Dosis Facit Effectum
Why the Scope of the Carbon Tax Matters – Evidence from the Swedish Residential Sector

Anita Thonipara, University of Göttingen, +49551 3917 4888, anita.thonipara@wiwi.uni-goettingen.de
Petrik Runst, Institute for Small Business Economics, +49551 3917 4889, Petrik.runst@wiwi.uni-goettingen.de

Overview

As climate change is one of the most urging problems on the international political agenda, effective instruments are needed in order to reduce greenhouse gas emissions, particularly carbon dioxide emissions. In this regard, carbon taxation is gaining in importance in climate change debates. However, literature has so far neglected to comprehensively assess the effects of the carbon tax in the residential building sector.
This paper, therefore contributes to the literature by examining the impact of the Swedish carbon tax on residential carbon emissions as well as on consumer behavior. We perform Difference-in-Differences (DiD) regression and Synthetic Control Methods (SCM) in order to evaluate the causal impact on carbon taxation and carbon emission in the residential sector. We find a strong relationship and results are robust in the face of various placebo tests. Finally, we find that overall tax burden has a highly significant effect on the consumption of the respective energy carrier and even a stronger impact than net prices. We also find different effects of adaption, namely inter-fuel substitution as well as investments in more efficient technologies.
Overall, we conclude that taken together the evidence clearly points toward the effectiveness of carbon taxation and future political action to address climate change should focus on this cost efficient solution.

Methods

We employ Synthetic Control Methods which uses several donor countries as comparison units and constructs a synthetic control group out of a weighted average of these donr pool countries. That means in order to estimate the effect of the carbon ta xincreasae in Sweden, we construct a synthetic Swedish residential sector as a weightes combination of other European countres' residential sector as a weighted combination of other European countries' residential sectors that did not implement a carbon tax of comparable scope.

We use data on residential CO2 emissions per capita for 19 European countries for the time period 1990-2016. As explanatory variables country and year specific prices on oil and electricity, GDP per capita as well as HDD (in order to control for weather fluctuations) are included. We do not use prices for gas, district heating and biomass due to missing panel data. Furthermore, we use different lags of per capita CO2 emissions. We use a set of different samples. We drop certain countries at different stages depending on their energy taxation, prices or carbon tax implementation.

For each sample, we run several specifications. In specification 1 we use three lags (1990, 1994, and 2000) of CO2 emissions. In specification 2 we use the years 1996, 1997, 1998, 1999, and 2000 as lags. Finally, we include all lags in specification 3. Specification 4 does not include lags but adds HDD and GDPpC as control variables, after which oil prices and electricity prices are added in specification 5. The final specification combines the best lag model with all controls (combined specification). In order to determine which specification is 'best' we compare the root mean squared prediction error (RMSPE) in order to evaluate which specification has achieved a minimization of the pre-treatment gap between treatment group and and synthetic control group.

In order to select predictor weights, we use a fully nested optimization method which yields more precise estimates according to Mcclelland and Gault (2017). The model takes the following form:

$$\sum_{m=1}^{k} v_m \left(X_{1m} - X_{0m}W\right)^2$$

Vector X1 represents the characteristics of the treated unit, namely the Swedish residential sector, in the period before the treatment. m represents the respective comparison country. Vector X0 captures the characteristics of the comparison units which are multiplied by the vector of weights W. Thus, (X_1m-X_0m W) captures the difference between the treated unit and the comparison units. v_mis the weight for each comparison country. In the case of the synthetic control W*,〖 v〗_m is chosen such that the difference (X_1m-X_0m W) is minimized meaning that it best resembles the original Swedish residential sector before the year 2001.

As the data set consists of countries which implemented carbon taxes of different scopes at different point of times whilst reducing the rate of other energy taxes to different extents at different point of times, we use the overall tax burden for each energy carrier per country and year in order to detect the general effect that energy taxation has on the consumption of different energy carriers. The analysis is limited to the time period from 1990-2016 and to 19 European countries both due to data availability.

Our dependent variables (consumption of the respective energy carrier α_1 = gas, α_2= oil, α_3= electricity, α_4 = district heating, α_5= biomass) includes water heating, space heating (and cooling) as well as appliance use. Besides net prices of the respective energy carrier α_(1-3) we use the energy carrier specific tax per 1000 liters of oil, mwh of gas and electricity in order to capture the effect of energy taxes on energy consumption. We further include a number of other explanatory variables, namely HDD in order to control for year specific weather effects, population as more people use more energy as well as GDP per capita and the squared term of GDP per capita. We expect that the use of energy increases with increasing income due to more appliances, larger homes as well as lower energy price intensities. Furthermore the other energy carriers' (μ) end user prices are included in the model.

A conducted Durbin-Wu-Hausman test of endogeneity led to reject the hypothesis of exogenous variables (p=2.680). We therefore use an instrumental variable approach in which we use the first year lag of the energy carrier's net price as an instrument for the considered year's net price in order to rule out endogeneity caused by reverse causality.

The econometric model takes on the following form:

First specification

$$\begin{aligned} Consumption(\alpha)_{it} &= \beta_0 + \beta_1 log(\widehat{netprices}(\alpha_c))_{it} + \beta_2 \log(tax(\alpha_c))_{it} + \beta_3 HDD_{it} + \beta_4 population_{it} \\ &+ \beta_5 GDPpC_{it} + \beta_6 energy\ prices\ (\mu)_{it} + \varepsilon_{it} \end{aligned}$$

Where:

$$\widehat{netprices}(\alpha_c)_{it} = \gamma_0 + \gamma_1(\log(netprices(\alpha_c))_{it-1} + \gamma_2 exogenous\ regressors_{i(t)} + \varepsilon_{it}$$

Where:

$$\gamma_2 = 0$$

Results

The five specifications of the SCM in which the minimization of pretreatment difference of the outcome variable was successful provide evidence for a causal relationship of carbon taxation and residential carbon emissions. The effect size range from 200 to 450 kg of carbon emissions per capita per year. After the year 2012, we see that the gap between Sweden and synthetic Sweden shrinks. We interpret this development as further evidence in favour of the hypothesized relationship between taxation and emission. Many countries have only recently begun to introduce carbon taxation, such as France (2014), Switzerland (2008), the UK (2013) and Ireland (2010) and thereby decreased the differencte in the treatment intensity between Sweden and all other countries.

The Panel Data Analysis shows that overall tax burden has a highly significant effect on the consumption of the respective energy carrier and even a stronger impact than net prices. We also find different effects of adaption. Consumers switch from carbon-emission intensive energy carriers to less carbon emission-intensive energy carriers. Besides this, investments in more efficient technologies such as the use of heatpumps were increased.

Conclusions

As the residential sector accounts for a a major part of carbon emissions this study provides valuable empirical evidence on the effectiveness of the carbon tax as an instrument to combat climate change. Significant reductions in the use of emission intensive energy carriers and carbon emissions can be achieved by a stringent carbon tax scheme such as in Sweden. A high carbon tax encourages owners of residential buildings to invest in more efficient technologies.