Econometric Assessment of the Effectiveness of the World's Highest Carbon Taxation - Evidence from the Swedish Residential Building Sector (Work in Progress)

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

First, we perform a simple Difference-in-Differences Regression (DiD) in which residential CO2 emissions (in tons of CO2, by country and year) serves as the dependent variable. Instead of using a single pre- and post-period, we interact the treatment group dummy variable ($Sweden_i$) with a year dummy. The Sweden dummy as well as the annual dummy variables are included. In addition, the vector X contains further controls, namely HDD, GDP per capita as well as GDP per capita squared. We use several different sub-samples. First, the overall sample of all European countries is used, except Luxembourg for which we do not have sufficient data. We also included the data from Switzerland. Thus, the first sample containing all countries will underestimate the true effect since some control group countries also received treatment, albeit on a much lower scale. Secondly, we drop Italy and Denmark from the sample because they experienced a major tax increase after the year 2000. Finally, we drop all countries from the sample which have a carbon tax of more than 20 Euros per ton and countries that appear to have experienced some form of tax increase after the year 2000 (see figure 2) in order to get a control group which is not tainted by treatment (Switzerland, Finland, Norway, UK, and Ireland).

$$\boldsymbol{CO_2/capita_{it} = \ \alpha + \beta_1 * Sweden_i + \ \beta_2 Year_t + \beta_3 (Sweden_i * Year)_t + \sigma \overline{X}_{it} + \varepsilon_i}$$

DiD-methods can only be used if treatment and comparison groups would have developed equally without the treatment. The DiD results can only be interpreted as causal if the parallel regression assumption is valid and if there are no confounding factors which selectively affected the treatment or control group after the year in which treatment begins. We can check the parallel regression assumption by plotting the development of CO2/capita for the treatment and the control group over time. In addition, none of the yearly interaction terms before treatment must be significant in order to infer a causal relationship.

Secondly, 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 weighted combination of other European countries' residential sector 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. Furthermore, we use different lags of per capita CO2 emissions. We use a set of different samples and 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.

Results

The DiD regressions show that there is a strong suggestion of a negative relationship between carbon taxation and carbon emissions. The interaction terms of the Sweden dummy variable and the year dummy is insignificant before the year 2000, except in 1997, in which case the effect size is small to moderate (84 to 120 kg of CO2 per capita). We conclude that the parallel regression assumption is not completely fulfilled. After the year 2000, the interaction terms are generally significant and effect sizes are negative and sizable, ranging from reductions of 200 kg to almost 500 kg per capita and year. Effect sizes become generally larger over time, although one must be careful when interpreting coefficients in later years. The farther we move away from the initial treatment date the more likely it is that confounding factors exert an influence. In specification (1) and (3) the coefficients of the interaction terms are negative and significant for six out of six post-treatment years. In specification (2), five out of six post-treatment interaction term coefficients are significant and negative, the other one being negative but not significant at the 10% level.

The five specifications of the Synthetic Control Model in which the minimization of pre- treatment differences 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 year. After the year 2012, we see that the gap between Sweden and synthetic Sweden shrinks. We interpret this development as further evidence in favor 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 difference in the treatment intensity between Sweden and all other countries. In the specifications in which countries with a carbon tax higher than 20 Euros are left out from the control group the peak treatment effect is close to 800 kg of carbon emissions per capita per year.

Conclusions

Summarizing, we can say that suggestive evidence exists that points toward a possible causal relationship between taxation and emissions in the residential sector. However, the parallel trends assumption is not completely fulfilled. Moreover, since we are working with country level data, there are a number of possible confounding factors, which could have selectively affected the carbon emissions per capita in Sweden or the control group in the post-treatment period.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. 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.