Effects of B.C.'s Carbon Tax on GDP

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Ⅰ Introduction

- Policy Concern: effect of environmental taxes on GDP
- B.C.’s carbon tax
- Research objective: estimation of effects of B.C.’s gasoline and diesel carbon tax on its GDP
- Analytical framework: VAR

Ⅱ Outline

- Literature Review
- Data
- Model, Estimations and Results
- Conclusion

Ⅲ Literature Review

- Elgie and McClay (2013)
- Beck et al. (2015)
- Yamazaki (2017)
- Yip (2018)

IV Data

Figure 1
Gasoline price (net-of-carbon tax) and carbon tax (¢2007/litre)

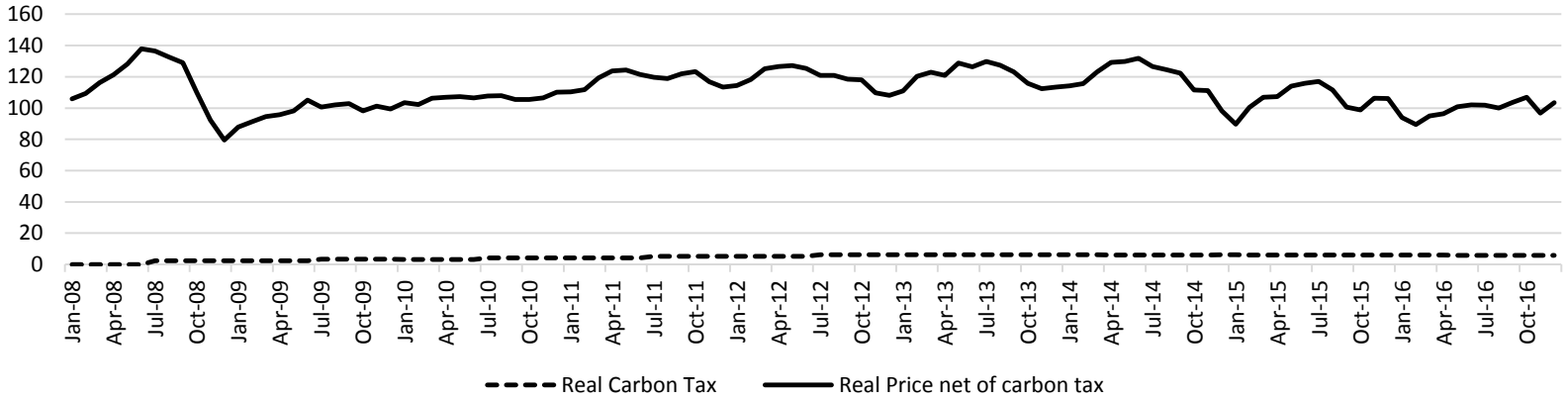
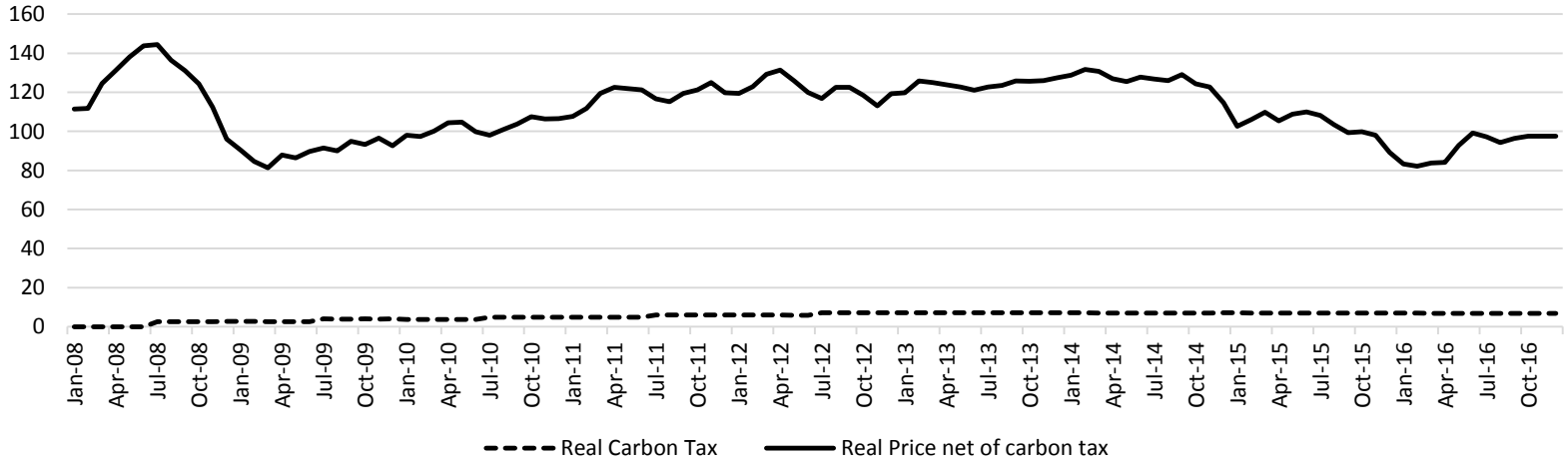
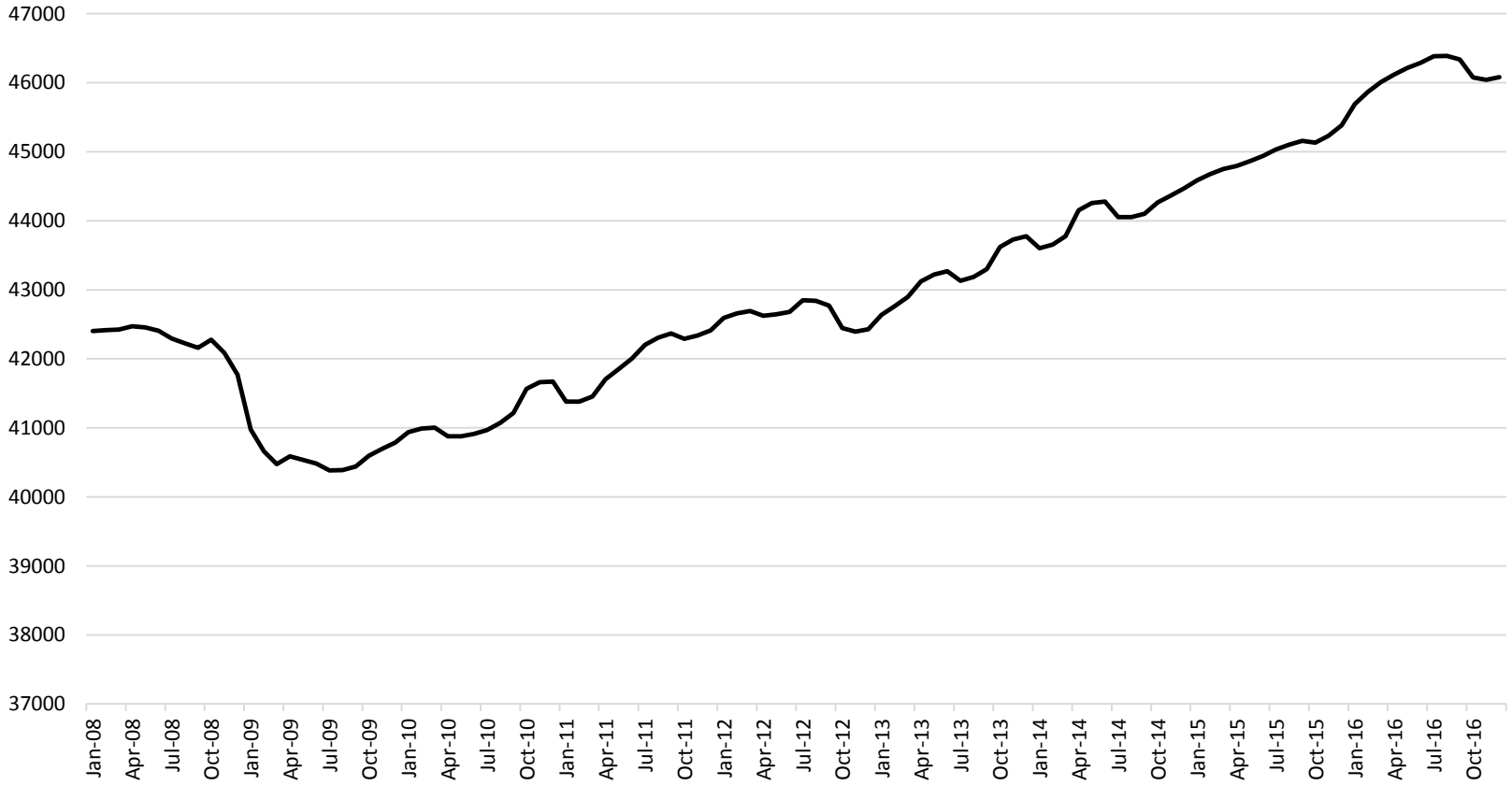


Figure 2
Diesel price (net-of-carbon tax) and carbon tax (¢2007/litre)



IV Data

Figure 3
Per Capita Real GDP (2007$)



IV Data

Figure 4
U.S. Real Interest Rate (%)

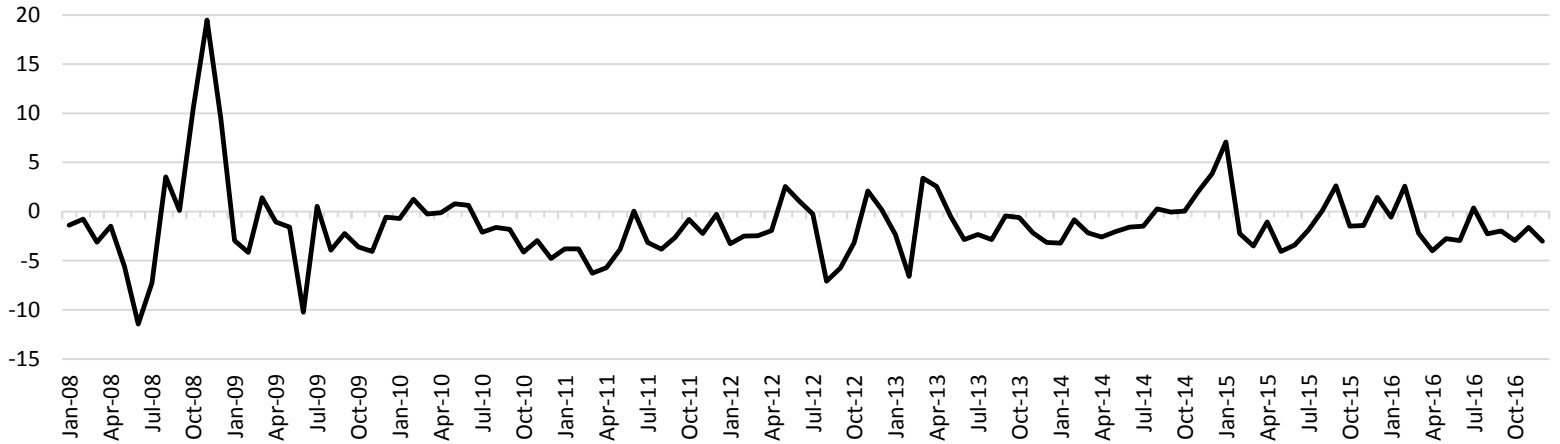
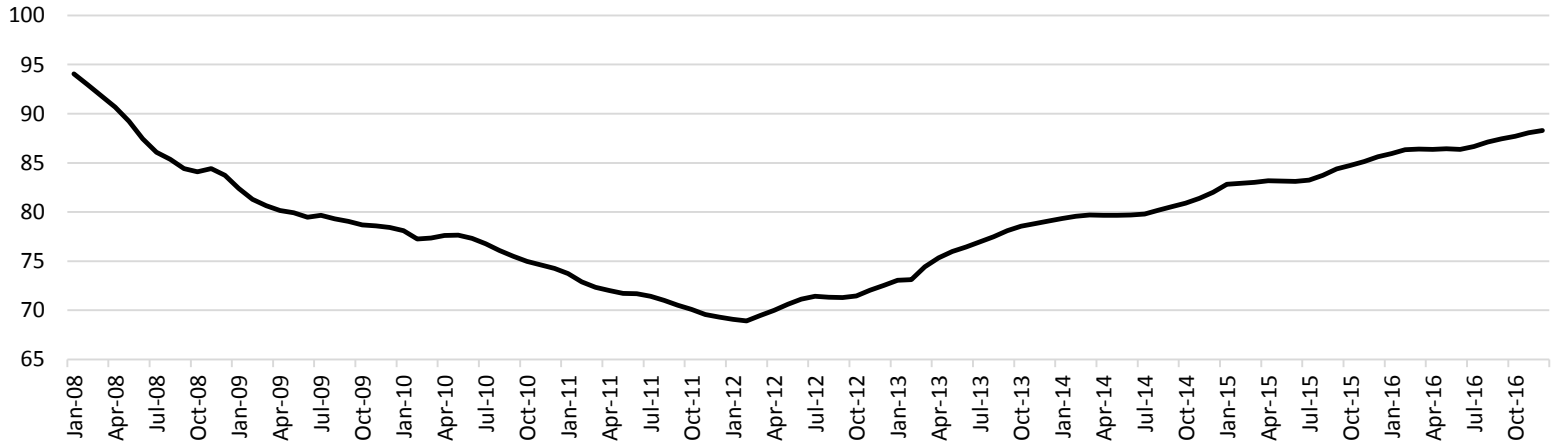


Figure 5
Case-Shiller U.S. National Home Real Price Index (2007=100)



V .Model, Estimations and Results

5.1 Test for Asymmetry

$$\Delta\bar{P}_t = \ a_{10} \ + \ \sum_{i=1}^{L} a_{11,i}\Delta\bar{P}_{t-i} + \ \sum_{i=1}^{L} a_{12,i}\Delta y_{t-i} + \ \varepsilon_{1,t},$$

$$\Delta y_t = \ a_{20} \ + \ \sum_{i=0}^{L} a_{21,i}\Delta\bar{P}_{t-i} + \ \sum_{i=1}^{L} a_{22,i}\Delta y_{t-i} + \ \sum_{i=0}^{L} g_{21,i}\Delta\bar{P}^{\#}_{t-i} \ + \ \varepsilon_{2,t} \ , \qquad (1)$$

where $\bar{P}_t$ is the total real price of gasoline or diesel in B.C. inclusive of taxes, y_t is per capita GDP in the province, Δ is the first difference operator, L is the lag order, a's are structural coefficients and $\varepsilon_{j,t}$, $j = 1,2$ are error terms.

5.1 Tests for Asymmetry

Table 1

	Gasoline						Diesel					
	$\Delta\bar{P}_t^+$		$\Delta\bar{P}_t^{12}$		$\Delta\bar{P}_t^{36}$		$\Delta\bar{P}_t^+$		$\Delta\bar{P}_t^{12}$		$\Delta\bar{P}_t^{36}$	
h	1sd	2sd	1sd	2sd	1sd	2sd	1sd	2sd	1sd	2sd	1sd	2sd
0	0.17	0.23	0.69	0.45	0.99	0.76	0.87	0.90	0.81	0.68	0.92	0.66
1	0.36	0.45	0.90	0.76	1.00	0.84	0.98	0.99	0.91	0.88	0.99	0.89
2	0.42	0.52	0.96	0.83	1.00	0.94	0.99	1.00	0.96	0.82	1.00	0.90
3	0.29	0.39	0.98	0.92	1.00	0.98	1.00	1.00	0.98	0.92	1.00	0.93
4	0.09	0.10	0.98	0.21	1.00	0.97	0.39	0.60	0.91	0.12	1.00	0.70
5	0.12	0.14	0.98	0.30	1.00	0.61	0.51	0.72	0.81	0.17	1.00	0.76
6	0.15	0.15	0.99	0.30	1.00	0.65	0.25	0.45	0.87	0.19	1.00	0.64
7	0.17	0.16	0.99	0.26	1.00	0.74	0.06	0.10	0.88	0.18	1.00	0.53
8	0.23	0.21	0.99	0.33	1.00	0.66	0.03	0.03	0.89	0.08	1.00	0.53
9	0.28	0.25	1.00	0.27	1.00	0.72	0.05	0.04	0.92	0.12	1.00	0.50
10	0.31	0.26	1.00	0.26	1.00	0.79	0.07	0.06	0.95	0.16	1.00	0.55
11	0.38	0.33	1.00	0.32	1.00	0.81	0.08	0.07	0.97	0.21	1.00	0.60
12	0.46	0.40	1.00	0.34	1.00	0.85	0.10	0.08	0.98	0.21	1.00	0.66
13	0.54	0.48	1.00	0.39	1.00	0.89	0.14	0.11	0.99	0.25	1.00	0.72
14	0.61	0.56	1.00	0.46	1.00	0.93	0.19	0.15	0.99	0.31	1.00	0.78
15	0.68	0.63	1.00	0.53	1.00	0.96	0.24	0.19	1.00	0.38	1.00	0.83
16	0.74	0.69	1.00	0.60	1.00	0.96	0.29	0.25	1.00	0.44	1.00	0.88
17	0.80	0.75	1.00	0.67	1.00	0.98	0.35	0.30	1.00	0.51	1.00	0.91

Reported numbers are p-values. Tests are conducted assuming a VAR model of order 12. The p-values pertain to tests of impulse responses at horizon *h* assuming a null of symmetry. 1sd refers to an impulse of magnitude 1 standard deviation while 2sd designates a 2 standard deviation shock.

V .Model, Estimations and Results

5.2 Examining structural stability: pre and post tax period

$$\Delta\bar{P}_t = b_{10} + \sum_{i=1}^{L} b_{11,i}\Delta\bar{P}_{t-i} + \sum_{i=1}^{L} b_{12,i}\Delta y_{t-i} + \sum_{i=1}^{L^*} b_{13,i}\Delta x_{t-i} + e_{1,t}$$

$$\Delta y_t = b_{20} + \sum_{i=0}^{L} b_{21,i}\Delta\bar{P}_{t-i} + \sum_{i=1}^{L} b_{22,i}\Delta y_{t-i} + \sum_{i=1}^{L^*} b_{23,i}\Delta x_{t-i} + e_{2,t}. \qquad (2)$$

5.2 Test of structural stability: pre and post tax period

Figure 1a. Response of GDP growth to an innovation in gasoline price: sample 1987:01-2007:12

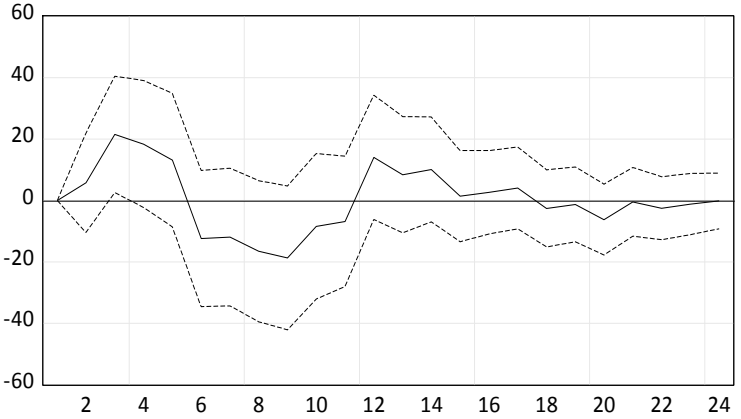


Figure 1b. Response of GDP growth to an innovation in gasoline price: sample 2008:01-2016:12

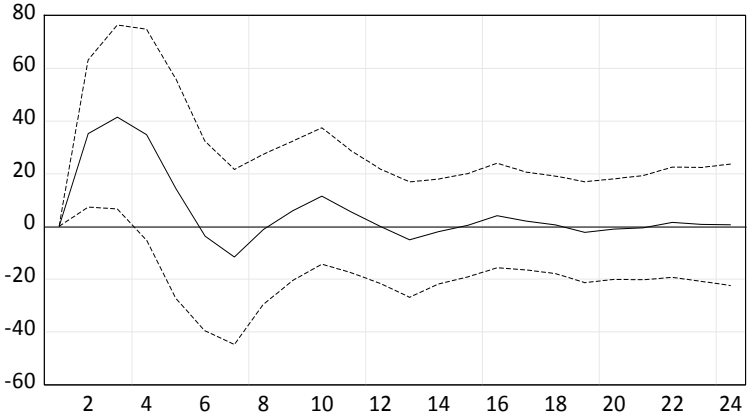


Figure 2a. Response of GDP growth to an innovation in desel price: sample 1987:01-2007:12

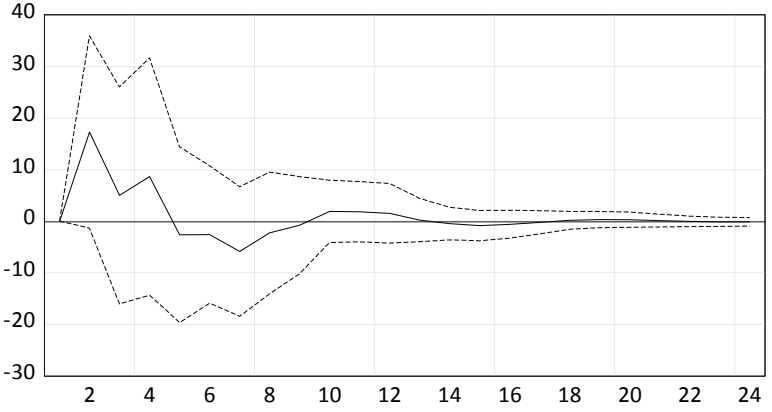
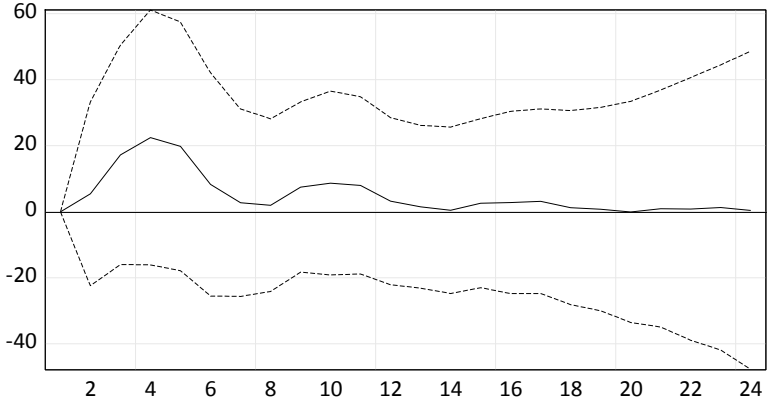


Figure 2b. Response of GDP growth to an innovation in desel price: sample 2008:01-2016:12



V. Model, Estimations and Results

5.3 Tests of carbon tax effects: slope

$$\Delta P_t = b_{10} + \sum_{i=1}^{L} b_{11,i}(\Delta P_{t-i} + \Delta T_{t-i}) + \sum_{i=1}^{L} b_{12,i}\Delta y_{t-i} - \Delta T_t + \sum_{i}^{L*} b_{13,i}\Delta x_{t-i} + e_{1,t}$$

$$\Delta y_t = b_{20} + \sum_{i=1}^{L} b_{21,i}(\Delta P_{t-i} + \Delta T_{t-i}) + \sum_{i=1}^{L} b_{22,i}\Delta y_{t-i} + \sum_{i}^{L*} b_{23,i}\Delta x_{t-i} + e_{2,t}. \quad (3)$$

$\bar{P}_t$, is real total fuel price. That is, $\bar{P}_t = (P_t + T_t)$, where P_t is the real price of gasoline or diesel in B.C. excluding carbon tax, and T_t is real carbon tax.

$$\Delta P_t = c_{10} + \sum_{i=1}^{K} c_{11,i}\Delta P_{t-i} + \sum_{i=1}^{K} c_{12,i}\Delta y_{t-i} + \sum_{j=-4}^{4} c_{13,j}\Delta T_{t-j} + \sum_{i}^{L*} c_{14,i}\Delta x_{t-i} + e_{1,t}$$

$$\Delta y_t = c_{20} + \sum_{i=1}^{K} c_{21,i}\Delta P_{t-i} + \sum_{i=1}^{K} c_{22,i}\Delta y_{t-i} + \sum_{j=-4}^{4} c_{23,j}\Delta T_{t-j} + \sum_{i}^{L*} c_{24,i}\Delta x_{t-i} + e_{2,t}. \quad (4)$$

Table 2: VAR Estimation Results

	Gasoline		Diesel	
	GDP	*Price*	*GDP*	*Price*
Constant	12.2 (0.428)	-0.60 (0.378)	12.0 (0.546)	-0.88 (0.340)
ΔP_{t-1}	6.94(0.025)	**0.01 (0.069)***	0.95(0.789)	0.13 (0.427)
ΔP_{t-2}	0.04 (0.991)	0.00 (0.475)	4.14 (0.239)	-0.13 (0.437)
ΔP_{t-3}	-0.86 (0.793)	0.00 (0.299)	-2.61 (0.463)	-0.02 (0.922)
ΔP_{t-4}	0.83 (0.799)	0.00 (0.398)	**7.89 (0.042)****	0.14 (0.424)
ΔP_{t-5}			-6.29 (0.129)	0.12 (0.519)
ΔP_{t-6}			-6.56 (0.144)	0.04 (0.846)
ΔP_{t-7}			-1.21 (0.773)	0.01 (0.955)
Δy_{t-1}	**0.75 (0.000)****	0.04 (0.746)	**0.78 (0.000)****	0.01 (0.118)
Δy_{t-2}	0.15 (0.171)	**-0.31 (0.034)****	**0.40 (0.013)****	0.00 (0.824)
Δy_{t-3}	**-0.80 (0.000) ****	0.00 (0.997)	**-1.43 (0.000) ****	0.00 (0.813)
Δy_{t-4}	**0.53 (0.000) ****	-0.22 (0.125)	**1.00 (0.000) ****	0.01 (0.581)
Δy_{t-5}			0.24 (0.123)	0.00 (0.534)
Δy_{t-6}			**-0.72 (0.000) ****	-0.01 (0.495)
Δy_{t-7}			**0.44 (0.002) ****	0.00 (0.899)
ΔT_{t+4}	23.8 (0.602)	2.35 (0.244)	24.8 (0.499)	3.00 (0.083)
ΔT_{t+3}	5.17 (0.914)	-0.02 (0.991)	34.7 (0.432)	0.61 (0.765)
ΔT_{t+2}	7.00 (0.884)	2.33 (0.272)	-5.96 (0.898)	-0.17 (0.937)
ΔT_{t+1}	19.19 (0.669)	1.60 (0.419)	10.2 (0.809)	-0.50 (0.800)
ΔT_{t}	42.91 (0.356)	**-3.57 (0.084)***	-31.0 (0.462)	-2.85 (0.150)
ΔT_{t-1}	-6.85 (0.883)	0.28 (0.893)	-15.5 (0.744)	-2.33 (0.292)
ΔT_{t-2}	4.48 (0.919)	-1.75 (0.368)	40.2 (0.376)	-0.79 (0.707)
ΔT_{t-3}	**84.1 (0.058)***	**-5.58 (0.005)****	**137.4 0.003) ****	-2.12 (0.304)
ΔT_{t-4}	**-82.0 (0.087)***	**-5.47 (0.011)****	**-133.5 (0.006) ****	0.57 (0.789)
R-bar square	0.59	0.20	0.72	0.30
F-Test	4.15 (0.000)	1.54 (0.057)	5.07 (0.000)	1.67 (0.046)
Corr(1) Test	2.66 (0.615)		2.45 (0.653)	
Corr(4) Test	0.69 (0.952)		6.00 (0.199)	
Corr(8) Test	5.71 (0.221)		5.86 (0.210)	
Corr(12) Test	4.06 (0.397)		3.91 (0.419)	
Lutkepohl Test	5.44 (0.245)		6.02 (0.198)	

Table 2: VAR Estimation Results

Top Panel: reported values are coefficient estimates. Corresponding p-values are in parentheses.

Lower Panel: Various tests and their p-values.

F-test is the Wald test for the joint exclusion of all the regressors in the equation.

Corr(j) refers to an LM test for a null hypothesis of no autocorrelation at order j.

The Lutkepohl test posits joint normality under the null hypothesis.

The coefficients of the U.S. lag variables are included in the estimation but not reported to save space.

* implies significance at the 10% level while ** refers to significance at the 5% level.

VAR Estimations: Actual vs Fitted

Figure 3a: GDP change(2007$), gasoline

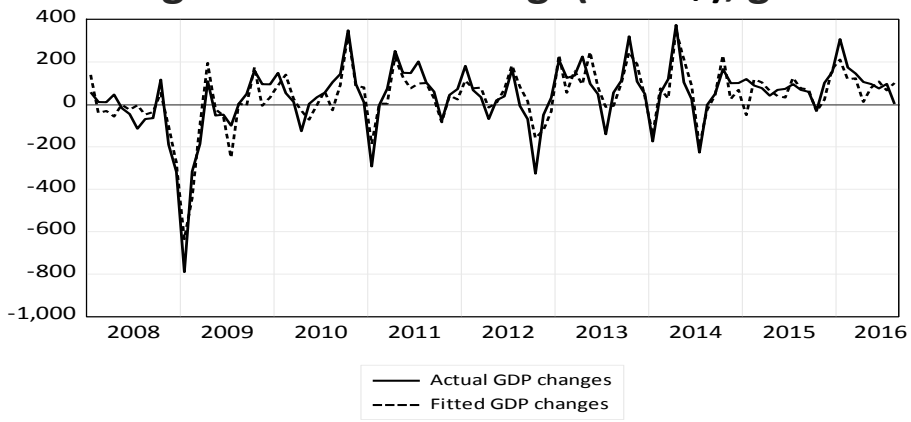


Figure 3b: Price change(2007¢/litre), gasoline

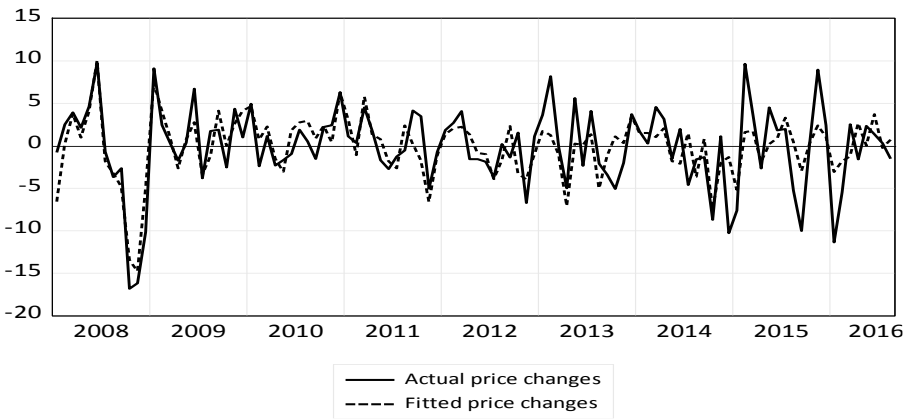


Figure 4a: GDP change (2007$), diesel

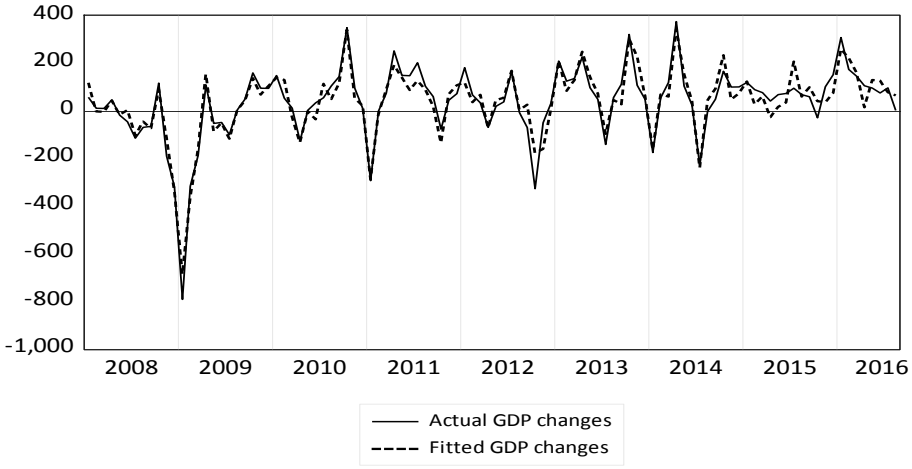


Figure 4b: Price change (2007¢/litre), diesel

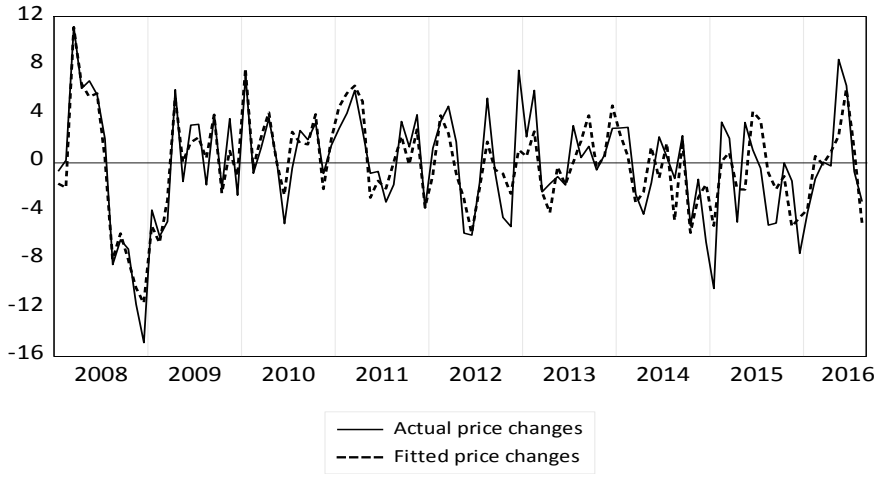


Table 3
Testing the sum of carbon tax variable coefficents

	Gasoline		Diesel	
	GDP	$Price$	GDP	$Price$
$\sum_{j=-4}^{-1} c_j$	-0.29 (0.998)	**-12.5 (0.001)****	28.65 (0.807)	-4.68 (0.393)
$\sum_{j=-4}^{0} c_j$	42.6 (0.741)	**-16.1 (0.006)****	-2.37 (0.986)	-7.53 (0.238)
$\sum_{j=1}^{4} c_j$	55.2 (0.654)	6.25 (0.250)	63.8 (0.572)	2.95 (0.573)
$\sum_{j=-4}^{4} c_j$	97.8 (0.651)	-9.85 (0.302)	61.4 (0.780)	-4.58 (0.654)

Reported values are Wald test F-statistics and corresponding p-values in parentheses.

** refers to significance at the 5% level.

5.4 Counterfactual Exercises

Figure 5a: GDP change, (2007$) with/no carbon taxes; gasoline

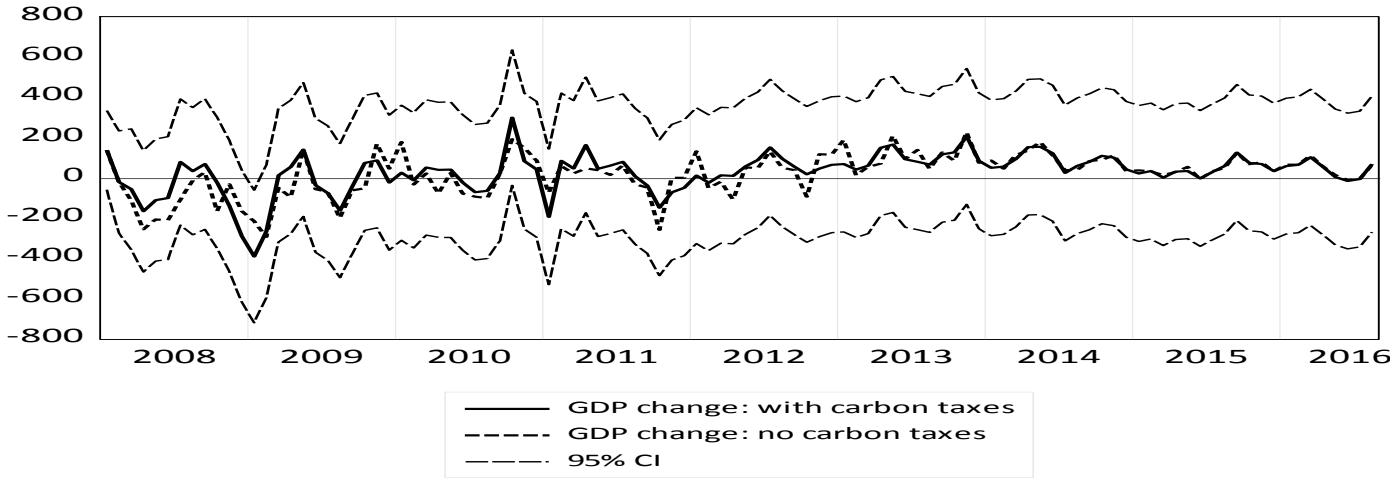
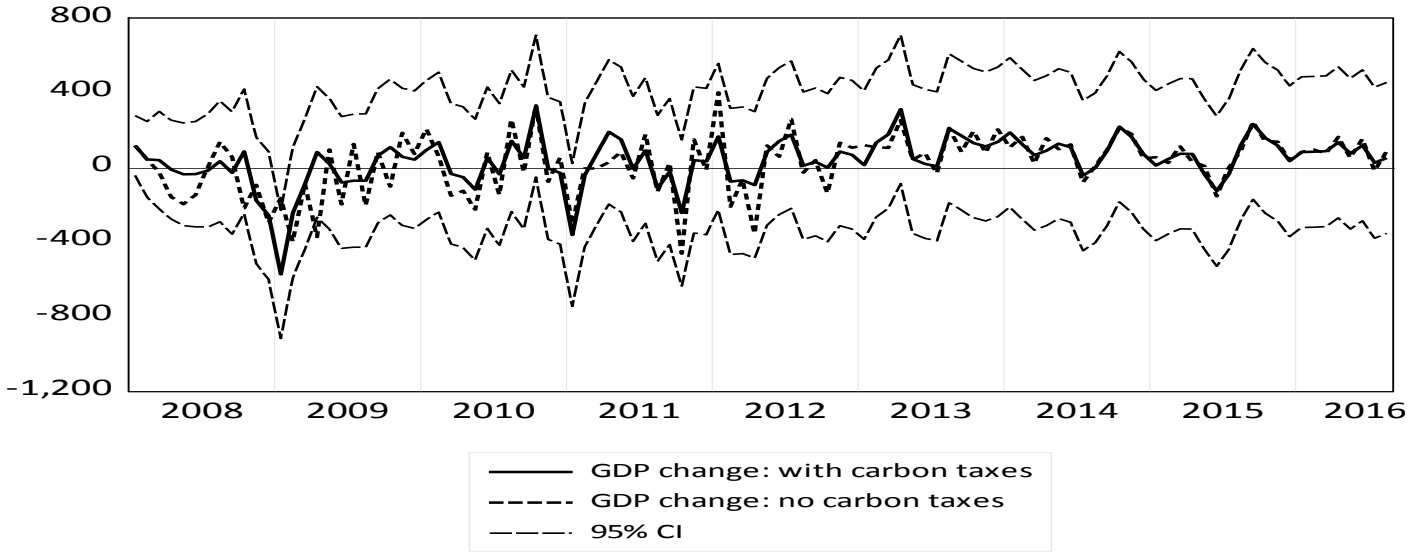


Figure 6a: GDP change, (2007$) with/no carbon taxes; diesel



5.4 Counterfactual Exercises

Figure 5b: Price change, (2007¢/litre) with/no carbon taxes; gasoline

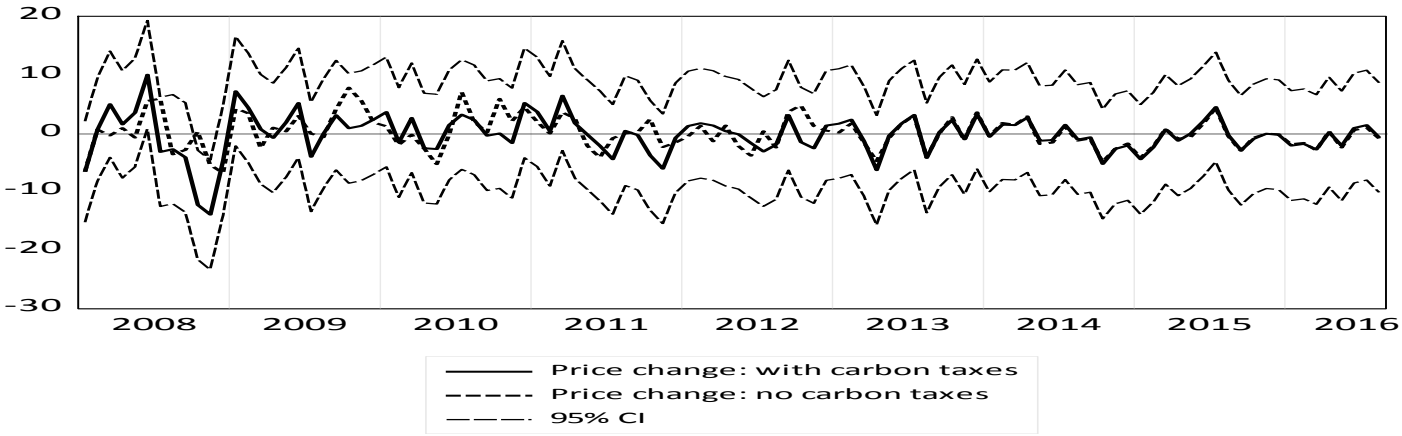
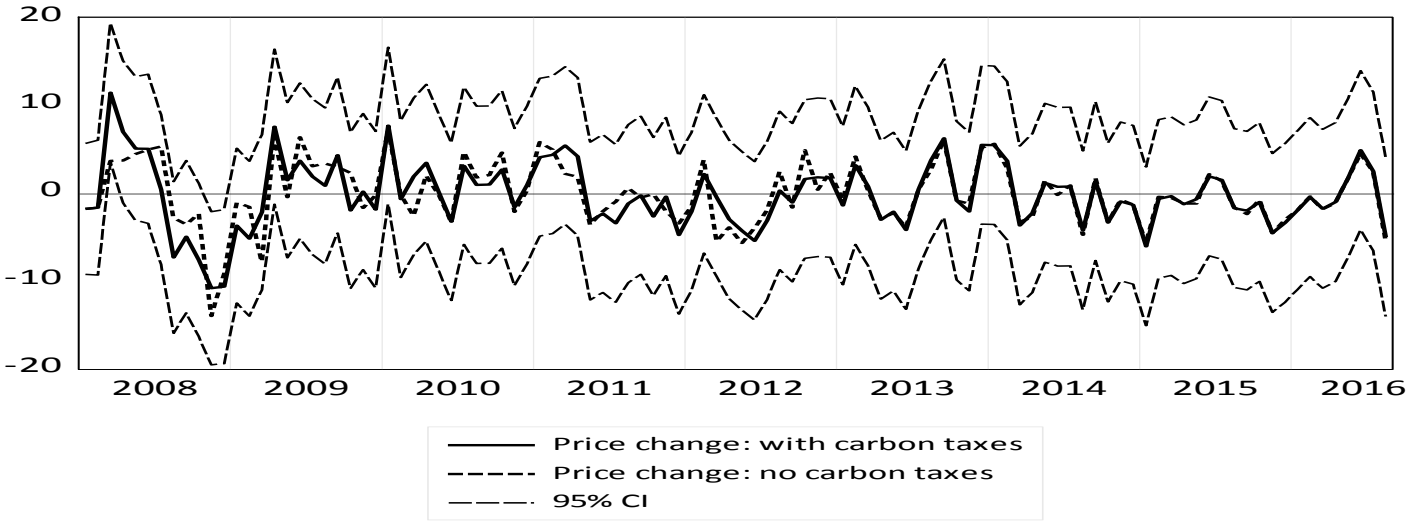


Figure 6b: Price change, (2007¢/litre) with/no carbon taxes; diesel



Ⅵ Conclusion