Assessing the Impact of Carbon Taxes on CO2 Emissions: Sweden as a Case Study

A Replication Study of Sweden's Case by Julius J. Andersson



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Table of contents

Introduction

Research Question: How do carbon taxes affect consumer’s carbon emission behavior and to what extent is there a difference between the carbon tax and a change in gasoline prices?

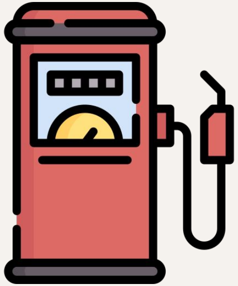
1. Address effectiveness of carbon taxes as a policy tool to reduce CO2 emissions
   a. Specifically Sweden's carbon tax and value-added tax on transport fuel
2. Do carbon taxes lead to significant reductions in emissions?
3. Are consumers are more responsive to changes in carbon taxes compared to changes in gasoline prices?

Summary

Methodology: Employed four OLS and two 2SLS regressions

Objective:

- Analyzing the impact of the Swedish carbon tax and Value-Added Tax (VAT) on transport emissions, aiming to understand their individual contributions.



- **Data Analysis:**

1. Used annual time-series data on gas consumption and real gasoline prices in Sweden from 1970 to 2011.
2. Employed Ordinary Least Squares (OLS) regression analysis to estimate the effect of the carbon tax and price changes on gasoline consumption.
3. Found that the carbon tax elasticity is significantly larger than the price elasticity, indicating a significant impact of the carbon tax on gasoline consumption.

Summary

Addressing Biases:

- Mitigated potential biases, such as omitted variables, anticipatory effects, and endogeneity of gasoline prices, using instrumental variable methods of energy tax rate and crude oil price (2SLS).

- Instrumented the carbon tax-exclusive gasoline price using the energy tax rate and crude oil price to ensure validity and exogeneity of instruments.

Insights:

- Examined behavioral responses to tax and price changes, providing comprehensive insights into the effectiveness and implications of carbon taxation policies on reducing CO2 emissions from the transport sector.

Replication: *OLS*

Andersson's regression model:

$$\ln(x_t) = \alpha + \beta_1 p_t^v + \beta_2 \tau_{t\,,CO2}^{v} + \beta_3 D_{t,CO2} + X_t\gamma + \varepsilon_t$$

- p^v_t = tax-exclusive gasoline price
- $\tau_{t\,,CO2}^{v}$ = carbon tax
- $D_{t,CO2}$ = dummy of value of 1 when year > 1990 and zero otherwise
- X_t = vector of other control variables (urbanization, GDP per capita, unemployment rate)
- ε_t = idiosyncratic shocks

Our replicated regression model:

$$\ln(\hat{Y}) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_n x_n + \varepsilon_t$$

- x_1 = tax-exclusive gasoline price
- x_2 = carbon tax
- x_3 = dummy of value of 1 when year > 1990 and zero otherwise
- x_n = vector of other control variables (urbanization, GDP per capita, unemployment rate)
- ε_t = idiosyncratic shocks

Replication: *2SLS*

1. Regress x_1 on z_1, x_2, x_3, x_n to obtain $\hat{x}_1$
    a. $\hat{x}_1 = \beta_0 + \beta_1 z_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_n x_n + \varepsilon_t$
    b. z_1 = Instrumental Variable

2. Plug in fitted values of $\hat{x}_1$ derived above into original linear regression equation
    a. $\ln(\hat{Y}) = \beta_0 + \beta_1 \hat{x}_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_n x_n + \varepsilon_t$

Our code:

ECON 140 Fina Proj.R

Source on Save

```r
library(haven)
install.packages("modelsummary")
library(modelsummary)
library(ivreg)

data_carbon <- read_dta("Downloads/data/disentangling_regression_data.dta")

model1 <- lm(log_gas_cons ~ real_carbontaxexclusive_with_vat +
                 real_carbontax_with_vat + d_carbontax + t, data =
                 data_carbon)
model2 <- lm(log_gas_cons ~ real_carbontaxexclusive_with_vat +
                 real_carbontax_with_vat + d_carbontax + t + real_gdp_cap_1000,
               data = data_carbon)
model3 <- lm(log_gas_cons ~ real_carbontaxexclusive_with_vat +
                 real_carbontax_with_vat + d_carbontax + t + real_gdp_cap_1000 + urban_pop,
               data = data_carbon)
model4 <- lm(log_gas_cons ~ real_carbontaxexclusive_with_vat +
                 real_carbontax_with_vat + d_carbontax + t + real_gdp_cap_1000 + urban_pop + unemploymentrate,
               data = data_carbon)

iv_model1 <- ivreg(log_gas_cons ~ real_carbontaxexclusive_with_vat + real_carbontax_with_vat +
                     d_carbontax + t + real_gdp_cap_1000 + urban_pop + unemploymentrate | real_energytax_with_vat + real_carbontax_with_vat +
                     d_carbontax + t + real_gdp_cap_1000 + urban_pop + unemploymentrate,
                   data = data_carbon)
iv_model2 <- ivreg(log_gas_cons ~ real_carbontaxexclusive_with_vat + real_carbontax_with_vat +
                     d_carbontax + t + real_gdp_cap_1000 + urban_pop + unemploymentrate | real_oil_price_sek + real_carbontax_with_vat +
                     d_carbontax + t + real_gdp_cap_1000 + urban_pop + unemploymentrate,
                   data = data_carbon)

modelsummary(list(model1, model2, model3, model4, iv_model1, iv_model2), vcov = "stata")
```

Replication Methodology

Data Analysis:

Used annual time-series data of gasoline consumption and real prices in Sweden from 1970-2011 from Andersson's replication package.

Conducted regressions on gasoline consumption per capita using OLS and 2SLS methods.

Implementation:

Conducted regressions in R, utilizing the RStata package to access the .dta file. Used lm() function for OLS and ivreg() function for 2SLS regressions.

Regression Models:

OLS regressions included tax-exclusive gas price, carbon tax, a dummy variable for tax implementation, and control variables.

Implemented 2SLS regressions using energy tax rate and crude oil price as instruments for tax-exclusive gas price. Negates endogenous effect of tax incidence on consumers

Original

Table 3—Estimation Results from Gasoline Consumption Regressions

	OLS (1)	OLS (2)	OLS (3)	OLS (4)	IV(EnTax) (5)	IV(OilPrice) (6)
Gas price with VAT	−0.0575	−0.0598	−0.0612	−0.0603	−0.0620	−0.0641
	(0.024)	(0.021)	(0.016)	(0.012)	(0.020)	(0.014)
Carbon tax with VAT	−0.260	−0.232	−0.234	−0.186	−0.186	−0.186
	(0.042)	(0.049)	(0.053)	(0.043)	(0.038)	(0.038)
Dummy carbon tax	0.109	0.0604	0.0633	0.0999	0.0977	0.0949
	(0.040)	(0.061)	(0.061)	(0.066)	(0.070)	(0.059)
Trend	0.0207	0.0253	0.0244	0.0341	0.0342	0.0344
	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
GDP per capita		−0.00108	−0.00105	−0.00366	−0.00367	−0.00368
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Urban population			0.0127	0.0301	0.0313	0.0329
			(0.075)	(0.067)	(0.064)	(0.058)
Unemployment rate				−0.0242	−0.0242	−0.0242
				(0.006)	(0.005)	(0.005)
Constant	6.228	6.407	5.372	4.407	4.313	4.198
	(0.167)	(0.142)	(6.202)	(5.446)	(5.152)	(4.693)
p-value: $\beta_1 = \beta_2$	0.001	0.004	0.003	0.004	0.004	0.001
Instrument *F*-statistic					3.57	310.93
p-value					0.067	<0.001
Observations	42	42	42	42	42	42
R^2	0.72	0.73	0.73	0.76	0.76	0.76

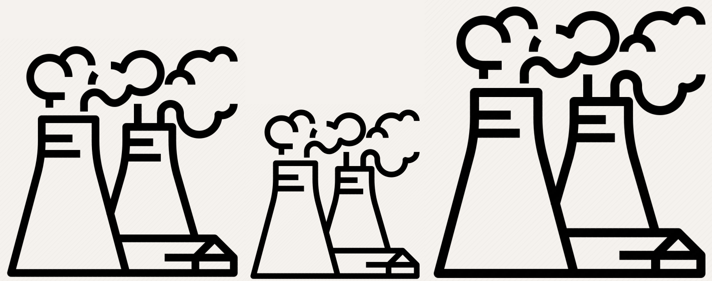
Replication

	(1)	(2)	(3)	(4)	(5)	(6)
(Intercept)	6.228	6.407	5.372	4.407	4.313	4.198
	(0.100)	(0.190)	(3.365)	(3.107)	(3.941)	(3.103)
real_carbontaxexclusive_with_vat	-0.057	-0.060	-0.061	-0.060	-0.062	-0.064
	(0.015)	(0.015)	(0.015)	(0.014)	(0.035)	(0.017)
real_carbontax_with_vat	-0.260	-0.232	-0.234	-0.186	-0.186	-0.186
	(0.032)	(0.044)	(0.045)	(0.045)	(0.045)	(0.045)
d_carbontax	0.109	0.060	0.063	0.100	0.098	0.095
	(0.038)	(0.065)	(0.066)	(0.058)	(0.078)	(0.062)
t	0.021	0.025	0.024	0.034	0.034	0.034
	(0.002)	(0.005)	(0.005)	(0.007)	(0.005)	(0.007)
real_gdp_cap_1000		-0.001	-0.001	-0.004	-0.004	-0.004
		(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
urban_pop			0.013	0.030	0.031	0.033
			(0.041)	(0.038)	(0.049)	(0.039)
unemploymentrate				-0.024	-0.024	-0.024
				(0.007)	(0.008)	(0.007)
Num.Obs.	42	42	42	42	42	42
R2	0.720	0.726	0.726	0.758	0.758	0.758

Conclusion

***Results*:**

1. Consumers are more sensitive to changes in carbon tax than gasoline prices.
   a. Carbon tax elasticity of demand for gasoline approximately 3x larger than the gasoline price elasticity.



Results and Discussion:

Replication efforts yielded consistent results with Andersson's study, after rounding data to three decimal places.

Conclusions supported the effectiveness of the carbon tax in reducing gasoline consumption in Sweden.

Comparison between OLS and 2SLS we see that there is generally a negative relationship between a positive change in the tax-exclusive gas price and carbon tax price, and gasoline consumption.