Price and Carbon Tax Effects on Gasoline and Diesel Demand

by

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and

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Summary

In July 2008 the government of the province of British Columbia, Canada, became the first North American jurisdiction to impose a significant tax on carbon emissions originating from fossil fuel use. The new tax was increased annually to reach 30$/ton of CO$_2$ in July 2012. We use monthly data related to this policy to analyze its effects on the use of gasoline and diesel for road transportation. In particular we study consumer responses to carbon tax, standard excise tax and price net of these taxes. For gasoline demand, we find that that there is no significant difference between consumers responses to a CO$_2$ tax versus a standard excise tax. We also find that this tax effect is ten times larger than the effect of the net-of-tax price at the pump that depends mostly on the price of crude oil. For diesel demand, our results show that the new CO$_2$ tax has a significant downward effect, while the standard excise tax and the net-of-tax price play no role.

Key words: Gasoline demand, diesel demand, price at the pump, excise tax, and carbon tax.

JEL code: Q410, Q580, H230.
Introduction

In policy discussions regarding the most appropriate instrument to choose so as to reduce greenhouse gas emissions in road transportation, a carbon tax has, on theoretical grounds, received widespread support from economists. However, in order to empirically quantify the effects of such a new tax on the demand for oil products that are related to road transportation, appropriate price elasticity estimates need to be obtained. While a large set of price elasticity estimates are readily available from existing studies, the bulk of these studies use the total price paid by consumers as an explanatory variable in the specified demand model; Dahl (2012) presents a survey. Such an approach is in agreement with the canonical neoclassical economic theory that treats all the components of prices in the same way: a dollar is a dollar. However, there is a growing literature that questions this tenet; in particular, do people react in the same way to tax changes as they do to changes in other components of prices that are market determined? Recent examples such as Davis and Kilian (2011) and Li et al. (2012) provide empirical support for the position that gasoline taxes have a larger impact on demand than net of tax prices that are mostly made up of crude oil prices.

In this paper, we explore the above-mentioned issues using monthly data associated with a unique policy initiative (at least in North America) where the government of the province of British Columbia (B.C.) introduced a revenue-neutral carbon tax on a broad range of CO₂ emissions originating from fossil fuel use. The tax rate was set at 10$/ton of CO₂ in July 2008 and increased by 5$ on July of every year to reach 30$ in 2012. We focus on oil products related to road transportation, namely, gasoline and diesel. Our research questions are as follows: first, do users respond in the same way to the new carbon tax as they did to the standard excise tax? Second, do users respond in the same way to changes in excise taxes (carbon and standard) as opposed to changes in other components of the price at the pump? Finally, is there a difference between gasoline demand coming mostly from private car and small truck owners, and diesel demand that is related to commercial operations of providers of road transportation services through buses and trucks?

The presentation proceeds as follows: section 1 introduces the neutral carbon tax that has been implemented in B.C.; section 2 includes the literature review; section 3 describes the data and section 4 presents the econometric model and the estimation results. We conclude with some comments on the revenue neutrality of the B.C. tax.

Here are our main conclusions: for gasoline demand, we find that there is no statistically significant difference between consumer responses to a carbon tax as opposed to a standard excise tax; however, the response to these two taxes is ten times larger than the response to the other components of gasoline price. For diesel, we find no statistically significant effects of standard excise taxes and of non-tax components of the diesel price for the demand for diesel. However, the introduction of the carbon tax has a significant downward effect on the latter.

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2 A recent example is Bushnell (2014).
3 Chetty et al. (2009) provide a cogent illustration and they emphasize the role played by tax salience.
4 All values are expressed in Canadian dollar, except where it is indicated otherwise.
1. The B.C. Carbon Tax

University economists played a very active role in the inception of an explicit tax on carbon emissions in the province of British Columbia. During a community meeting in October 2007 where global warming issues and related policy interventions were discussed, the B.C. premier asked a participant, David Green, a UBC professor of economics, to present the argument in favour of a revenue-neutral carbon tax. Following the invitation, an open letter that was signed by 70 economists from the four main university campuses in B.C., was addressed to the finance minister on November 1st 2007. The government took action in the next few months and B.C. became the first North American jurisdiction to introduce a significant and broadly based tax on carbon emissions from fossil fuel consumption.

The B.C. government published its plan to impose a carbon tax in the February 2008 budget. The main features of this new tax on fossil fuel consumption, including gasoline, diesel, natural gas, coal, propane, and home heating fuels are as follows. The new carbon tax was to be phased in through five annual increments: the initial rate was set at $10/ton starting on July 1st 2008 and the rate was to increase by $5/ton every July 1st up to 2012 to reach $30/ton. This is equivalent to 2.34 ¢/litre of gasoline rising to 7.24 ¢ in 2012. This was revised downward in 2010 to take into account the biofuel mandate; so the actual 2012 rate is 6.67 ¢/litre. For diesel, the starting rate was 2.69 ¢/litre and increased to 7.68 ¢ over the same five year period. A very interesting feature of the new carbon tax was revenue neutrality. All the revenues were to be returned to individuals and businesses through tax reductions. The lower two personal income tax rates were to be decreased to provide a tax cut of 2.0% in 2008, and 5.0% in 2009, respectively, on the first $70,000 earnings for every individual. Effective on July 1st, 2008, the general corporate income tax rate was reduced from 12.0% to 11.0% and then to 10.0% in 2011. Similarly the small business income tax rate was cut from 4.5% to 2.5% over the same period. The income threshold between small businesses and general corporations was increased from $400,000 to $500,000. Finally a new tax credit was to provide low income residents $100 per adult and $30 per child every year. The minister of finance must publish an annual report describing how the carbon tax revenues are used to ensure neutrality.

The carbon tax has been rather well received by British Columbians. According to a poll conducted by the Pembina Institute, “69.0% of B.C. residents are worried about global warming

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5 Green (2007).
6 Since 2007, the province of Quebec requires that fossil fuel distributors pay a tax of $3/tonne of CO$_2$, i.e. 0.7 cents/litre of gasoline. This tax yields approximately $200 million per year that are used to fund environmental initiatives. Also since 2007 Alberta regulates the large industrial companies that emit more than 100,000 tons of CO$_2$ per year to reduce emissions intensity by 12.0% or pay $15/ton of emissions above the threshold.
8 Gasoline and diesel used in road transportation accounted for 15.3% and 8.1% respectively of 61.5 million tons of CO$_2$ emitted in 2012. See B.C. Ministry of Environment (2014).
9 A price increase of 4.85% per litre of gasoline and of 5.72% per litre of diesel with respect to July 2012 average price.
and 70.0% support the province being a leader in taking action to solve the problem. 36.0% believe that reducing greenhouse gas pollution helps grow or 44.0% has little impact on B.C.’s economy. Figure 1 shows the relative (to the peak of July 2008) evolution of interest in the B.C. carbon tax as registered by the web search since 2007 to the present. The interest indicator jumped with the announcement of the February 2008 budget and reached an all-time peak when the tax became effective on July 1st, 2008. Very small bumps occurred on July 1st of every ensuing year until 2012.

The fact that the B.C. carbon tax was phased in over a five year period allows us to measure its specific effect since the first rate increase occurred at the same time as the 2008 recession was hitting the world economy.

2. Literature Review

Because of widespread policy interests and reasonably good data availability, a large set of papers have been published on gasoline and diesel demand. Obviously price and income elasticities are of particular interest. Dahl (2012) presents an extensive survey of estimates obtained from a static model specification for 124 countries. The median price elasticities are estimated at -0.34 and -0.16, for gasoline and diesel, respectively. Several authors have adopted a dynamic specification to take into account the adjustment processes over time. An illustration that is relevant to our work is provided by Hughes et al. (2008) who use monthly data on U.S. gasoline consumption to test the stability of price and income elasticity estimates over two periods when prices were displaying strong upward trends; these two periods extend from 1975 to 1980, and from 2001 to 2006. Their estimates of short run price elasticities, obtained from various specifications of this model, range from -0.21 to -0.39 for the early period, and from -0.034 to -0.077 for the more recent period. Long run price elasticities estimates are 12.0%, and 49.2% larger, respectively, in the two periods, the latter period elasticity being smaller than its value in the earlier period. They observed no significant changes in the income elasticities. Hughes et al. (2008) also raise the issue of possible structural changes that occur over time, which limits the extent of the historical experience as an appropriate source of a homogeneous sample.

More recently, a growing literature has been focusing on whether there is a difference between price changes that originate from tax innovations, and price changes that result from other market factors. The question of interest is: do consumers pay more attention to price changes induced by taxation relative to other factors? This is particularly relevant in the case of gasoline prices that are continuously moving up and down reflecting crude oil price changes,

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10 Home (2011).
11 A static specification could be interpreted as a long run structural relationship in the context of cointegration or error-correction model.
12 The effects of a tax change may also depend on the stage of its application, i.e. tax inclusive price or price excluding tax. See Chetty et al. (2009)
whereas nominal tax changes are usually long-lasting. For example, on the basis of a pooled sample of U.S. states from 1966 to 2008, Li et al. (2012) conduct an explicit statistical test where the null hypothesis is that there is no difference between the effects of the net of tax price and the percent tax rates on the use of gasoline per capita. According to various model specifications, they find that the tax responses are larger than the net of tax price responses by 0.28 to 2.69.\textsuperscript{13}

Similarly, and using a monthly national aggregate and a pooled sample of U.S. states from 1989 to 2008, Davis and Kilian (2011) find that gasoline demand price elasticity estimates are higher when tax changes are explicitly taken into account relative to the situation where only total price changes are considered. They observe that, according to various sample splits based on the size of the tax changes, the price elasticity estimates vary from -0.28 to -0.74 for the state panel\textsuperscript{14} while the standard total price effect is only -0.19.\textsuperscript{15} The objective of Davis and Kilian (2011) was to measure appropriate gasoline price elasticity estimates if U.S. jurisdictions were to introduce carbon taxes. Since no such taxes exist in the U.S. at this time, this amounts to assuming that there is no difference between a standard per unit tax and a carbon tax.\textsuperscript{16} This is an issue that is addressed in this paper.

Rivers and Schaufele (2012) share the same objective as this paper for the case of gasoline, that is, to measure the effects of the B.C. carbon tax on gasoline demand while taking explicitly into consideration the carbon tax. Using a monthly sample running from 1990 to 2011, the authors find that the carbon tax effect is almost five times larger than the effect of the price net of the carbon tax.\textsuperscript{17} There are three reasons why we revisit the B.C. carbon tax experiment. First, Rivers and Schaufele (2012) test for the effects of the carbon tax relative to the price net of the carbon tax. However, given that the carbon tax is a per unit tax that is comparable to the standard excise tax, it is of interest to test whether there is a distinct effect attached particularly to carbon taxation. Second, we use a different set of data on B.C. transportation fuel consumption. Although both sets of data are published by Statistics Canada, they are based on different monthly surveys. The data used by Rivers and Schaufele (2012) come from information collected by provincial tax agencies that apply various sales taxes, while the data used in this paper comes from surveys addressed to oil refineries and oil product wholesalers.\textsuperscript{18} Although the objective of both surveys is to measure gasoline purchase over a given month, there is not an exact match in both published series between the numbers that are reported and the actual gasoline purchase over the month of interest. The simple correlation between the two series is around 0.88. The series that we are using allows us to have access to more

\textsuperscript{13} See Li, Linn, and Muehlegger (2012), Table 2, Panel B.
\textsuperscript{14} Table IV in Davis and Kilian (2011; p. 1199).
\textsuperscript{15} Table I in Davis and Kilian (2011; p. 1196).
\textsuperscript{16} Ad valorem taxes are included in the gasoline prices net of the per unit prices since the main source of variation of ad valorem taxes is the change in the price of oil.
\textsuperscript{17} See Rivers and Shaufele (2012), Table 2, column (2). The authors use a pooled sample of the Canadian provinces. However, they allow for separate parameter estimates for B.C.. Except for Quebec that introduced a small carbon tax in 2007, no other provinces had an explicit carbon tax on transportation fuel.
\textsuperscript{18} Kopczuk et al. (2014) find that there is more tax evasion when U.S. states collect diesel taxes at the retail level than at the wholesale level.
recent data. Finally, the source that we are using, also presents data on diesel use which constitutes an important share of total road transportation. Indeed, while most of gasoline is used by car and small truck owners, diesel is used for commercial purposes such as bus and truck transportation. It is therefore of interest to study whether the responses to tax changes vary by types of owners.

3. Data

The sample used to analyze the effects of the carbon tax on gasoline and diesel sales in B.C. runs from January 1997 to April 2013. A summary of the evolution of the price of crude oil over this period is as follows: in the nineties, the average annual nominal price of crude oil remained below 20$/barrel; however, in 2000, it moved upward to 26.27$ and kept increasing to reach 93.33$/barrel in 2008. The great recession brought it down to 63.23$ in 2009; it resumed its upward march and stayed above 100.00$/barrel from 2010 to 2013. On the whole, crude oil price was trending upward except for the sharp drop in the early part of the 2008 recession.

Our sample includes monthly data on the domestic sales of gasoline and diesel used for road transportation, prices, taxes, income, population, and a few other variables that also play a role in the B.C. context; the appendix shows the source of each variable. Here are some additional observations on variable measurement. Natural Resources Canada presents separate information on final prices paid by purchasers and total taxes per liter. These total taxes that are applied to gasoline and diesel used for road transportation are the sum of: the goods and services tax (GST), the excise tax and the carbon tax after it was introduced. The GST is the last tax applied at the pump, so it is used to obtain the excise tax from total taxes. The GST rate changed only twice over the sample period: starting at 7.0%, it fell to 6.0% in January 2006, and to 5.0% in January 2008. As in Davis and Kilian (2011), the GST is included in the net-of-tax price given that the rate was modified only twice, and because the price of crude oil that varies continuously is the main source of sales tax changes.

The excise tax on gasoline and diesel was modified six times over the sample period: +2.0 cents/liter on April 2002, +3.5 on March 2003, +1.0 on January 2006, -1.0 on July 2006, +3.0 on

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19 As of December 2013, there was a 14 months’ difference between the two most recent dates of the two series. This difference may vary depending on the time of year data is obtained from the two sources.
20 Heavy duty vehicles accounted for 97.1% of diesel used in road transportation in 2012 while they accounted for only 17.6% of gasoline. See B.C. Ministry of Environment (2014).
21 Dahl (2012) found that the diesel demand price elasticity estimates are lower than the gasoline demand elasticity estimates.
22 Average landed cost of U.S. crude oil imports in U.S. dollars. See Energy Information Administration.
23 Vancouver prices are taken to represent the prices for the whole province.
24 The federal and the provincial government each collect their own excise tax. In this paper the sum of the two taxes are treated as a single tax.
25 The excise tax on gasoline which was 25 cents/litre in 1997 is 5.5 cents/litre higher than the excise tax on diesel.
January 2010, +2.0 on April 2012 while the carbon tax increased four times after it was introduced in July 2008. The changes in the excise tax and in the carbon tax are of the same size. Figure 2 shows the real price of gasoline net of carbon and excise taxes, the real excise tax and the real carbon tax. It can be seen that the price net of carbon and excise taxes follows closely the price of crude oil with an upward trend interrupted by the 2008 recession. The two taxes display small jumps that are slowly erased by inflation.

Figure 3 presents the gasoline and diesel sales per capita; both series are subject to seasonal patterns. Gasoline sales were rather stable up to 2004 and then moved slowly downward. Diesel sales were increasing slowly, then dropped markedly with the 2008 recession to resume its movement upward.

Monthly data on B.C. real Gross Domestic Product (GDP) are not available. However, the Conference Board of Canada produces quarterly estimates, and linear interpolation is thus used to generate monthly data that are displayed in Figure 4; on the whole, real GDP per capita was increasing, with only a few minor reversals except for a large one at the end of 2008 and early 2009.

Weather conditions influence outdoor activities and hence travelling; this is why monthly rainfalls registered at the Vancouver international airport are considered to be an explanatory factor of gasoline sales. Similarly, the real effective exchange rate is added as an explanatory factor of diesel sales, since an increase in the value of the Canadian dollar may change the balance between exports and imports, with corresponding changes in transport requirements for goods and people.

4. Model specification and results

Since our sample includes monthly time series, particular attention is paid to their statistical properties, including stationarity, volatility, and the lag structure of the adjustment processes. These time series properties thus lead to different specifications for gasoline and diesel sales.

The first step toward model specification is to test for stationarity of variables of interest. We found that the null hypothesis of a unit root is not rejected for sales of gasoline per capita, the net of tax prices of gasoline and diesel, GDP per capita, and the real effective exchange rate of the Canadian dollar, while it is rejected for diesel sales per capita. The non-stationary variables were first-differenced. We then postulated a general distributed lag model structure for the two commodities, estimated the model, and discarded coefficients that were

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26 The price of diesel is not displayed since it followed the same path as gasoline, albeit at a different level.
27 Since gasoline and diesel sales are subject to seasonal patterns both series are first deseasonalized through the application of monthly dummy OLS regression.
28 Dickey-Fuller test and KPSS test lead to the same conclusion (results are available upon request).
not significant at the 5% level. We then tested the residuals of the constrained equations for conditional heteroskedasticity. As the latter could not be rejected for the gasoline case, the model was expanded to include a GARCH(1,1) component for the variance of the residuals, and subsequently estimated using maximum likelihood. Dummy variables were also added to the models for both commodities based on visual inspection of the fitted residuals and on the results of Jarque–Bera normality tests.\(^{29}\) The specifications that were retained for our estimations thus are:

**Gasoline sales:**

\[
\Delta GAS_t = a_0 + a_1 \Delta NET PG_t + a_2 JEXTAX_t + a_3 JGCTAX_t + a_4 \Delta RAIN_t + a_5 \Delta GAS_{t-1} \\
+ a_6 \Delta GAS_{t-2} + a_7 DUM_1 + e_t \\
e_t \sim N(0, h_t) \\
h_t = \gamma_0 + \gamma_1 h_{t-1} + \gamma_2 e_{t-1}^2 
\] (1)

**Diesel sales:**

\[
\text{DIESEL}_t = b_0 + b_1 DCTAX_t + b_2 \Delta GDP_{t-4} + b_3 \Delta REER_{t-2} + b_4 \text{DIESEL}_{t-1} + b_5 \text{DIESEL}_{t-2} \\
+ b_6 \text{DIESEL}_{t-3} + b_7 DUM_2 + b_8 DUM_3 + v_t \\
v_t \sim N(0, \sigma^2) 
\] (2)

Table 1 presents the definition of the variables in the above equations. In addition, \(\Delta\) is the first difference operator, \(J\) indicates that the change (jump) in the real per unit tax is taken into account only in the month when the tax authorities make the change, while \(e_t\) and \(v_t\) are error terms.

The residuals for the retained specifications above were further tested for serial correlation of order 1 to 4, for additional ARCH effects, and for normality of the (standardized) residuals. Results showed no evidence for any remaining serial correlation, both in the mean and in the variance, and the normality hypothesis was also not rejected at the 5% level. Note that the price net of taxes is treated as being exogenous since its main component is the price of crude oil which is determined by the world market, and given that there are no restrictions on imports and exports of crude oil and of refined products in Canada.\(^{30}\)

\(^{29}\) For the gasoline equation, dummies were introduced for observations 2012-04 and 2013-02. For the diesel equation, one dummy variable accounts for high-value outliers, that is observations 2008-10, 11, 12 and 2012-05, while the other accounts for low-value outliers, notably the observations for 2009-01, 02, 03 and 2011-05. The 2012 dates are in proximity to a train strike in B.C. while the 2008-2009 observations are likely related to adjustments due to the great recession.

\(^{30}\) Studies have shown that changes in the crude oil prices are fully passed on to consumers.
Table 2 reports the maximum likelihood estimation results for the gasoline sales model. The results show a fairly good model fit, with an adjusted R-squared value of 0.45, and where both tax effects, as well as net-of-tax price changes, are found to be significant at the 10% level. To test our first question of interest, namely whether carbon and excise taxes have a similar impact on demand, we test the null hypothesis \( H_0: a_2 = a_3 \). The resulting test statistic has \( p \)-value of 0.52, and is thus not rejected at the 5% level. We then re-estimated the model imposing the constraint \( a_2 = a_3 = a_2^* \), that is, assuming a similar effect for the two tax types. The estimated value of \( a_2^* \) is -0.738 with a \( p \)-value of 0.0039, and all the other coefficient estimates of the model show values that are almost identical values to those reported in Table 2. Finally, we test whether tax effects are similar to the net-of-tax price effects. We find that the null hypothesis \( a_1 = a_2^* \) has a \( p \)-value of 0.01, and hence it is rejected at the 5% significance level.

The above results show that there is no specific effect associated with carbon tax relative to the standard excise tax, however there is a different effect associated with taxes relative to the net-of-tax price of gasoline. Indeed, the effect of the former is ten times larger than the effect of the latter. Rivers and Schaufele (2012) estimated the carbon tax effect to be five times larger than the effect of the price net of the carbon tax. Their smaller estimated effect relative to our own estimate comes from the fact that they include the standard excise tax in the price of gasoline net of the carbon tax; we find this to be a variable misspecification.

We also find, as expected, that rainfalls have a significant negative effect; however, real income per capita plays no statistically significant role. The significant negative coefficient of the lagged dependent variable indicates that the demand responses are getting smaller over time: the users revert partially back to their old habits. In addition, the error term is subject to volatile bursts that can be represented by a significant GARCH(1,1) process.

Finally, we found that estimation of the model in the log-linear form yields very similar results to the current specifications. Moreover, we studied whether positive changes in the real net of tax price of gasoline present different effects than negative such changes, but did not find any statistically significant differences. The result presented here are therefore quite robust.

The short run price elasticity estimate is -0.077 and the long run estimate is -0.041 while they are -0.775, and -0.412, respectively, for the excise and carbon taxes. Short run price elasticity estimates from Hughes et al. (2008) range from -0.034 to -0.077 according to a model specification with partial adjustment, and for the 2001 to 2006 period, while the implied fully adjusted estimate is -0.049. On the base of a VAR model, Davis and Kilian (2011) estimate the net-of-tax price elasticity to be -0.02 contemporaneously, and -0.07 at 12 months, while for the

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31 This may be due to the fact that the monthly data were interpolated from quarterly GDP.
32 The elasticity estimates are based on data at the mid-sample period, i.e. June 2000.
33 Hughes et al. (2008), Table 8, P. 109.
excise tax the estimates are -0.14 and -0.15 respectively.\(^{34}\) Our low price elasticity estimates fall within the range of values provided in the above two studies that make use of recent data. Furthermore, Davis and Kilian (2011) found also a large gap between the price and the excise tax elasticities.

Table 3 shows the estimation results for diesel sales. We see that the net-of-tax price of diesel and the excise tax are not statistically significant, however the carbon tax turns out to be statistically significant. In this specification, GDP has a small but significant positive effect, and the real effective rate of exchange of the Canadian dollars has also a positive effect indicating that B.C. imports make relatively more use of diesel for transportation than do exports. We also find that B.C. diesel sales have a relatively elaborate adjustment process, which comes through via lags of the dependent variable and via the lags of explanatory variables. This introduces some discrepancy between short run and long run responses. The short run carbon tax elasticity is thus -0.41, and the long-run equivalent is -0.80.\(^{35}\)

**Conclusion**

Based on the new carbon tax introduced by the government of British Columbia since 2008, our empirical analysis lends support to the following conclusions: for gasoline demand, which is mostly associated with individual owners of cars and small trucks, consumer responses to the carbon tax and to the standard excise tax are not significantly different; however, the response to these taxes is ten times larger than the response to the other components of the gasoline price at the pump. For diesel demand, related mostly to the provision of road transportation services by buses and trucks, there are no significant effects of the standard excise tax and of the other components of the diesel price at the pump; however the new carbon tax has a significant downward effect. So, overall, the new carbon tax has effects on both the gasoline and the oil demand in B.C., and the effects are much larger than impacts related to other elements of prices at the pump.

The B.C. carbon tax has been designed to be revenue-neutral. However, in order to design a revenue-neutral tax change, we must take into account the shift in consumer behaviour caused by the relative price changes. Specifically, a proper value for the demand elasticity must be determined. On the one hand if it is underestimated, a revenue shortfall will result; on the other hand if it is overestimated, a surplus will occur. Neither outcome is desirable. The B.C carbon tax is currently generating a shortfall. In the 2011/12 fiscal year, the carbon tax brought in $960 million while the tax cuts cost the government $1.1 billion.\(^{36}\) Although it is difficult to forecast peoples’ responses to simultaneous tax changes, part of the

\(^{34}\) See Davis and Kilian (2011), Table VII, p. 1208. The lag structure of the VAR model is selected by applying AIC. They estimate separate VAR models for price and tax. They observe that tax elasticity estimates may decrease as the horizon gets longer.

\(^{35}\) See note 30.

revenue gap may be the consequence of using too low demand elasticity estimates. Our study shows that the user response to carbon tax is markedly higher than the response to the other components of gasoline and diesel prices at the pump. More generally this indicates that the fairly widespread practice of transferring parameter estimates may lead to poor policy design.
References


Table 1: Definition of variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>$GAS_t$</td>
<td>Monthly gasoline sales per capita (litre)</td>
</tr>
<tr>
<td>$DIESEL_t$</td>
<td>Monthly diesel sales per capita (litre)</td>
</tr>
<tr>
<td>$NETPG_t$</td>
<td>Real price of regular gasoline net of excise and carbon tax (2007¢/litre)</td>
</tr>
<tr>
<td>$NETPD_t$</td>
<td>Real price of diesel net of excise and carbon tax (2007¢/litre)</td>
</tr>
<tr>
<td>$EXTAX_t$</td>
<td>Real excise tax (2007¢/litre)</td>
</tr>
<tr>
<td>$GCTAX_t$</td>
<td>Real gasoline carbon tax (2007¢/litre)</td>
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<tr>
<td>$DCTAX_t$</td>
<td>Real Diesel carbon tax (2007¢/litre)</td>
</tr>
<tr>
<td>$RAIN_t$</td>
<td>Monthly rainfalls at Vancouver International Airport (mm)</td>
</tr>
<tr>
<td>$GDP_t$</td>
<td>Real Gross Domestic Product per capita (2007$)</td>
</tr>
<tr>
<td>$REER_t$</td>
<td>Real effective exchange rate (U.S. $/CAN $)</td>
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<td>$DUM_i$</td>
<td>Dummy variable</td>
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Table 2: Estimation results: Gasoline sales

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Coefficient estimates</th>
<th>Standard error</th>
<th>Prob.</th>
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<tr>
<td>$Constant$</td>
<td>0.026</td>
<td>0.158</td>
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<tr>
<td>$\Delta NETPG_t$</td>
<td>-0.074</td>
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<td>$DUM_1$</td>
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<td>0.000</td>
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Variance equation

<table>
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<tr>
<th>Term</th>
<th>Coefficient estimates</th>
<th>Standard error</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Constant$</td>
<td>0.171</td>
<td>0.213</td>
<td>0.422</td>
</tr>
<tr>
<td>$\hat{e}_{t-1}^2$</td>
<td>0.111</td>
<td>0.057</td>
<td>0.052</td>
</tr>
<tr>
<td>$h_{t-1}$</td>
<td>0.857</td>
<td>0.068</td>
<td>0.000</td>
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</table>

Ad. R-squared 0.452
D.-W. 2.062
Table 3: Estimation results: Diesel sales

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Coefficient estimates</th>
<th>Standard error</th>
<th>Prob.</th>
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<tbody>
<tr>
<td>Constant</td>
<td>0.155</td>
<td>0.315</td>
<td>0.621</td>
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<tr>
<td>DCTAXₜ</td>
<td>-0.311</td>
<td>0.129</td>
<td>0.018</td>
</tr>
<tr>
<td>ΔGDPₜ⁻⁴</td>
<td>0.007</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>ΔREERₜ⁻²</td>
<td>0.367</td>
<td>0.173</td>
<td>0.035</td>
</tr>
<tr>
<td>DIESELₜ⁻¹</td>
<td>0.163</td>
<td>0.058</td>
<td>0.006</td>
</tr>
<tr>
<td>DIESELₜ⁻²</td>
<td>0.172</td>
<td>0.059</td>
<td>0.004</td>
</tr>
<tr>
<td>DIESELₜ⁻³</td>
<td>0.254</td>
<td>0.061</td>
<td>0.000</td>
</tr>
<tr>
<td>DUM₂</td>
<td>-13.71</td>
<td>1.894</td>
<td>0.000</td>
</tr>
<tr>
<td>DUM₃</td>
<td>12.168</td>
<td>1.816</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Ad. R-squared       0.618
D.-W.                1.898

Figure 1: Public interest in the B.C. carbon tax over time
Figure 2: Real price of regular gasoline (2007 ¢/litre)

Figure 3: Monthly gasoline and diesel sales (litres per capita)
**Figure 4:** Real GDP per capita (2007$ in thousand)

![Real GDP per capita graph](image)

**Appendix**

**Data Sources**

<table>
<thead>
<tr>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly domestic sales of gasoline in litre</td>
<td>Statistics Canada, The Supply and Disposition of Refined Petroleum Products in Canada, Catalogue no. 45-004-X.</td>
</tr>
<tr>
<td>Monthly domestic sales of diesel in litre</td>
<td>ibid.</td>
</tr>
<tr>
<td>Monthly regular gasoline average final price and total taxes in Vancouver, (¢/litre)</td>
<td>Natural Resources Canada, <a href="http://www2.nrcan.gc.ca/eneene/sources/pripri/prices_bycity_e.cfm">http://www2.nrcan.gc.ca/eneene/sources/pripri/prices_bycity_e.cfm</a></td>
</tr>
<tr>
<td>Monthly diesel average final price and total taxes in Vancouver, (¢/litre)</td>
<td>ibid.</td>
</tr>
<tr>
<td>Real Gross Domestic Product at base price in 2007 $</td>
<td>Quarterly data provided by Conference Board of Canada.</td>
</tr>
<tr>
<td>B.C. monthly population</td>
<td>Statistics Canada. Table 051-0005 - Estimates of population, Canada, provinces and territories, quarterly (persons).</td>
</tr>
<tr>
<td>Monthly Rainfall at Vancouver International Airport in mm</td>
<td><a href="http://climate.weather.gc.ca">http://climate.weather.gc.ca</a></td>
</tr>
<tr>
<td>Real effective exchange rate monthly average, C.P.I. based (2010=100.0)</td>
<td>Bank of Industrial Settlement (BIS).</td>
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</table>