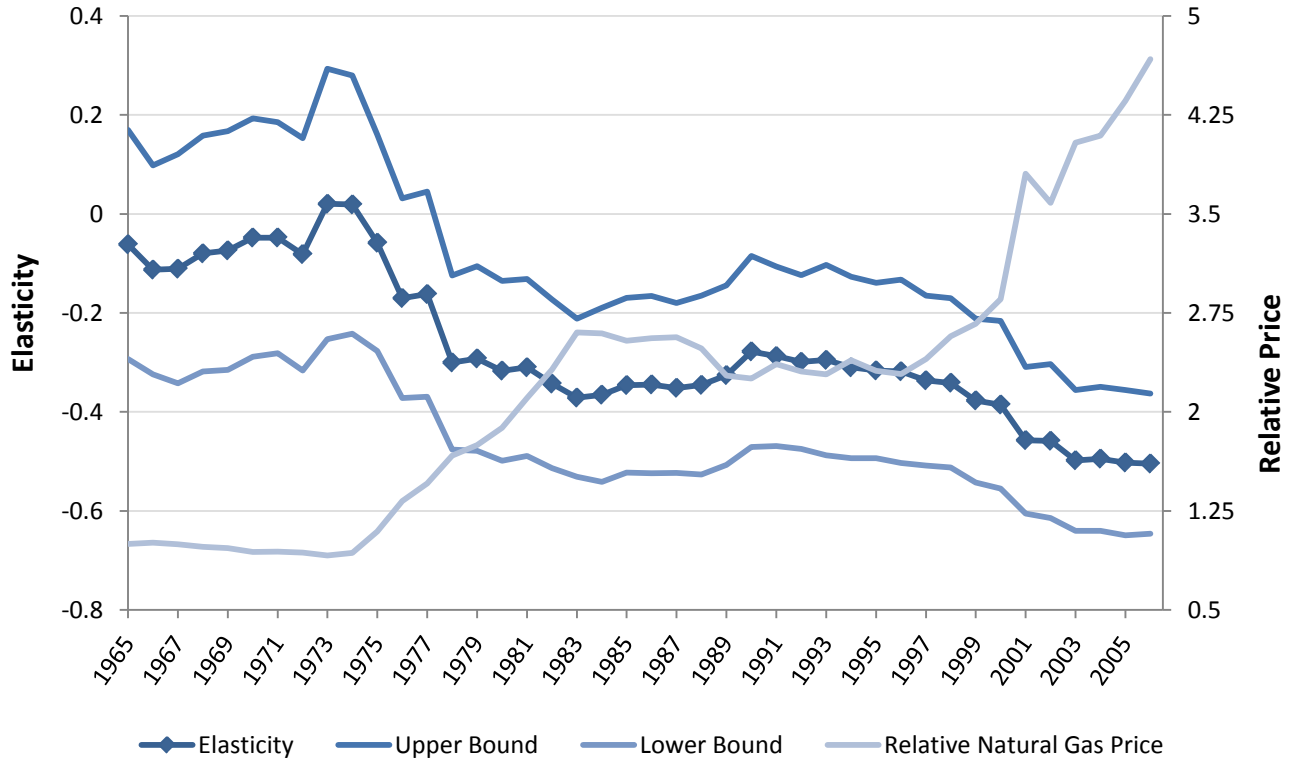


Figure 4. Residential Elasticity of Demand of Oil - Ontario

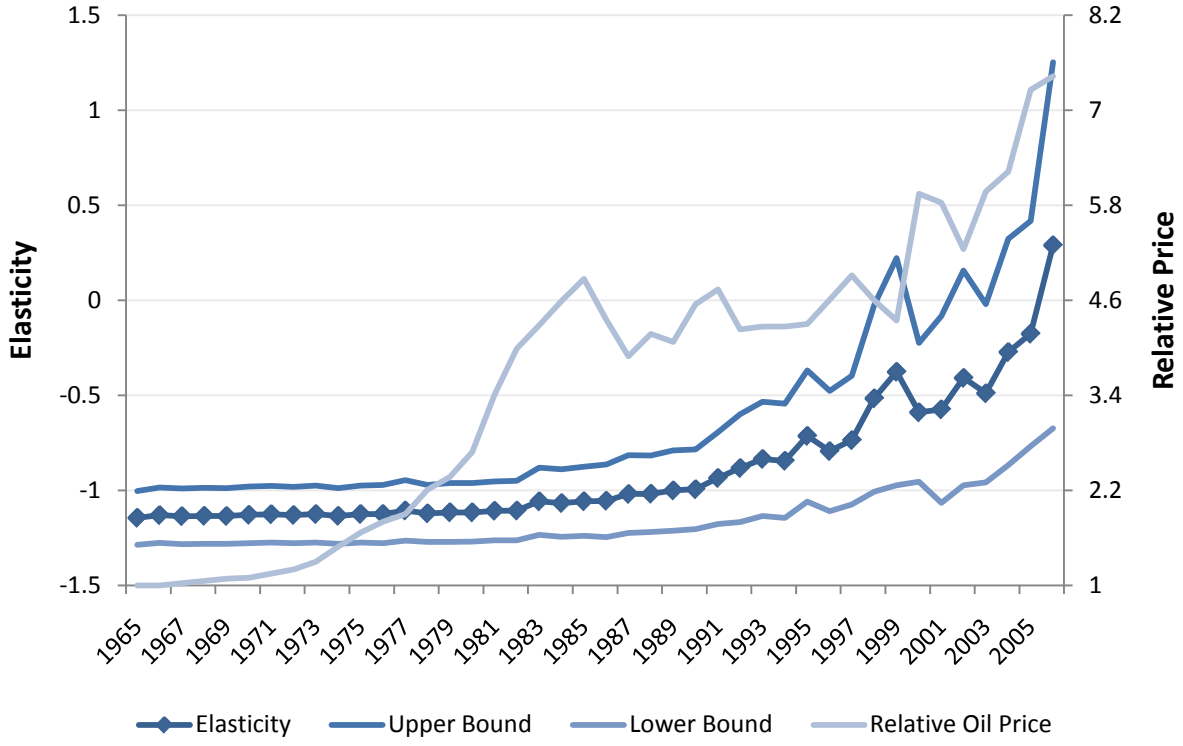


Figure 5. Residential Elasticity of Demand of Electricity - Atlantic Region

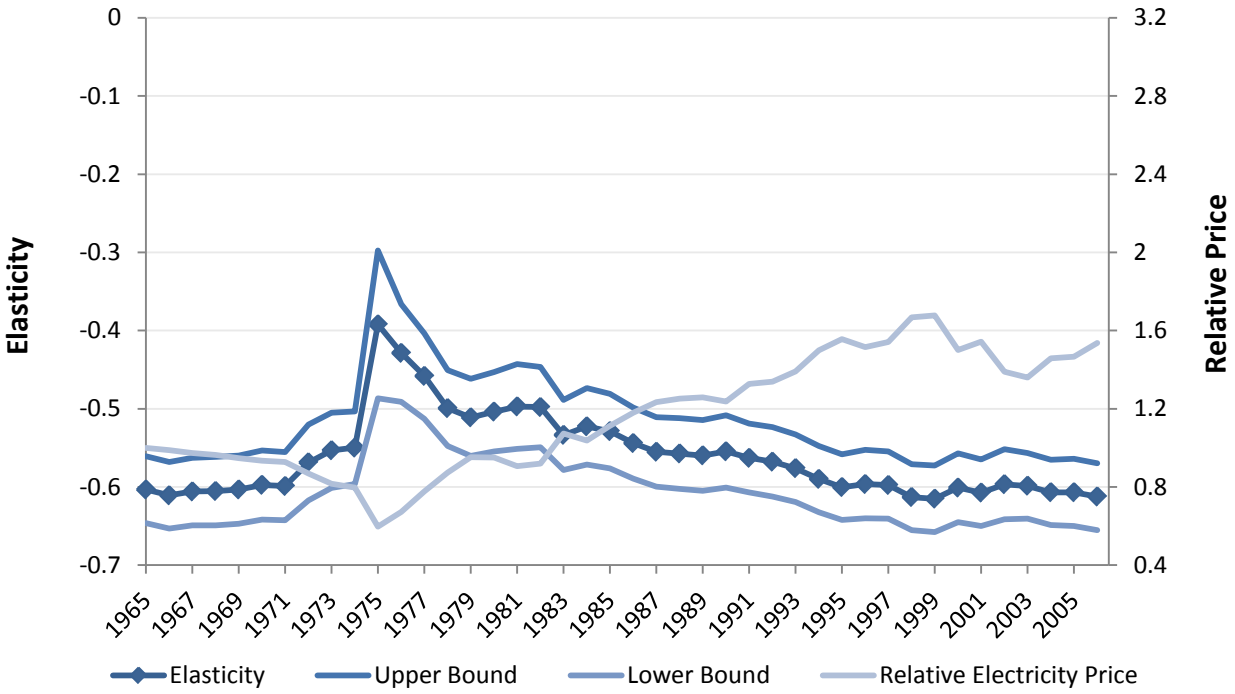


Figure 6. Residential Elasticity of Oil to its Own Price- Atlantic Region

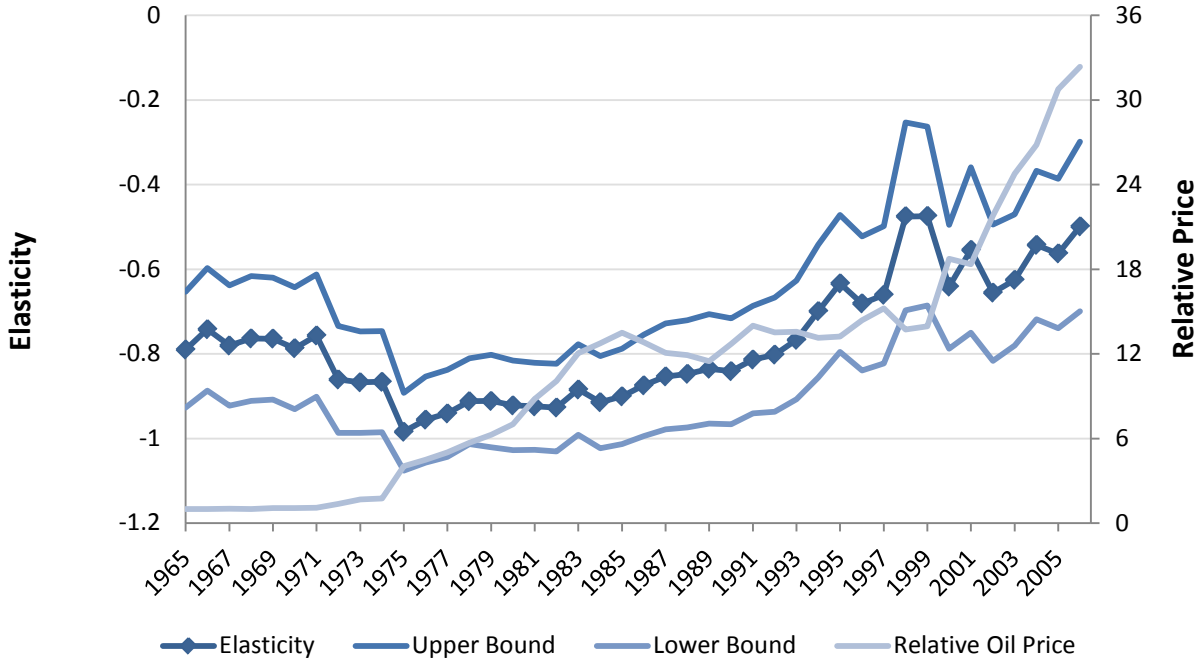
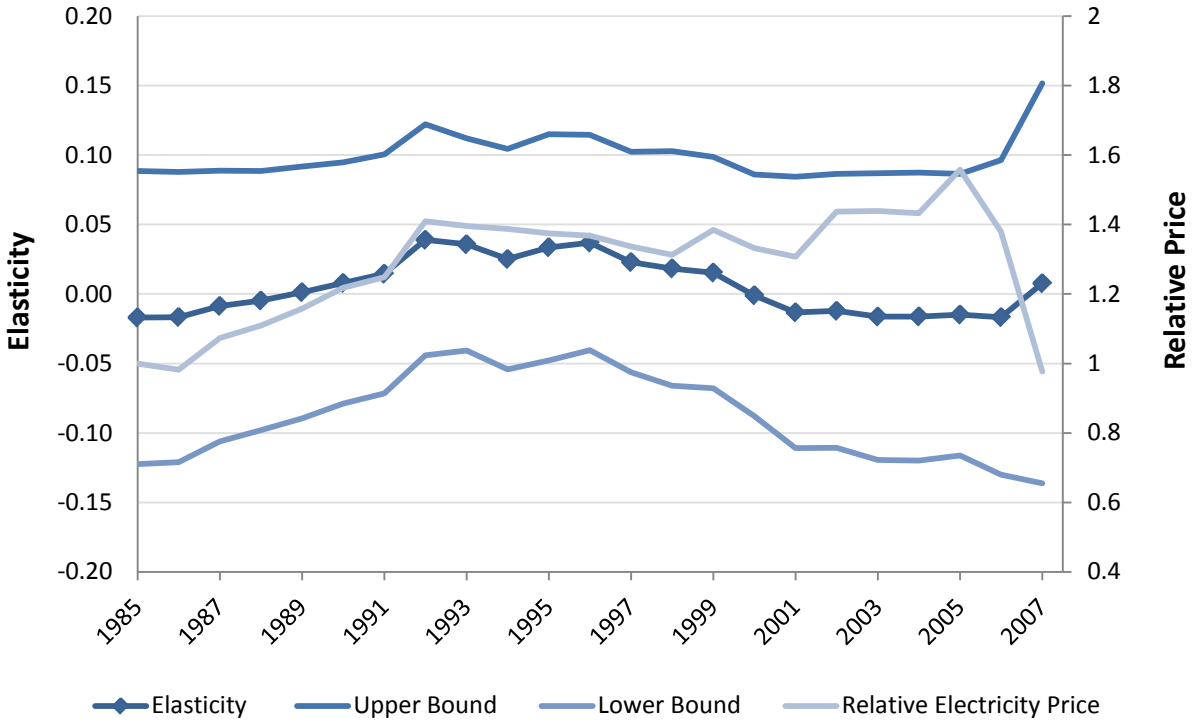


Figure 7. Industrial Elasticity of Demand of Electricity - Ontario



Implications for policy-makers

This paper is an overview of the concept of price elasticity of demand for energy. It presents an updated data set on elasticities for Canadian energy products. Based on the overview, the following conclusions are of direct relevance to policy-makers engaged in the development of carbon policy in Canada:

- Elasticity of demand numbers for energy products generally allow policy-makers to understand who will bear the impact of a carbon price. This paper shows that in the short-run, demand for energy products is largely inelastic, so assuming constant supply, any energy price shock is borne by consumers. Consumers in regions with lower absolute elasticity values would suffer more.
- Policy-makers looking at carbon-pricing as a method to curb greenhouse gas emissions must take into account consumers' responses to price changes. If consumer demand is inelastic, then a carbon price would not generate a significant decrease in demand. Moreover, the government would be able to generate significant revenues via a carbon tax even though carbon emissions would not significantly decrease.
- Policy-makers require robust and reliable long-term price elasticity of demand estimates for residential, industrial and commercial users across regions and over time. These enable them to adjust policies to account for the reaction of energy consumers with different characteristics. The elasticity figures in this paper are for the short-term, which implies that they may not reflect changes in behaviour if a carbon price is introduced. Consumers and companies usually have several years to adjust before a carbon price is introduced, which gives them time to prepare by reallocating their resources (i.e. investing in a more energy efficient furnace) to potentially reduce the impact of the carbon price.
- As shown in this paper, the price elasticity of demand for different energy products varies widely depending on the type, the user, and where it is consumed. Nonetheless, understanding the choices and restrictions that energy consumers face is essential for policy-makers. Longer-term elasticity statistics and cross-regional comparisons will assist policy makers in deciding what kind of carbon pricing policy will be most effective at reducing greenhouse gas emissions while at the same time maintaining quality of life standards.