Carbon Taxes and CO_2 Emissions: Sweden as a Case Study[†]

By Julius J. Andersson*

This quasi-experimental study is the first to find a significant causal effect of carbon taxes on emissions, empirically analyzing the implementation of a carbon tax and a value-added tax on transport fuel in Sweden. After implementation, carbon dioxide emissions from transport declined almost 11 percent, with the largest share due to the carbon tax alone, relative to a synthetic control unit constructed from a comparable group of OECD countries. Furthermore, the carbon tax elasticity of demand for gasoline is three times larger than the price elasticity. Policy evaluations of carbon taxes, using price elasticities to simulate emission reductions, may thus significantly underestimate their true effect. (JEL H23, L91, Q54, Q58)

In Paris in 2015, countries renewed their commitment to address climate change. As part of the Paris Agreement, each country put forward a "nationally determined contribution" toward the common goal of limiting global warming. This bottom-up approach of voluntary pledges will put the focus on national mitigation policies. At the center of these policies should be an effort to put a price on greenhouse gas emissions such as carbon dioxide (CO_2), by issuing tradable emission permits or through a carbon tax[1] (Arrow et al. 1997, Howard and Sylvan 2015, IMF 2017), where most economists favor a tax (see, e.g., Nordhaus 2008, 2013 and Weitzman 2015, 2016). Public support for carbon taxes are, however, generally low, and people tend to believe they are environmentally inefficient, although when provided with evidence that they indeed reduce emissions, the support for carbon taxes increases (Murray and Rivers 2015, Carattini et al. 2016). Few countries, however, have implemented carbon taxes, and there are, surprisingly, even fewer ex post empirical studies of their causal effect on emissions to draw from (Baranzini and Carattini 2014, Sterner 2015). This lack of empirical studies of carbon taxes is unfortunate given the urgency of tackling climate change, and relying on less efficient measures will make

[1] The purpose of a carbon tax is to reduce emissions by equalizing the private and social costs of releasing carbon.

it hard to reach current targets under the Paris Agreement, not to mention the even more ambitious abatement targets that are needed if we are serious about curbing warming to no more than 2°C above preindustrial levels. Correctly estimating the effectiveness of carbon taxes empirically is thus important for shoring up much needed public support, as well as ensuring that environmentally and economically efficient mitigation policies are adopted across countries by the diffusion of lessons from existing national climate policies (Carraro et al. 2015).

I investigate empirically the environmental efficiency of carbon taxes by analyzing the Swedish experience of introducing a carbon tax on transport fuels in the early 1990s. Sweden was one of the first countries in the world to implement a carbon tax in 1991. It was introduced at the level of US\$30 per ton of CO_2 and then successively increased to today's rate of US\$132, currently the highest carbon tax in the world (Kossoy et al. 2015). In the year prior, in March of 1990, Sweden also extended the coverage of its existing value-added tax (VAT) to include gasoline and diesel (Swedish Government 1989–1990). The VAT rate of 25 percent is applied to all components of the retail price: the production cost of the transport fuel, producer margin, and any added excise taxes.

The Swedish carbon tax mainly affects the transport sector. Today, around 90 percent of the revenues from the carbon tax comes from the consumption of gasoline and motor diesel (Ministry of Finance 2017). When implemented, large sectors of the economy, especially industry and agriculture, received a considerably lower carbon tax rate because of concerns of international competitiveness and carbon leakage, and fuels used for electricity production were fully exempted from paying the tax (Johansson 2000, Hammar and Åkerfeldt 2011). In addition, in 1991, the energy tax on fossil fuels was reduced by 50 percent for industry, leading to a combined tax rate that was slightly lower than before the reform. In fact, the Swedish EPA (1995) analyzed all sectors that were covered by the carbon tax and found that, besides transport, it was only for heating that the carbon tax had an effect on emissions. I expect the impact on heating to have been small however, as in 1991, only around 37 percent of heating fuels were fossil fuel based (Swedish Energy Agency 2017). Furthermore, a reduction in the energy tax rate meant that the total tax for heating oil was on the whole almost unaffected by the introduction of the carbon tax (Hammar and Åkerfeldt 2011). The transport sector, though, is fully covered by the carbon tax and thus a suitable sector to analyze.[2] It is also Sweden's largest source of CO_2 emissions—from 1990–2005 the sector was responsible for close to 40 percent of total annual CO_2 emissions (Ministry of the Environment and Energy 2009).

In the first half of this paper, I estimate empirically the reduction of CO_2 emissions in the transport sector using panel data and the synthetic control method (Abadie and Gardeazabal 2003; Abadie, Diamond, and Hainmueller 2010, 2015). From a carefully chosen control group of OECD countries, I construct the counterfactual, "synthetic Sweden": a comparable unit consisting of a weighted combination of countries that did not implement carbon taxes or similar policies during the

---

[2] Fuels used for domestic aviation are exempt from energy and carbon taxation as well as VAT. Domestic aviation, however, is only responsible for 3.5 percent of transport's CO_2 emissions (Hammar and Åkerfeldt 2011).

treatment period and that prior to treatment resemble Sweden on a number of key predictors of CO_2 emissions in the transport sector and have similar levels and paths of these emissions. The synthetic control method provides an estimated emission reduction from the transport sector of 10.9 percent, or 2.5 million metric tons, in an average year during 1990–2005—the chosen posttreatment period of interest in this paper.

In the second half of this paper, I disentangle the carbon tax and VAT effect by first estimating tax and price elasticities of demand for gasoline in Sweden.[3] To this end, I use time-series analysis of the consumption and price of gasoline in Sweden during 1970–2011. Exploiting yearly changes to the carbon tax rate and the carbon tax-exclusive price of gasoline (the total gas price minus the carbon tax), I find that the carbon tax elasticity of demand is around three times larger than the price elasticity. Using the estimated carbon tax and price elasticities— together with the estimated emission reductions from using the synthetic control method—I then disentangle the effect of the carbon tax on emissions from the effect of the VAT. From the carbon tax alone I estimate a posttreatment reduction of 6.3 percent, or 1.5 million metric tons of CO_2 emissions in an average year. This result is in contrast to earlier empirical studies that find no effect from the Swedish carbon tax on domestic transport CO_2 emissions (Bohlin 1998, Lin and Li 2011), and the estimated reduction is 40 percent larger than an earlier simulation study finds (Ministry of the Environment and Energy 2009). In fact, my finding differs from all earlier empirical studies of carbon taxes, which find that the taxes have had very small to no effect on CO_2 emissions in the countries that implemented them (Bohlin 1998, Bruvoll and Larsen 2004, and Lin and Li 2011). This is thus the first quasi-experimental study to find a significant causal effect of a carbon tax on emissions.

There are a number of advantages to using the synthetic control method when it comes to evaluating the environmental effects of carbon taxation. First, with the synthetic control method we use ex post empirical data on CO_2 emissions as the outcome variable, and there is thus no need to use a simulation approach to estimate changes to emissions. Earlier studies of the environmental effect of carbon taxes—or transport fuel taxes in general—are typically ex ante (or ex post) simulations, using price elasticities of demand for gasoline to estimate reductions in consumption of transport fuel (see, e.g., Rivers and Schaufele 2015; Li, Linn, and Muehlegger 2014; Davis and Kilian 2011; and Ministry of the Environment and Energy 2009). Changes to the consumption of gasoline are in these studies used as a proxy for total changes in CO_2 emissions from the transport sector or the economy as a whole.

There are, however, a number of problems with this simulation approach. There is now growing evidence that consumers respond more strongly to tax changes compared to equivalent price changes, especially in the gasoline market. A number of studies find that the tax elasticity is two and a half to four times larger than the price elasticity. Simulations that use price elasticities of demand thus underestimate the

---

[3]I focus on gasoline since 95 percent of CO_2 emissions in the transport sector come from road transport (Ministry of the Environment and Energy 2009), where gasoline is the main fuel used (see Figure 2).

true causal effect of carbon taxes on CO_2 emissions. Furthermore, by focusing on changes in demand for only gasoline, these earlier studies don't account for substitution between fuels, most notably from gasoline to diesel,[4] as well as substitution between modes of transport. In Europe, the share of passenger cars using diesel as engine fuel is in many countries equal to the share that uses gasoline (Eurostat 2017). This is a different situation compared with the United States and Canada where gasoline is overwhelmingly the main fuel used in passenger cars (Chambers and Schmitt 2015). The increased share of diesel in Europe is an important form of adaptation to higher fuel taxes since the diesel engine offers significantly better fuel efficiency (Sterner 2006). The difference in the vehicle fleet between Europe and North America may thus be seen as a direct response to comparatively higher fuel taxes in Europe. In Sweden, the percentage of passenger cars using diesel in 1991 was 2.7 percent; this share increased to 5.2 percent in 2005 and 29.6 percent in 2015 (Eurostat 2017). This substitution is important to capture when evaluating the effect of environmental taxation in the transportation sector, as a failure to do so will bias the results.[5]

An additional benefit of looking at transport emissions directly is that we capture all fuel demand adjustments made on the extensive margin in response to a carbon tax, such as an increased use of public transport. Buses used for public transport typically use diesel as engine fuel.

Second, in the setting of this paper, with only one treated unit and the use of aggregated data, the synthetic control method has some advantages over the differences-in-differences (DiD) estimator frequently used in comparative case studies. Besides simulations, the use of the DiD estimator is the most common research design in evaluations of the effects of carbon taxes (see, e.g., Elgie and McClay 2013, Lin and Li 2011). To begin with, the synthetic control method relaxes the parallel trends assumption that underlies the DiD estimator by allowing the effects of unobserved confounders on emissions to vary over time (Abadie, Diamond, and Hainmueller 2010). Furthermore, with the inclusion of predictors of CO_2 emissions from the transport sector, we weigh the units in the control group so as to create a comparison unit that most resembles Sweden. Addition of these covariates, such as level of urbanization and number of motor vehicles per capita, is not possible in the DiD regression as they are likely affected by the implementation of the carbon tax—themselves being outcome variables—and are thus considered "bad controls." With the synthetic control method, we use the predictive power of the covariates to construct a convincing counterfactual, without the confounding effect of having them included posttreatment. With DiD there is also often an ambiguity in the choice of comparison units (see, e.g., Card 1990, Lin and Li 2011), whereas the synthetic

---

[4] Rivers and Schaufele (2015, 32), analyzing the carbon tax in British Columbia, Canada, acknowledges this in a footnote: "Note that the BC carbon tax affects all fossil fuels consumed in the province, not just gasoline. However, our analysis is restricted to the impact of the carbon tax on gasoline sales."

[5] Davis and Kilian (2011, 1210) simulates carbon emission reductions from an increase of the gasoline tax in the United States, and admits, also in a footnote, that their results assume away any substitution: "This estimate presumes that substitution away from gasoline does not raise greenhouse gas emissions. To the extent that consumers substitute from gasoline to other carbon-producing goods, the aggregate reductions will be overestimated by our approach." Although the authors refer to "carbon-producing goods" in general, the argument also applies to a possible substitution between different transport fuels.

control method chooses them through a data-driven method. Lastly, in the synthetic control framework, the relative contribution of each control unit is made explicit, and we can analyze the similarities, or lack thereof, between our selected synthetic control and the treated unit, on the pre-intervention outcomes and observable predictors of the post-intervention outcomes.

In addition to the merits of using empirical ex post data on emissions and a synthetic control, my paper contributes to the empirical literature on carbon taxation on a few other dimensions. First, Sweden's geographical location makes it less susceptible to carbon leakage from the transport sector, leaving estimated emission reductions unbiased. Sweden is a peninsula in the most northern region of Europe, only sharing land border with Norway along a de-populated area of Sweden. Gasoline prices in Norway are also, on average, 15 percent higher than in Sweden during the posttreatment period, making cross-border shopping of fuel by Swedes unlikely (IEA 2019). This is a different situation than, for instance, the carbon tax that was implemented in British Columbia, Canada, in 2008—studied in Rivers and Schaufele (2015) and Elgie and McClay (2013). British Columbia is surrounded by other Canadian states and the United States in three out of four directions. There is thus an obvious risk of carbon leakage, evidence of which is reported in Antweiler and Gulati (2016).

Second, since Sweden implemented a carbon tax as early as 1991, my paper is better able to capture long-term changes to behavior. The 16 years of posttreatment data in my study can be compared with the 4 years in Rivers and Schaufele (2015). Fuel demand adjusts in response to a carbon tax on two different margins: the intensive, changes in mileage driven; and the extensive, buying a more fuel-efficient car or using alternative transportation means, such as public transport or a bicycle. With Sweden as our case study, we are able to capture adjustments made on both of these margins.

The remainder of the paper is organized as follows. Section I presents the Swedish carbon tax. Section II presents the data and methods used for the estimation of emission reductions. Section III presents the results of the empirical analysis as well as several robustness checks. Section IV disentangles the carbon tax effect from the VAT. Section V compares the paper's findings with earlier studies and discusses general lessons to take away from the study. Finally, Section VI concludes.

I. The Swedish Carbon Tax

Sweden is a small, open economy with a population of 9.5 million and a nominal GDP per capita that ranked it as the eleventh richest country in the world in 2015 (IMF 2016). With regard to climate change policies, in 1991, Sweden was one of the first countries in the world to implement a carbon tax. The tax was first suggested by the Social Democrats in 1988, citing the threat of climate change, and signed into law by the Social Democratic government in 1990 (Collier and Löfstedt 1997, Swedish Government 1989–1990). The full carbon tax rate is levied on heating fuels (used by households) and transport fuels. Measures to combat climate change had broad political support in the late '80s and early '90s, but concerns about international competitiveness and carbon leakage meant that industry paid only 25 percent

of the full rate.[6] This differential has changed over the years—industry paid from 21–50 percent of the general carbon tax rate in the years 1991–2005, and today industry pays 80 percent of the full rate. Owing to the lower rate paid, and coupled with a reduction in the existing energy tax and a relatively small reliance on fossil fuels (less than 30 percent) for the energy supply, the impact of the carbon tax on the Swedish industry has been rather limited (Johansson 2000, Swedish Energy Agency 2017).

The carbon tax was introduced at US\$30 per ton of CO_2 and increased slightly during the 1990s to US\$44 in 2000. Then, from 2001–2004, the rate was increased in a step-by-step manner to US\$109. Today, in 2018, the rate is US\$132 per ton of CO_2, the world's highest CO_2 tax imposed on non-trading sectors and households.[7] The final tax rates applied to fossil fuels are set in accordance with their carbon content. For example, the combustion of one litre of gasoline releases 2.323 kg of CO_2. The carbon tax rate of 0.25 SEK per kg of CO_2 (1 SEK $=$ US\$0.12) in 1991 thus equated to an addition to the consumer price of gasoline of 0.58 SEK per liter.

When the carbon tax was implemented, it complemented an existing energy tax that was added to the price of gasoline as early as 1924 and diesel in 1937 (Speck 2008). With the addition of VAT of 25 percent in 1990, the retail price of gasoline and diesel today consists of a tax-exclusive price p_t, energy tax $\tau_{t,energy}$, carbon tax τ_{t,CO_2}, and a value-added tax

$$(1) \qquad\qquad p_t^* = \left(p_t + \tau_{t,energy} + \tau_{t,CO_2}\right) VAT_t.$$

Figure 1, panel A, shows that the real (inflation-adjusted) energy tax applied to gasoline was fairly constant from 1960–2000, before decreasing in the years 2001–2005.[8] This decrease was counteracted by a simultaneous increase in the carbon tax rate, sustaining the upward trend in the total tax, as evident in Figure 1, panel B. The total tax rate increased by 39 percent in 1990 and more than 82 percent between 1989–2005—from 4 SEK to over 7 SEK per liter. Figure 2 plots per capita consumption of gasoline and diesel during 1960–2005 (World Bank 2015). The figure gives a descriptive indication that the carbon tax and VAT had an impact on the consumption of transport fuel and that consumers substituted gasoline for diesel in response to the large increase in taxes.

---

[6] The economic effects of the domestic recession between 1991–1993 may also have factored in (Swedish Government 1991–1992). Sweden's economic problems in the early 1990s started in the housing and financial sectors but soon affected the economy as a whole. An earlier expansion of credit (and debt), coupled with an overvalued currency, had made the economy vulnerable to adverse shocks. From mid-1990 to mid-1993, GDP dropped by a total of 6 percent and unemployment went from 3 to 10 percent of the labor force. The economy and the banking sector eventually stabilized in the summer of 1993, following the decision in late 1992 to move from a fixed to a floating exchange rate.

[7] Total revenue from the Swedish carbon tax constituted 1.75 percent of government revenues in 2006 and is not ear-marked for any specific purpose when entering the governmental budget. The administrative cost for the tax authority is also low, around 0.1 percent of total revenues from the tax (Withana et al. 2013).

[8] In Section IV, I estimate how much larger total emission reductions would have been if the energy tax rate had stayed constant between 2001–2005. Note also that the VAT rate is constant during the entire time period of our analysis, acting as a multiplier of movements in the other price components—thus, taking the value of 1, in equation (1), for years prior to 1990, and 1.25 thereafter.
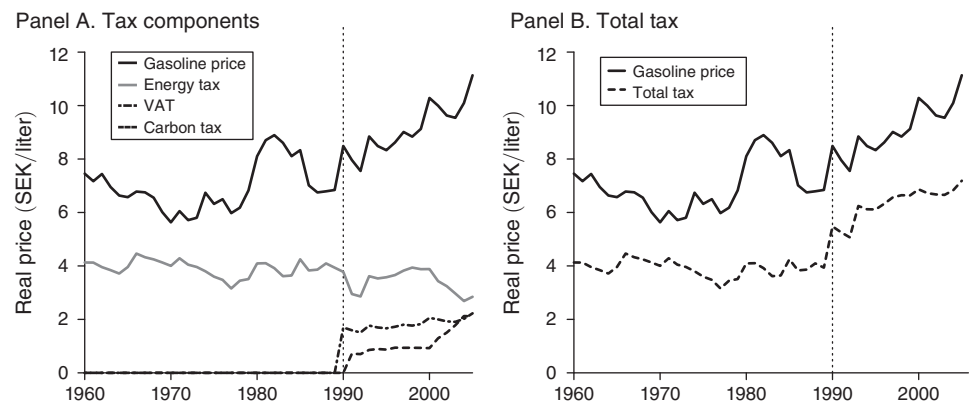
Panel A. Tax components

Panel B. Total tax

FIGURE 1. GASOLINE PRICE COMPONENTS IN SWEDEN 1960–2005

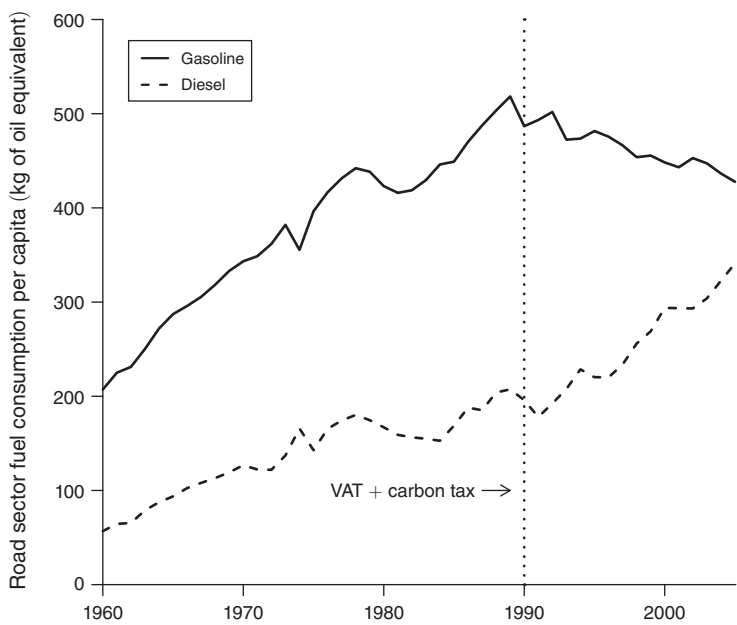*Source:* SPBI (2016); Statistics Sweden (2015); Swedish Tax Agency (2018)

FIGURE 2. ROAD SECTOR FUEL CONSUMPTION PER CAPITA IN SWEDEN 1960–2005

Tax Incidence.—An important question for our subsequent analysis of the effect on emissions is to what extent fuel taxes are borne by consumers. If the carbon tax is fully passed through to consumers, that will result in higher prices at the fuel pump, and higher prices reduce demand and thus fuel use, resulting in lower CO$_2$ emissions from the transport sector. Furthermore, if tax changes are fully passed on to consumers, we can view estimated tax elasticities as demand elasticities.

I analyze empirically the question of tax incidence by decomposing the Swedish retail price of gasoline into oil prices and excise taxes. Using first-differences, I regress the nominal tax-inclusive price of gasoline during time-period t on the crude oil price, and excise taxes

$$(2) \qquad \Delta p_t^* = \alpha_0 + \alpha_1 \Delta \theta_t + \alpha_2 \Delta \tau_t + \epsilon_t,$$

where p_t^* is the retail price of gasoline, θ_t is the crude oil price, and τ_t is the sum of the energy and carbon tax (I exclude VAT and the producer margin from the model). Using yearly data from 1970–2015 ($N = 45$), I find an estimate for the coefficient on taxes of 1.15 (95 percent confidence interval of [0.90–1.39]). The coefficient is statistically indistinguishable from 1, and the data thus indicate that tax changes are borne heavily by consumers. Furthermore, I split up the total tax into its energy and carbon tax part. The result stays unchanged—the coefficients being 1.17 [0.91–1.43] for the nominal energy tax and 1.00 [0.70–1.29] for the nominal carbon tax, both statistically indistinguishable from 1. Changes to the Swedish energy and carbon tax rates are thus both fully passed through to consumers, a result similarly found in studies of US gasoline taxes by, among others, Marion and Muehlegger (2011); Davis and Kilian (2011); and Li, Linn, and Muehlegger (2014).

II. Empirical Methodology

A. *Data*

To empirically analyze the effect on emissions from the environmental tax reform in 1990–1991, I use annual panel data on per capita CO_2 emissions from transport for the years 1960–2005 for 25 OECD countries, including Sweden.[9] The outcome variable is measured in metric tons, and the data, obtained from the World Bank (2015), contains emissions from the combustion of fuel (taken to be equal to the fuel sold) from road, rail, domestic navigation, and domestic aviation, excluding international aviation and international marine bunkers. For all the OECD countries in my sample, transport emissions are calculated based on empirical data on the sale of transport fuels and their carbon content, with the data typically available from national statistical agencies. For road vehicles, emissions are attributed to the country where the fuel is sold (Eggleston et al. 2008). By focusing on CO_2 emissions from the combustion of all transport fuels, and not only gasoline, we capture changes in demand for fuel in the different modes of transport, as well as substitutions made between fuels, most notably between gasoline and diesel.

I choose 2005 as the end date because that year was the start of the European Union Emissions Trading System (EU ETS), one of the main building blocks of the EU's climate change policy, and also because many countries in the sample implemented carbon taxes or made marked changes to fuel taxation from 2005 and

---

[9] Included are the 24 countries that were OECD members in 1990 plus Poland, which became a member in 1996 and is geographically close to Sweden.

onward. The sample period hence gives me 30 years of pretreatment data and 16 years of posttreatment data, which is sufficient to construct a viable counterfactual and enough time posttreatment to evaluate the effect of the policy changes.

From this initial sample of 25 OECD countries, I exclude countries that during the sample period enacted carbon taxes that cover the transport sector, in this case Finland, Norway, and the Netherlands, or made large changes to fuel taxes, which exclude Germany, Italy, and the United Kingdom.[10] Additionally, I exclude Austria and Luxembourg because of "fuel tourism" distorting their emissions data (Sterner 2006). Austria's emissions data is skewed from the year 1999 and onward. This is due to Austria lowering fuel taxes in 1999, while neighboring Germany and Italy increased their fuel taxes the same year. Austria is a major transit country, and large trucks in particular tend to fill up in countries with low diesel prices on their way through Europe. In 2005, diesel sales in Austria were 150 percent higher than a decade earlier, a clear indication that "fuel tourism" had taken place. Luxembourg has had lower fuel taxes than neighbouring European countries for many years, which explains them having five to eight times higher per capita consumption of fuel than their neighbors (European Federation for Transport and Environment 2011), and thus more than two times higher per capita CO_2 emissions from transport than the next highest emitter in the sample. Similarly, I omit Turkey, which had average per capita emissions in the pretreatment period way below the other countries in the sample. Lastly, I exclude Ireland because of their unique economic expansion in the 1990s—the "Celtic Tiger"—that more than doubled their GDP per capita and CO_2 emissions per capita from transport during the posttreatment period. This rapid economic expansion is dissimilar to Sweden's and the other donor countries' development during the same time period. We exclude Turkey and Ireland to avoid interpolation bias: including countries in the donor pool with important characteristics that are very different from Sweden (Abadie, Diamond, and Hainmueller 2015). Note, however, that my main results from using the synthetic control method are identical and unaffected by whether or not Austria, Luxembourg, Turkey, or Ireland are included in the sample, since these four countries all obtain zero weight in synthetic Sweden. Furthermore, as will be evident in the result section, the estimated emission reductions from comparing Sweden with its synthetic counterpart are never driven by any one single country in the donor pool.

In the end, my donor pool consists of 14 countries: Australia, Belgium, Canada, Denmark, France, Greece, Iceland, Japan, New Zealand, Poland, Portugal, Spain, Switzerland, and the United States.

B. *The Synthetic Control Method*

The DiD estimator, commonly used in comparative case studies, constructs the counterfactual using an unweighted average of the outcome variable from the control group. An estimate of the emission reduction (the "treatment" effect) is gained by comparing the change in the outcome variable pre- and posttreatment, for the treated unit and the control group. What makes the DiD estimator attractive for

---

[10] Denmark also implemented a carbon tax, in 1992. Their tax level, however, is set relatively low—US$24 in 2015 (Kossoy et al. 2015)—and, more importantly, the transport sector is exempted.

comparative studies is that, by taking time differences, it eliminates the influence of unobserved covariates that predict the outcome variable, assuming that the effects on the outcome variable are constant over time. A further assumption is that any macroeconomic shocks, or other time effects, are common to the treated unit and the control group. Together, these two assumptions are usually referred to as the "parallel trends assumption," implying in our case that, in the absence of a carbon tax and VAT, CO_2 emissions from the transport sector in Sweden and our control group follow parallel paths.

The parallel trends assumption is difficult to verify, which is a drawback for the DiD method. It is sometimes possible pretreatment by analyzing the trends of the outcome variable, but obviously impossible after treatment. When the treated unit and the control group do not follow a common trend, the DiD estimator will be biased. Therefore, finding a method that relaxes the parallel trends assumption is preferable for comparative case studies. The synthetic control method allows the effects of unobserved confounders on the outcome variable to vary over time by weighting the control group, so that prior to treatment it resembles Sweden on a number of key predictors of CO_2 emissions in the transport sector and has similar levels and paths of emissions. Thus, by relaxing the parallel trends assumption, the synthetic control method improves upon the DiD estimator.

Let $J + 1$ be the number of OECD countries in my sample, indexed by j, and let $j = 1$ denote Sweden, the "treated unit." The units in the sample are observed for time periods $t = 1, 2, \ldots, T$, and it is important to have data on a sufficient amount of time periods prior to treatment $1, 2, \ldots, T_0$ as well as posttreatment $T_0 + 1, T_0 + 2, \ldots, T$ to be able to construct a synthetic Sweden *and* evaluate the effect of the treatment. Synthetic Sweden is constructed as a weighted average of the control countries $j = 2, \ldots, J + 1$ and represented by a vector of weights $W = (w_2, \ldots, w_{J+1})'$ with $0 \leq w_j \leq 1$ and $w_2 + \cdots + w_{J+1} = 1$. Each choice of W gives a certain set of weights and hence characterizes a possible synthetic control.

We choose W so that the difference between Sweden and the control units on a number of key predictors of the outcome variable and the outcome variable itself is minimized in the pretreatment period, subject to the above (convexity) constraints. As key predictors, I use GDP per capita, number of motor vehicles, gasoline consumption per capita, and percentage of urban population.[11] The level of GDP per capita is shown in the literature to be closely linked to emissions of greenhouse gases, and OECD countries that are less urbanized have a higher usage of motor vehicles and hence higher emissions from transport (Neumayer 2004). I average the four key predictors over the 1980–1989 period. Finally, to the list of predictors, I add three lagged years of CO_2 emissions: 1970, 1980, and 1989.

The predictors are in turn assigned weights to allow more weight to be given relative important predictors of the outcome variable. There are various methods available for selecting the diagonal matrix of predictor weights V, for instance, by assigning weights based on empirical findings in the literature on the main drivers of CO_2 emissions, or cross-validation methods (Abadie, Diamond, and Hainmueller

---

[11] Sources: Feenstra, Inklaar, and Timmer (2013); Dargay, Gately, and Sommer (2007); and World Bank (2015). See the online Appendix for details.
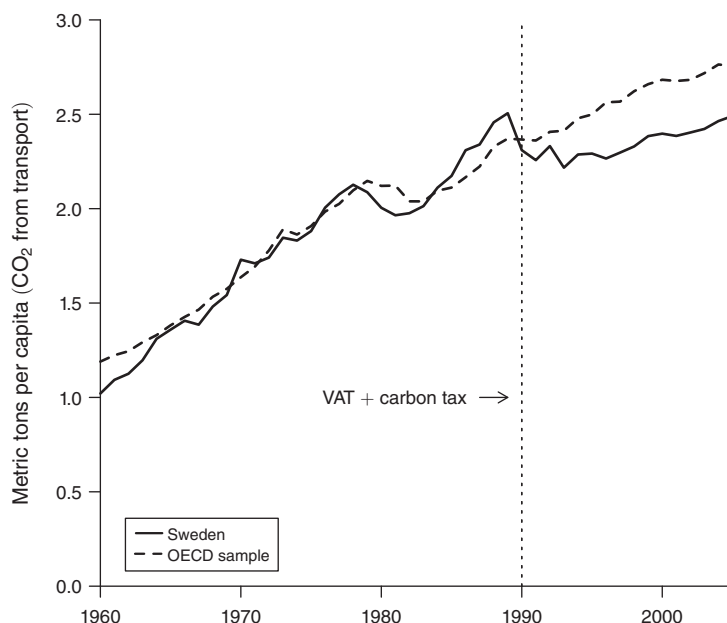
FIGURE 3. PATH PLOT OF PER CAPITA CO_2 EMISSIONS FROM TRANSPORT DURING 1960–2005:
SWEDEN VERSUS THE OECD AVERAGE OF MY 14 DONOR COUNTRIES

2015). In this paper, however, *V* and the vector of country weights *W* are jointly chosen so that they minimize the mean squared prediction error (MSPE) of the outcome variable over the entire pretreatment period.[12]

With a large number of pre-intervention periods, an accurate prediction of the outcome variable during these years makes it more plausible that unobserved and time-varying confounders affect the treated unit and the synthetic counterpart in a similar way (Kreif et al. 2016). The intuition is that synthetic Sweden is only able to reproduce the level and trend of CO_2 emissions from the transport sector in Sweden for the 30 years before treatment, if it is true that the two units are similar when it comes to observed as well as unobserved predictors and the effects of these predictors on emissions.

III. Results

Figure 3 shows the trajectory of emissions from transport in Sweden and the average of the 14 OECD countries during the sample period.[13] Overall, before 1990, emissions seem to follow a similar trend, but the fit is poor in the 1980s. A statistical analysis shows that on average, from 1960–1989, emissions in Sweden

---

[12] To find *V* and *W*, I use a statistical package for R called Synth (Abadie, Diamond, and Hainmueller 2011).

[13] The slump in emissions in Sweden and the OECD countries in the years following 1979 is a response to what is commonly called the "second oil crisis," prompted by the Iranian Revolution in 1979. It wasn't until around 1986 that the price of oil was back down at pre-1979 levels. This increase in the oil price hence acts as a "natural experiment" that shows that increased prices of fuel leads to reductions in CO_2 emissions from transport.
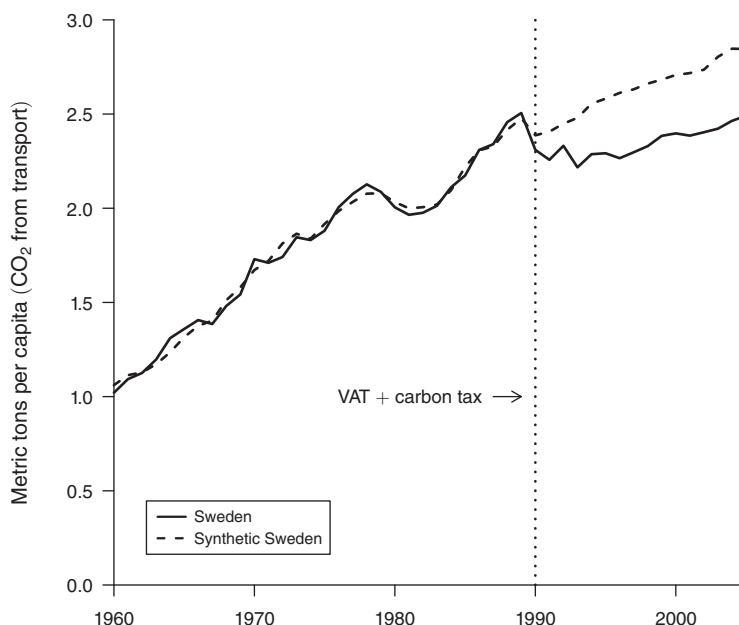
Figure 4. Path Plot of Per Capita CO_2 Emissions from Transport during 1960–2005:
Sweden versus Synthetic Sweden

and the OECD average grew at a similar pace. Between 1980–1989, however, emissions in Sweden grew twice as fast, a difference in trend that is statistically significant. This result indicates that the common trends assumption underlying the differences-in-differences estimator is violated and that the result if we used a DiD framework would be biased.[14] So, let's turn to the synthetic control method and see if it produces more promising results.

A. *Sweden versus Synthetic Sweden*

If synthetic Sweden is able to track CO_2 emissions from transport in Sweden in the pretreatment period and reproduce the values of the key predictors, it lends credibility to our identification assumption that the synthetic control unit provides the path of emissions from 1990–2005 in the absence of taxes.

Figure 4 shows that, prior to treatment, emissions from transport in Sweden and its synthetic counterpart track each other closely—an average (absolute) difference of only around 0.03 metric tons of CO_2. Hence, the synthetic control doesn't underestimate the treatment effect in the way that the DiD estimator does by failing to capture the trend in the last ten years before treatment. Furthermore, Table 1 compares the values of the key predictors for Sweden prior to 1990 with the same values for synthetic Sweden and a population-weighted average of the 14 OECD

---

[14] See the online Appendix for the result from a DiD estimate of the treatment effect.

TABLE 1—CO_2 EMISSIONS FROM TRANSPORT PREDICTOR MEANS BEFORE TAX REFORM

Variables	Sweden	Synth. Sweden	OECD sample
GDP per capita	20,121.5	20,121.2	21,277.8
Motor vehicles (per 1,000 people)	405.6	406.2	517.5
Gasoline consumption per capita	456.2	406.8	678.9
Urban population	83.1	83.1	74.1
CO_2 from transport per capita 1989	2.5	2.5	3.5
CO_2 from transport per capita 1980	2.0	2.0	3.2
CO_2 from transport per capita 1970	1.7	1.7	2.8

Notes: All variables except lagged CO_2 are averaged for the period 1980–1989. GDP per capita is purchasing power parity (PPP)—adjusted and measured in 2005 US dollars. Gasoline consumption is measured in kilograms of oil equivalent. Urban population is measured as percentage of total population. CO_2 emissions are measured in metric tons. The last column reports the population-weighted averages of the 14 OECD countries in the donor pool.

TABLE 2—COUNTRY WEIGHTS IN SYNTHETIC SWEDEN

Country	Weight	Country	Weight
Australia	0.001	Japan	0
Belgium	0.195	New Zealand	0.177
Canada	0	Poland	0.001
Denmark	0.384	Portugal	0
France	0	Spain	0
Greece	0.090	Switzerland	0.061
Iceland	0.001	United States	0.088

Note: With the synthetic control method, extrapolation is not allowed so all weights are between $0 \leq w_j \leq 1$ and $\sum w_j = 1$.

countries in the donor pool. For all predictors, except gasoline consumption per capita, Sweden and its synthetic version have almost identical values and a much better fit compared with the OECD average. It is especially encouraging to see the good fit on GDP per capita.

The predictors are weighted (the *V* matrix) as follows: GDP per capita (0.219); motor vehicles (0.078); gasoline consumption (0.010); urban population (0.213); and, CO_2 emissions from transport in 1989 (0.183), 1980 (0.284), and 1970 (0.013).[15] The small weight assigned to gasoline consumption per capita may explain the poor fit between Sweden and its synthetic version on this variable.

Lastly, the *W* weights reported in Table 2 show that CO_2 emissions from transport in Sweden are best reproduced by a combination of Denmark, Belgium, New Zealand, Greece, the United States, and Switzerland (with weights decreasing in this order). The rest of the countries in the donor pool get either a weight of zero, or close to zero. The large weight given to Denmark (0.384) is reasonable considering that Sweden and Denmark are similar in many social and economic dimensions. Belgium and Sweden have had a similar level and growth rate of GDP per capita—a major predictor of CO_2 emissions—from 1960–2005, whereas New Zealand and

[15] I tried different combinations of lagged CO_2—e.g., (1989, 1981, 1969) and (1980–1989, 1970–1979, 1960–1969)—but none gave a better fit pretreatment or changed the *W* weights and estimated emission reductions substantially. Additionally, I switched to lags of GDP instead of CO_2, which again produced a similar result as the main analysis.
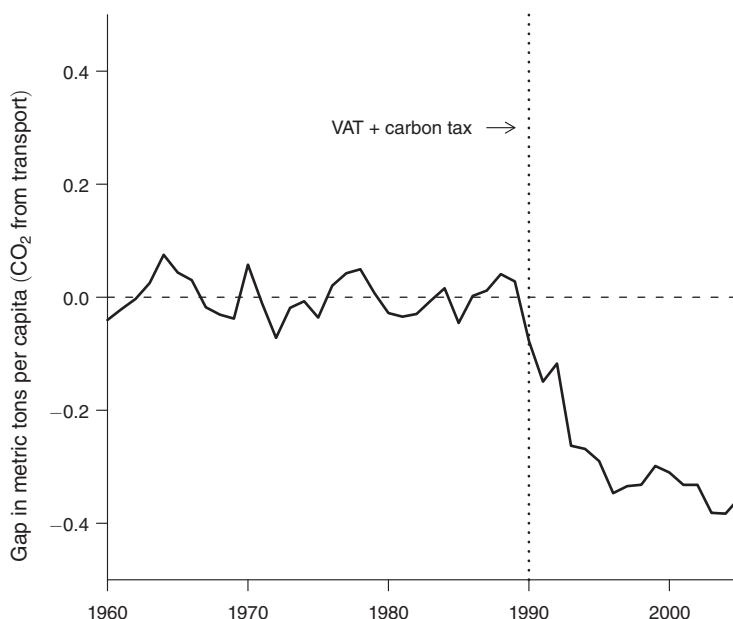
FIGURE 5. GAP IN PER CAPITA CO_2 EMISSIONS FROM TRANSPORT BETWEEN SWEDEN AND SYNTHETIC SWEDEN

Sweden have a comparable geography (low population density) and urbanization pattern (both level and trend is remarkably alike). Together, Denmark, Belgium, and New Zealand make up three-fourths of synthetic Sweden.

B. *Emission Reductions*

The posttreatment distance between Sweden and synthetic Sweden in Figure 4 measures the reduction in CO_2 emissions. This distance is further visualized in the gap plot of Figure 5. The introduction of the VAT and the gradual increase of the carbon tax create larger and larger reductions during the posttreatment period. In the last year of the sample period, 2005, emissions from transport in Sweden are 12.5 percent, or -0.35 metric tons per capita, lower than they would have been in the absence of treatment. The reduction in emissions for the 1990–2005 period is 10.9 percent, or -0.29 metric tons of CO_2 per capita in an average year. Aggregating over the total population gives an emission reduction of 3.2 million tons of CO_2 in 2005 and an average for the 1990–2005 period of 2.5 million tons of CO_2. The total cumulative reduction in emissions for the posttreatment period is 40.5 million tons of CO_2.

Because of the reduction of the energy tax rate in the years 2001–2005 (see Figure 1, panel A), the simultaneous increase of the carbon tax rate is almost canceled out during this period, leaving a nearly flat combined real tax rate. Consequently, we can be more confident in stating that the emission reductions from 1990–2000 is due to the introduction of the carbon tax and VAT alone, whereas for 2001–2005 the reductions is due to changes in all three tax components—assuming that a similar
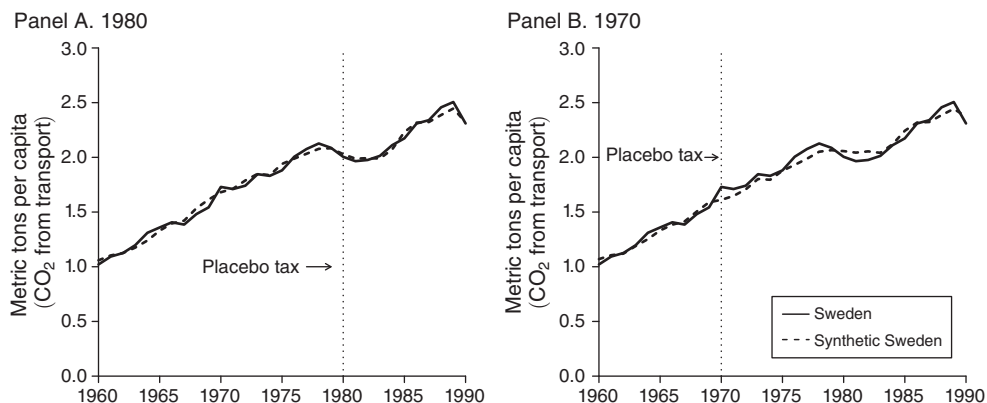
FIGURE 6. PLACEBO IN-TIME TESTS

Notes: In panel A, the placebo tax is introduced in 1980, ten years prior to the actual policy changes. In panel B, the placebo tax is introduced in 1970.

reduction in the energy tax rate did not take place in the countries that make up synthetic Sweden. In 2000, the last year before the energy tax was lowered, emissions from transport were reduced by 11.5 percent, or -0.31 metric tons per capita.

C. *Placebo Tests*

To further test the validity of the results, I performed a series of placebo tests: "in-time," "in-space," "leave-one-out," and "full sample." For the in-time tests, the year of treatment is shifted to 1970 and 1980, years that are both prior to the actual environmental tax reform. For the two tests, the choice of synthetic control is based only on data from 1960–1969 and 1960–1979, respectively. We want to find that this placebo treatment doesn't result in a post-placebo-treatment divergence in the trajectory of emissions between Sweden and its synthetic control. A large placebo effect casts doubt on the claim that the result illustrated in Figures 4 and 5 is the actual causal effect of the carbon tax and the VAT. Encouragingly, Figure 6 shows that no such divergence is found.

For the in-space placebo test, the treatment is iteratively reassigned to every country in the donor pool, again using the synthetic control method to construct synthetic counterparts. This gives us a method to establish if the result obtained for Sweden is unusually large, by comparing that result with the placebo results for all the countries in the donor pool. This form of permutation test allows for inference and the calculation of *p*-values: measuring the fraction of countries with results larger than or as large as the one obtained for the treated unit (Abadie, Diamond, and Hainmueller 2015, 6).

Figure 7 shows the results of the in-space placebo test. Panel A indicates that for some countries in the donor pool, the synthetic control method is unable to find a convex combination of countries that will replicate the path of emissions in the pretreatment period. This is especially true for the United States, Poland, and
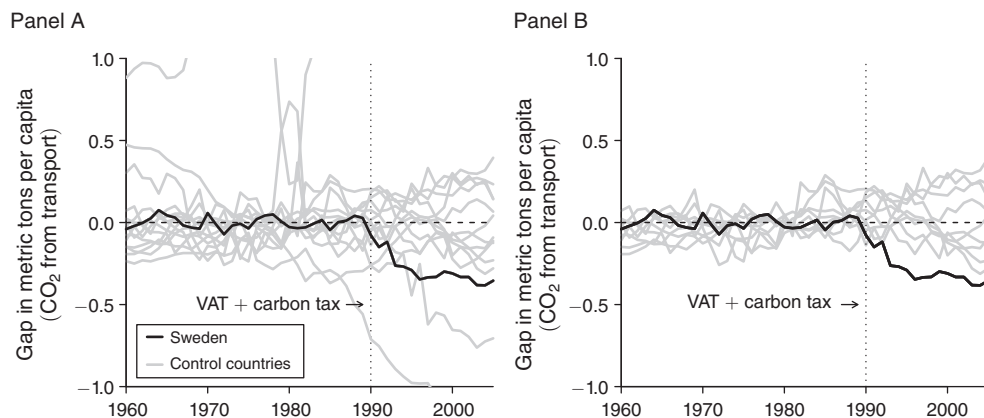
Panel A

Panel B

FIGURE 7. PERMUTATION TEST: PER CAPITA CO_2 EMISSIONS GAP IN SWEDEN
AND PLACEBO GAPS FOR THE CONTROL COUNTRIES

Notes: Panel A shows per capita CO_2 emissions gap in Sweden and placebo gaps in all 14 OECD control countries. Panel B shows per capita gap in Sweden and placebo gaps in nine OECD control countries (countries with a pretreatment MSPE 20 times higher than Sweden's are excluded).

Portugal, which is not surprising since the United States has the largest CO_2 emissions during all the pretreatment years and Poland and Portugal have the lowest. Therefore, in panel B, all the countries with a pretreatment MSPE (mean squared prediction error) at least 20 times larger than Sweden's pretreatment MSPE are excluded, which leaves 9 countries in the donor pool. Now the gap in emissions for Sweden in the posttreatment period is the largest of all remaining countries. The *p*-value of estimating a gap of this magnitude is thus $1/10 = 0.10$.

Even so, the choice of a particular cutoff threshold for the MSPE value when doing permutation testing is arbitrary. A better inferential method is to look at the ratio of posttreatment MSPE to pretreatment MSPE (Abadie et al. 2010), with the assumption that a large ratio is indicative of a true causal effect from treatment. With the ratio test we do not have to discard countries based on an arbitrarily chosen cutoff rule, and thus the ratio test is advantageous when you have a small number of control units.

Figure 8 shows that Sweden by far has the largest ratio of all the countries in the sample. If one was to assign the treatment at random, the probability of finding a ratio this large is $1/15 = 0.067$, the smallest possible *p*-value with my sample size.

For the leave-one-out test (Abadie, Diamond, and Hainmueller 2015), I iteratively eliminate one of the six control countries that got a *W* weight larger than 0.001 (0.1 percent) to check if the results are driven by one or a few influential controls. As we see from Figure 9, the main results are robust to the elimination of one donor pool country at a time. We get slightly larger reductions when we eliminate Denmark, slightly smaller reductions when we eliminate Switzerland or the United States, and basically unchanged results for the others. This test thus provides us with a range for the estimated emission reduction, from an average posttreatment reduction of 13.0 percent (when eliminating Denmark) to the most conservative estimate of an 8.8 percent reduction (omitting Switzerland). The average of the six iterations
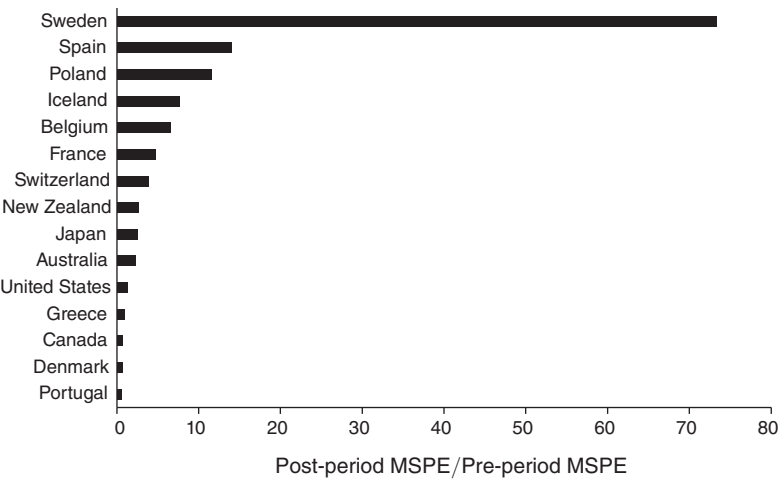
FIGURE 8. RATIO TEST: RATIOS OF POSTTREATMENT MSPE TO PRETREATMENT MSPE:
SWEDEN AND 14 OECD CONTROL COUNTRIES
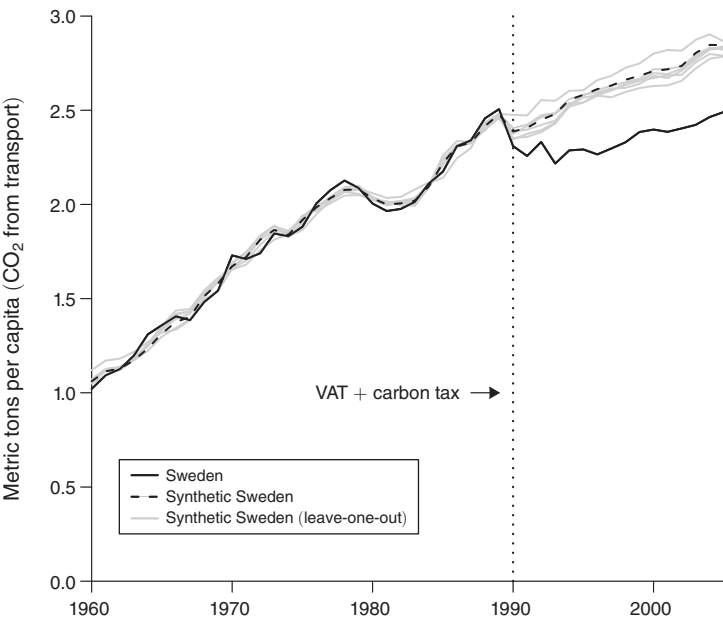
FIGURE 9. LEAVE-ONE-OUT: DISTRIBUTION OF THE SYNTHETIC CONTROL FOR SWEDEN

gives an emission reduction of 10.4 percent. Note also that the conservative estimate is still larger than the DiD estimate of an 8.1 percent reduction.

For the last robustness check, I include the full sample of 24 OECD countries when constructing the counterfactual. If we use the entire donor pool and rerun the estimation, the results are nearly unchanged: predictor means, gap plot, and path plot look similar to the main results, albeit with slightly larger emissions reductions in 2004 and 2005 (see Figure 10). The only previously excluded country that now gets a significant weight is the United Kingdom, with a weight of 0.128. The synthetic

FIGURE 10. PATH AND GAP PLOT OF PER CAPITA CO_2 EMISSIONS FROM TRANSPORT:
MAIN RESULTS VERSUS FULL SAMPLE

Notes: The main results use the restricted sample of 14 OECD countries to construct synthetic Sweden. The full sample results use all 24 OECD countries in the donor pool to construct synthetic Sweden.
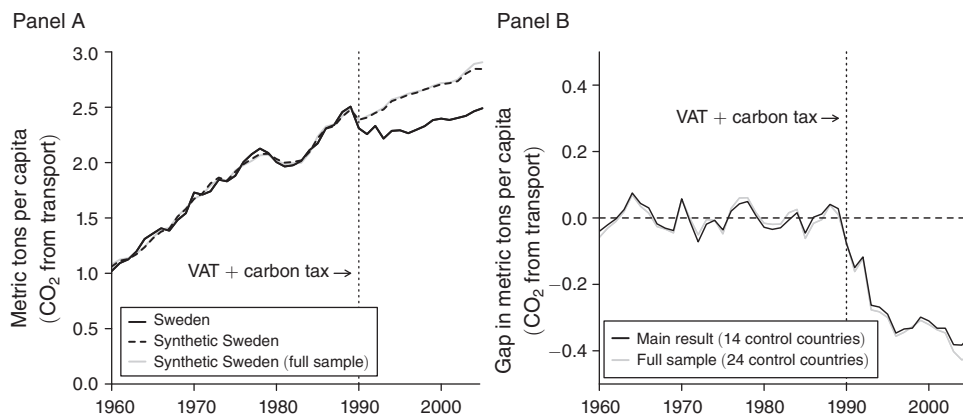
control is otherwise composed of Denmark, Belgium, New Zealand, and the United States, with three-fourths of the total weight still given to the first three countries. The two countries that drop out are Greece and Switzerland, which previously got a weight of 0.09 and 0.06 respectively.

My main criterion for dropping countries from the sample is large changes to fuel taxes during the sample period. Figure 4 shows that emissions in Sweden and its synthetic counterpart track each other closely for the 30 years before the carbon tax reform. This provides suggestive evidence that non-price policies haven't had a significant effect on CO_2 emissions from the Swedish transport sector, as otherwise we expect the two series to diverge at some point from 1960–1990. Non-price policies can in this context be viewed as unobserved confounders, and an advantage of the synthetic control method is that it relaxes the parallel trends assumption by allowing the effects of unobserved confounders on the outcome variable to vary over time. In any case, the leave-one-out and full sample tests show that the main results are neither driven by any one country alone nor that the exclusion of countries from the donor pool impacts the estimated emission reductions.

D. *Possible Confounder*

A common argument against carbon taxation is that it will hurt economic growth. We also find in the literature clear evidence of a link between GDP growth and growth in CO_2 emissions. Could it thus be that the introduction of the carbon tax reduced the level of GDP in Sweden posttreatment, and that this is the actual driver behind the emission reductions? Or, alternatively, is the exogenous shock of the domestic financial and economic crisis in the early 1990s driving the results?

Figure 11 shows that GDP per capita in Sweden and its synthetic counterpart track each other quite well during the 30 years before and 16 years after treatment. Yes, there is a reduction in real GDP per capita from 1990–1993, which is
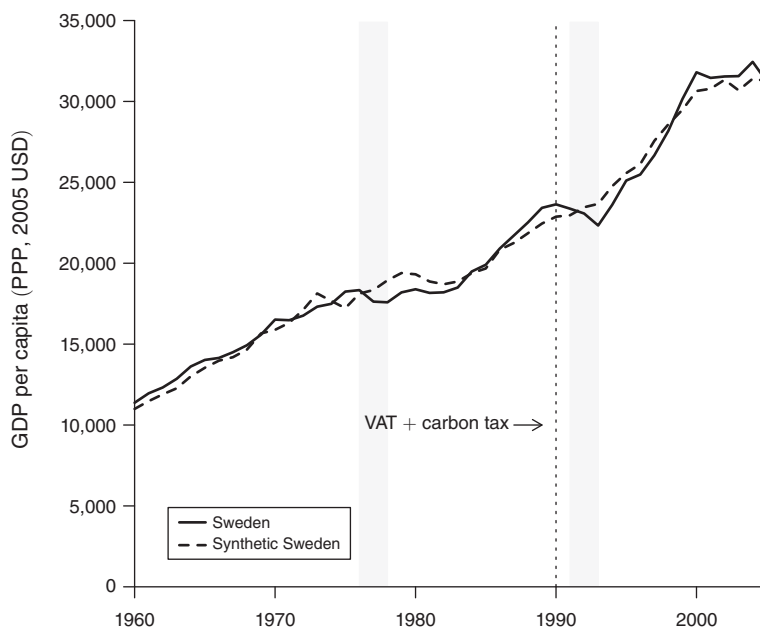
FIGURE 11. GDP PER CAPITA: SWEDEN VERSUS SYNTHETIC SWEDEN

Note: The shaded areas highlight the two major recessions in Sweden during the sample period.

not matched by a similar reduction in synthetic Sweden, but already by 1995 the two series are closely aligned again. If the recession drove the reduction in emissions, we would expect to see a "bounce back" in emissions once economic growth started to catch up again, and this we do not see.

The correlation between gaps in GDP per capita and gaps in CO$_2$ emissions from transport, between Sweden and its synthetic counterpart, is further illustrated in Figure 12. This figure allows us to compare and contrast the impact on emissions from the two major recessions in Sweden during the sample period; the first one in 1976–1978 and the second in 1991–1993. From the gap plot we see that the drop in relative GDP from 1975–1978 and from 1989–1993 are similar in magnitude: a decrease of around \$2,300 per capita. The impacts on emissions are, however, very different: from 1975–1978, CO$_2$ emissions from transport actually increased with +0.086 tons per capita in Sweden compared to synthetic Sweden, whereas from 1989–1993 they decreased with −0.291 tons. Furthermore, in both cases, the catch-up in growth following the recessions was not met with an increase in relative transport emissions. This comparison of the different effects of the two major recessions provides further evidence that the recession in the early 1990s is not the driver of emission reductions in the posttreatment period.

In conclusion, there is no indication that the domestic recession in 1991–1993 is driving emissions posttreatment and no observable (long-term) negative effect on GDP from the environmental tax reform.[16] Average GDP per capita in Sweden

---

[16] The online Appendix contains a detailed analysis of the unemployment rate as another possible major confounder. To summarize the analysis, I first show that GDP is more accurate than the unemployment rate in predicting
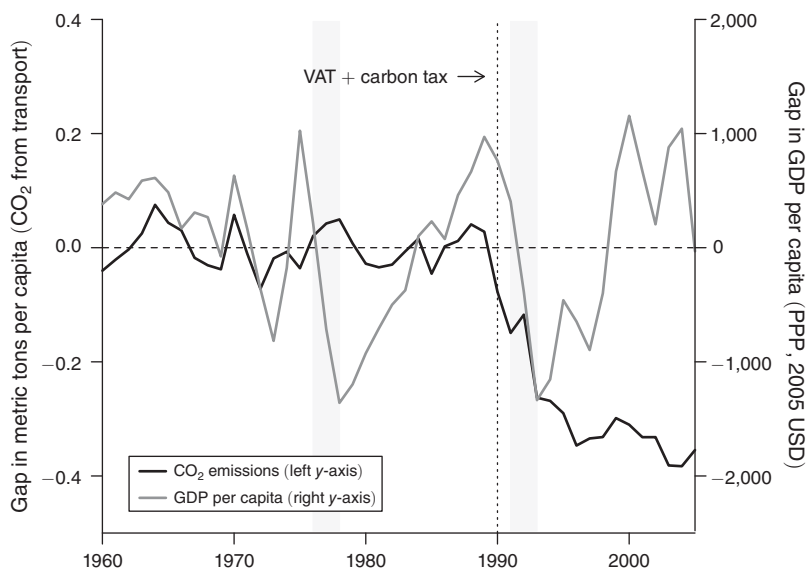
FIGURE 12. GAP IN GDP PER CAPITA AND CO_2 EMISSIONS PER CAPITA
FROM TRANSPORT BETWEEN SWEDEN AND SYNTHETIC SWEDEN

Notes: The variables are computed as the gap between Sweden and synthetic Sweden. Real GDP per capita is purchasing power parity (PPP)—adjusted and measured in 2005 US dollars. CO_2 emissions are measured in metric tons. The shaded areas highlight the two major recessions during the sample period.

during the posttreatment period of 1990–2005 is 0.1 percent higher than GDP in synthetic Sweden. Figure 11, together with the gap plot in Figure 5, signals that, since the introduction of the carbon tax, the long-run (positive) correlation between GDP growth and emissions in the transport sector has weakened considerably. There is tentative evidence that this holds for the economy as a whole: during 1990–2013, total greenhouse gas emissions fell by 23 percent in Sweden while real GDP increased by 61 percent (Hammar and Åkerfeldt 2015).

IV. Disentangling the Carbon Tax and VAT

The effect I find on transport emissions from the Swedish carbon tax and the VAT is larger than earlier empirical analyses of carbon taxes suggest and larger than a simulation analysis found that looked specifically at the effect on Swedish transport emissions (Ministry of the Environment and Energy 2009). Possible explanations for this result are that the carbon tax induces a larger behavioral response than we

---

long-run levels of emissions from transport. Furthermore, prior to the environmental tax reform in the early 1990s, large changes to the relative unemployment rate had no discernible impact on CO_2 emissions from transport. After the tax reform, the connection goes both ways: the large increase in unemployment from 1991 to 1993 is accompanied by a reduction in emissions, but the large *decrease* in unemployment from 1997 to 2001–2003 is also accompanied by a reduction in emissions. Lastly, using descriptive evidence and a regression model, I show that the variable that coherently explains all changes in emissions, both before and after the tax reform, is changes to the real fuel tax rate.

assume from just looking at price elasticities of demand, or that the VAT accounts for the largest part of the total emission reductions. To examine this result further, we turn now to the paper's second (but complementary) empirical analysis: the disentangling of the carbon tax and VAT effect, by comparing the behavioral response from changes to the carbon tax rate and equivalent gas price changes. I analyze this issue by using annual time-series data of the consumption and real price of gasoline in Sweden from 1970–2011. I decompose the retail price of gasoline into its carbon tax-exclusive price component, $p_t^v = (p_t + \tau_{t,energy})VAT_t$, and the carbon tax, $\tau_{t,CO_2}^v = (\tau_{t,CO_2})VAT_t$. Since the VAT is constant, and a multiplier, it is perfectly correlated with all price components. The VAT is hence added to each respective price component and not treated separately. I set up the following log-linear (static) model:

$$(3) \qquad \ln(x_t) = \alpha + \beta_1 p_t^v + \beta_2 \tau_{t,CO_2}^v + \beta_3 D_{t,CO_2} + X_t \gamma + \epsilon_t,$$

where x_t is gasoline consumption per capita; D_{t,CO_2} is a dummy that takes the value of 1 for years from 1991 and onward and zero otherwise; X_t is a vector of control variables GDP per capita, urbanization, the unemployment rate, and a time trend; and finally, ϵ_t is idiosyncratic shocks.

The results from the OLS regression of our log-linear model, columns 1–4 in Table 3, show that the carbon tax elasticity is around 3.1–4.5 times larger than the corresponding price elasticity, a difference that is statistically significant in all cases. With a log-linear function, the estimated coefficients are typically referred to as semi-elasticities. Thus, using the results in column 4, we see that a one unit change to the carbon tax or the tax-exclusive price is associated with a change in gasoline consumption of 18.6 and 6 percent, respectively.

There is a risk, however, that the results are biased because of omitted variables, anticipatory effects, or the endogeneity of gasoline prices: that gasoline consumption affects the gasoline price and not just the other way around. Endogeneity is arguably a lesser risk for a small country such as Sweden, compared with larger oil consumers such as the United States, since crude oil prices are set in a global market and changes in demand in Sweden will thus have a negligible impact on the world price. The issue still needs to be addressed, though, since domestic producers (at the retail and refinery level) may adjust their margin, and hence affect the pump price, as a response to local changes in demand. In columns 5 and 6 of Table 3, the carbon tax-exclusive gasoline price is instrumented using the energy tax rate and the (brent) crude oil price. The energy tax rate makes up a large part of the carbon tax-exclusive price and thus satisfies the instrument-relevance condition. At the same time, changes to the energy tax level occur with a considerable lag and are often driven by exogenous changes to environmental policies, and thus also satisfy the instrument exogeneity condition. Taken together, the energy tax rate is arguably a valid instrument.

Comparing the estimated coefficients in column 4 with 5 and 6, we see that they are almost identical; thus, endogeneity of gasoline prices is likely not a problem in our model. Running the Durbin-Wu-Hausman test also indicates that the carbon tax-exclusive gasoline price is indeed exogenous to gasoline consumption. Additionally, the Stock and Yogo (2005) test for weak instruments indicate that the

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 (0.024)	−0.0598 (0.021)	−0.0612 (0.016)	−0.0603 (0.012)	−0.0620 (0.020)	−0.0641 (0.014)
Carbon tax with VAT	−0.260 (0.042)	−0.232 (0.049)	−0.234 (0.053)	−0.186 (0.043)	−0.186 (0.038)	−0.186 (0.038)
Dummy carbon tax	0.109 (0.040)	0.0604 (0.061)	0.0633 (0.061)	0.0999 (0.066)	0.0977 (0.070)	0.0949 (0.059)
Trend	0.0207 (0.003)	0.0253 (0.004)	0.0244 (0.004)	0.0341 (0.003)	0.0342 (0.003)	0.0344 (0.003)
GDP per capita		−0.00108 (0.001)	−0.00105 (0.001)	−0.00366 (0.001)	−0.00367 (0.001)	−0.00368 (0.001)
Urban population			0.0127 (0.075)	0.0301 (0.067)	0.0313 (0.064)	0.0329 (0.058)
Unemployment rate				−0.0242 (0.006)	−0.0242 (0.005)	−0.0242 (0.005)
Constant	6.228 (0.167)	6.407 (0.142)	5.372 (6.202)	4.407 (5.446)	4.313 (5.152)	4.198 (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

Notes: The dependent variable is the log of gasoline consumption per capita. The real carbon tax-exclusive price of gasoline and the real carbon tax are measured in 2005 Swedish kronor. GDP per capita is measured in 2005 Swedish kronor (thousands). Urban population is measured as percentage of total population. Unemployment is measured as percentage of total labor force. Columns 5 and 6 use the real energy tax and the brent crude oil price as instrumental variables for the carbon tax-exclusive gasoline price. Newey-West standard errors are in parentheses; heteroscedasticity and autocorrelation robust. Standard errors are calculated using 16 lags, chosen with the Newey-West (1994) method.

Source: Data on GDP per capita and unemployment was obtained from Statistics Sweden (2015).

energy tax is a weak instrument, but not the crude oil price. If we still believe that the carbon tax-exclusive price is endogenous, we should use the results from column 6 that have the crude oil price as an instrument.

Anticipatory behavior—consumers increasing their purchases of transport fuel before tax increases—may also bias the estimated price and carbon tax coefficients (Coglianese et al. 2017). I included leads and lags in the regression to test for this, however, and found no indication of a potential anticipatory effect; the estimated price and carbon tax elasticities were very similar to the main regression result. Likely, anticipatory behavior is a larger issue when dealing with monthly instead of yearly data.

The earlier analysis of tax incidence in Section I indicated that tax changes are fully passed through to consumers, and we can thus view the estimated elasticities as demand elasticities. The results in column 4 of Table 3 give a price elasticity[17] of demand of −0.51 and a carbon tax elasticity of demand of −1.57, a ratio in the

---

[17] Elasticity of demand is given by $\varepsilon = (dY/dX)(X/Y)$, and our model is log linear: $\log(Y) = a + bX$, and thus the elasticity is $\varepsilon = be^{a+bX}(X/Y) = bY(X/Y) = bX$. Here, X is the real price of gasoline at its sample

demand response of just over 3. The model specification I use is a static model; no lags are included. Each observation of the outcome variable is hence modeled as depending only on contemporaneous values of the explanatory variables. Elasticity estimates using yearly data and a static model often fall in-between the short- and long-run elasticities found when using lagged models (Dahl and Sterner 1991) and are therefore viewed as "intermediate." Dahl and Sterner (1991)[18] reports an average intermediate price elasticity of demand for gasoline among OECD countries of -0.53, so my estimate of -0.51 is in line with the previous literature.

Now, using the estimated tax and price semi-elasticities from column 4, we can disentangle the effect of the carbon tax on emissions from the effect of the VAT, applying a simulation approach: the difference between a scenario where no VAT and no carbon tax is introduced and a scenario where either VAT or VAT and the carbon tax is added to the price of gasoline. Since the energy tax is included in all simulated scenarios, the effect of movements in the rate cancels itself out, thereby keeping it constant.

The distance between the top (dashed) line and the middle (dot-dashed) line in Figure 13 measures the emission reductions attributable to the VAT. Similarly, the distance between the middle line and the bottom (solid) line measures the emission reductions attributable to the carbon tax. Up until the year 2000, the carbon tax and the VAT are separately responsible for around half of the reduction in each year. In 2000, the carbon tax contributes to a 5.5 percent, or -0.15 metric tons per capita, reduction in Swedish transport emissions. Between 2000–2005, the carbon tax is increased, and consequently a larger and larger share of the emission reduction each year is attributed to it. In 2005, around three-fourths of the total emission reduction is due to the carbon tax, a 9.4 percent, or -0.27 metric tons per capita, reduction in transport emissions.[19]

In an average year during 1990–2000, the carbon tax contributed to emission reductions of 4.8 percent, or -0.13 metric tons per capita. If we look at the entire posttreatment period of 1990–2005, the carbon tax resulted in emission reductions of 6.3 percent, or -0.17 metric tons per capita in an average year.

Now, comparing directly the emission reductions we find using the simulation approach (Figure 13) with the earlier results from our empirical analysis (Figure 5), we will get an estimate of the effect on emissions from the increase in the carbon tax rate in the years 2001–2005, had the energy tax rate not been simultaneously decreased. The two estimates in Figure 14 track each other quite closely from 1990–2000, before diverging in the subsequent years. In 2005, the estimated emission reduction is more than twice as large when using simulation compared with the results using the synthetic control method: -0.757 to -0.355. The big difference in 2005 is due to the real carbon tax rate increasing by almost 130 percent from

---

mean: 8.48 SEK. The price elasticity of demand is hence given by $-0.0603 \times 8.48 = -0.51$ and the carbon tax elasticity: $-0.186 \times 8.48 = -1.57$.

[18] The Dahl and Sterner (1991) paper takes the average from 22 studies—that all use yearly time-series data—of the intermediate price elasticity of demand for gasoline across different OECD countries. Seventeen out of the 22 estimates are for European countries, most commonly France and Germany, but studies for Sweden are also included.

[19] Here, I am still using the total estimated emission reductions that we found using the synthetic control method. In 2005, three-fourths of the total emission reduction is attributable to the carbon tax, which gives an emission reduction of $0.75 \times (-0.35) = -0.27$ metric tons due to the carbon tax.
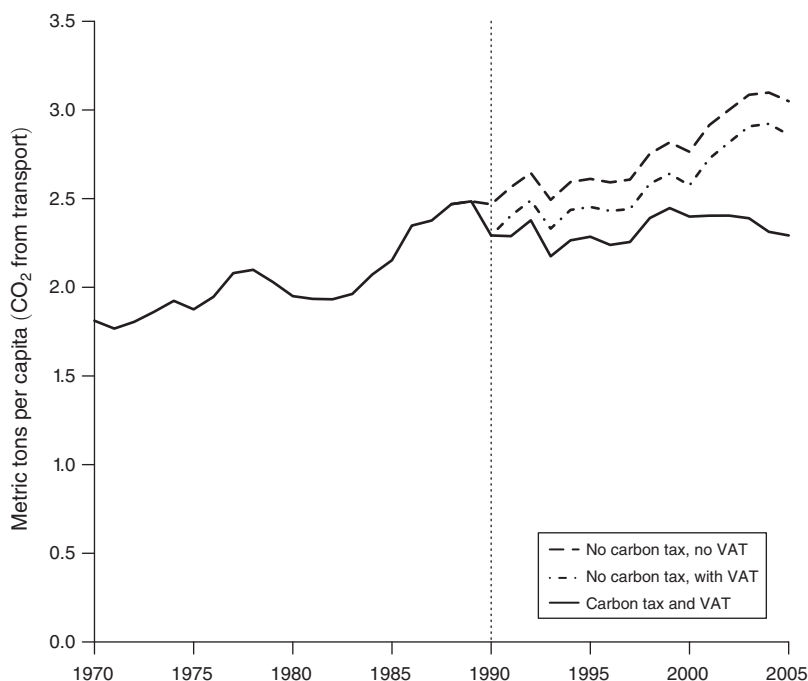
FIGURE 13. DISENTANGLING THE CARBON TAX AND VAT

Notes: The top (dashed) line shows predicted emissions when the carbon tax elasticity is set to zero, and the VAT is deducted from the gasoline price. For the middle line, the carbon tax elasticity is set to zero, but VAT is now included. The bottom (solid) line gives predicted emissions using the full model with the differentiated tax and price elasticities. The *x*-axis starts at 1970 instead of 1960 as earlier. This is due to missing price data for some years prior to 1970.

2000–2005. The synthetic control method thus gives us an estimate of the actual emission reductions attributable to the introduction of VAT and the carbon tax in 1990–1991 and the subsequent changes in the carbon and energy tax rates between 1991–2005. The simulation exercise further tells us what the possible emission reductions from the carbon tax had been if policymakers in Sweden kept the (real) energy tax level constant between 2000–2005.

V. Discussion

My results can be compared with previous analyses of the Swedish carbon tax.

In Bohlin (1998), the author concludes that during 1990–1995 the carbon tax had no effect on emissions from the transport sector. I instead find an average emission reduction of 3.6 percent during 1990–1995 attributed to the carbon tax with a reduction in 1995 alone of 5.8 percent. Bohlin (1998, 283) states that he doesn't use a modeling approach and instead relies on ex post data, but other than "using criteria developed by OECD in 1997" we are not given any detail on the methodology used to, for instance, derive the counterfactual emission levels. It is thus hard to determine why our estimates differ.
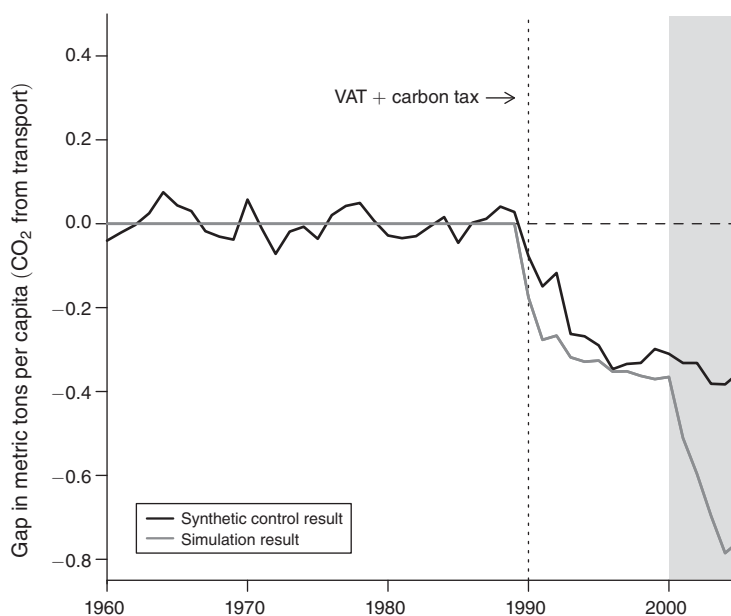
FIGURE 14. GAP IN PER CAPITA CO$_2$ EMISSIONS FROM TRANSPORT: SYNTHETIC CONTROL VERSUS SIMULATION

Notes: The shaded area highlights the period between 2000–2005 when the carbon tax rate was more than doubled (first tax increase in 2001).

Lin and Li (2011) adopts a DiD framework to estimate reductions in emission growth rates due to carbon taxation in Sweden, Denmark, Finland, Norway, and the Netherlands. They find a significant effect for Finland only, a 1.7 percent reduction in the growth rate of CO$_2$ per capita. There are, however, countries in their control group that are less than ideal when creating the counterfactual emissions, such as Austria, Luxembourg, and Ireland.[20] Furthermore, they use total CO$_2$ emissions as their outcome variable and hence combine "treated" and "untreated" sectors of the economies in their research design; all countries with carbon taxes have some sectors that are exempted.[21] This approach violates one of the assumptions underlying causal inference and therefore does not provide a true estimate of the environmental efficiency of carbon taxes.[22] Lastly, some of their included covariates, such as urbanization level, industry structure, and energy prices, are likely themselves affected by the carbon tax and thus also outcome variables. Including them on the right-hand side of their regression will thus bias the results.

Lastly, Sweden's fifth national report on climate change (Ministry of the Environment and Energy 2009) estimates that the reduction of CO$_2$ emissions from the transport sector in 2005 is 1.7 million metric tons compared with if Sweden had kept taxes at the 1990 level—an important assumption since the tax level then

---

[20] See Section IIA to why this is.

[21] Bruvoll and Larsen (2004), which analyzes the effects of the Norwegian carbon tax, similarly combines treated and untreated sectors.

[22] Two underlying assumptions in analyses of causal effects are no interference between units, and all treated units receive the same dose of the treatment.

already includes VAT. The emission reduction is simulated by estimating changes in gasoline consumption, using price elasticities of demand. Their estimate is markedly lower than my empirical estimate, which shows a reduction in 2005 of 2.4 million metric tons of CO_2 from the carbon tax. Besides assuming that the real gasoline tax stays constant at the 1990 level when calculating their counterfactual, they apply a (long-run) price elasticity of demand for gasoline of -0.8 (Edwards 2003), based on an average from a number of European studies. That I find, using empirical ex post data, an estimate of the emission reduction in 2005 that is 40 percent larger and a carbon-tax elasticity of -1.57, around twice the size of the price elasticity they use, shows how simulation analyses may underestimate the effectiveness of carbon taxes.

In addition to the the empirical finding that the Swedish carbon tax has been envrionmentally efficient, this paper shows that Swedish consumers exhibit larger behavioral responses to changes to the carbon tax rate compared with equivalent changes to the carbon tax-exclusive gasoline price. This finding is similar to some earlier studies of carbon and gasoline taxes (Davis and Kilian 2011; Li, Linn, and Muehlegger 2014; Rivers and Schaufele 2015; and Antweiler and Gulati 2016). My study is the first, however, to analyze a European market, whereas earlier studies have focused on the United States and Canada, where gasoline taxes are significantly lower. In 2008, excise gasoline taxes in US cents per liter was 120 in Sweden but only 32 in Canada and 13 in the United States (IEA 2019). As a percentage of the overall gasoline price, excise taxes constitutes 61.6 percent in Sweden, but only 27.5 percent in Canada, and 14.6 percent in the United States. Consequently, the tax-inclusive gasoline price is much less volatile in Sweden than in the United States and Canada, since the stable and certain part, the excise taxes, make up a larger part of the whole. Because of large differences in consumer prices for gasoline, a, say, 10 cent increase in gasoline taxes will create larger price increases (in percentage terms) in the United States and Canada than in Sweden, and thus larger relative reductions in consumption—assuming tax elasticities are similar across the three countries. Therefore, one should be careful regarding the external validity of the estimated emission reductions found in this paper. A Swedish-sized carbon tax rate applied to low-tax level countries will most likely lead to larger emission reductions than what is found in this paper. Nevertheless, countries that are similar to Sweden will likely experience comparable emission reductions from the same level of carbon tax. What is important here, though, is the term "similar" countries. Important predictors of emissions, such as level of GDP, degree of urbanization, and prior level of fuel taxes, are variables to take into account when considering the external validity of the results.

In summary, earlier studies of the environmental efficiency of carbon taxes have had issues with constructing a credible counterfactual, either by including countries in the donor pool that are themselves treated or including countries that are too dissimilar when it comes to important predictors of CO_2 emissions; combining emissions from treated and untreated sectors of the economy in their outcome variable; the choice of control variables—including "bad controls"; using price elasticities of demand that underestimate the environmental efficiency of carbon taxes; and not capturing substitutions between different transport fuels or between different modes

of transport. The take-home message is thus to think hard about research design (as always) and how to find a suitable identification strategy. Using ex post empirical data on emissions and important predictors of it, together with the synthetic control method, allowed me to capture all possible substitutions made and to recognize those control units that were most suitable for this comparative case study, and ultimately identify the causal effect of the Swedish carbon tax on emissions.

VI. Conclusion

The Paris Agreement is rightly seen as an important step taken toward the common goal of addressing climate change. To reach the mitigation targets put forward by each country, it is important to rely on environmentally and economically efficient measures such as carbon pricing.

This paper shows empirically that a carbon tax can be successful in significantly reducing emissions of carbon dioxide. After implementation of a carbon tax and VAT on transport fuels in Sweden, CO_2 emissions from transport declined almost 11 percent in an average year, with 6 percent from the carbon tax alone. This result is in contrast to earlier empirical studies that find little to no effect on emissions from carbon taxes. The identification strategy adopted is to carefully construct a control unit that did not implement a carbon tax, or similar policies, but had a similar level and trajectory of CO_2 emissions before treatment. The control unit, synthetic Sweden, is able to accurately reproduce the values for Sweden on a number of key predictors of CO_2 emissions from the transport sector, and to closely track emissions during the 30 years prior to treatment. Also, the use of empirical data on the outcome variable allows us to capture substitutions made between transport fuels—most notably from gasoline to diesel—as well as substitutions between modes of transport. This is an improvement upon simulation studies that use changes in gasoline consumption as a proxy for total changes in CO_2 emissions from transport. The results obtained are furthermore robust to a series of placebo tests. Reassigning the treatment at random in the sample shows that the probability of obtaining a posttreatment result as large as that for Sweden is just 0.067.

Lastly, this paper finds that consumers respond more strongly to changes to the carbon tax rate than equivalent market-driven gasoline price changes. The estimated carbon tax elasticity of demand for gasoline is three times larger than the price elasticity. This finding has implications for climate change policies in that carbon taxes would be more effective in reducing greenhouse gas emissions and air pollution than previous simulation studies suggests. Future analyses of the economics of climate change thus ought to take into consideration the finding that consumers' response to carbon taxes may be larger than existing estimates of price elasticities of demand indicate.

REFERENCES

Abadie, Alberto, Alexis Diamond, and Jens Hainmueller. 2010. "Synthetic Control Methods for Comparative Case Studies: Estimating the Effect of California's Tobacco Control Program." *Journal of the American Statistical Association* 105: 493–505.

Abadie, Alberto, Alexis Diamond, and Jens Hainmueller. 2011. "Synth: An R Package for Synthetic Control Methods in Comparative Case Studies." *Journal of Statistical Software* 42 (13): 1–17.

Abadie, Alberto, Alexis Diamond, and Jens Hainmueller. 2015. "Comparative Politics and the Synthetic Control Method." *American Journal of Political Science* 59 (2): 495–510.

Abadie, Alberto, and Javier Gardeazabal. 2003. "The Economic Costs of Conflict: A Case Study of the Basque Country." *American Economic Review* 93 (1): 113–32.

Andersson, Julius J. 2019. "Carbon Taxes and CO_2 Emissions: Sweden as a Case Study: Dataset." *American Economic Journal: Economic Policy.* https://doi.org/10.1257/pol.20170144.

Antweiler, Werner, and Sumeet Gulati. 2016. "Frugal Cars or Frugal Drivers? How Carbon and Fuel Taxes Influence the Choice and Use of Cars." http://dx.doi.org/10.2139/ssrn.2778868.

Arrow, Kenneth, Dale Jorgensen, Paul Krugman, William Nordhaus, and Robert Solow. 1997. "The Economists' Statement on Climate Change." https://web.archive.org/web/20170909132801/http://rprogress.org/publications/1997/econstatement.htm.

Baranzini, Andrea, and Stefano Carattini. 2014. "Taxation of Emissions of Greenhouse Gases." In *Global Environmental Change*, edited by Bill Freedman, 543–60. New York: Springer.

Bohlin, Folke. 1998. "The Swedish Carbon Dioxide Tax: Effects on Biofuel Use and Carbon Dioxide Emissions." *Biomass and Bioenergy* 15 (4–5): 283–91.

Bruvoll, Annegrete, and Bodil Merethe Larsen. 2004. "Greenhouse Gas Emissions in Norway: Do Carbon Taxes Work?" *Energy Policy* 32 (4): 493–505.

Carattini, Stefano, Andrea Baranzini, Philippe Thalmann, Frédéric Varone, and Frank Vöhringer. 2016. "Green Taxes in a Post-Paris World: Are Millions of Nays Inevitable?" Centre for Climate Change Economics and Policy Working Paper 273.

Card, David. 1990. "The Impact of the Mariel Boatlift on the Miami Labor Market." *Industrial and Labor Relations Review* 43 (2): 245–57.

Carraro, Carlo, Ottmar Edenhofer, Christian Flachsland, Charles Kolstad, Robert Stavins, and Robert Stowe. 2015. "The IPCC at a Crossroads: Opportunities for Reform." *Science* 350 (6256): 34–35.

Chambers, Matthew, and Rolf Schmitt. 2015. *Fact Sheet: Diesel-Powered Passenger Cars and Light Trucks.* Washington, DC: US Department of Transportation.

Coglianese, John, Lucas W. Davis, Lutz Kilian, and James H. Stock. 2017. "Anticipation, Tax Avoidance, and the Price Elasticity of Gasoline Demand." *Journal of Applied Econometrics* 32 (1): 1–15.

Collier, Ute, and Ragnar E. Löfstedt. 1997. *Cases in Climate Change Policy: Political Reality in the European Union.* London: Earthscan Publications.

Dahl, Carol, and Thomas Sterner. 1991. "Analysing Gasoline Demand Elasticities: A Survey." *Energy Economics* 13 (3): 203–10.

Dargay, Joyce, Dermot Gately, and Martin Sommer. 2007. "Vehicle Ownership and Income Growth, Worldwide: 1960–2030." *Energy Journal* 28 (4): 143–70.

Davis, Lucas W., and Lutz Kilian. 2011. "Estimating the Effect of a Gasoline Tax on Carbon Emissions." *Journal of Applied Econometrics* 26 (7): 1187–1214.

Edwards, Henrik. 2003. "Utveckling av transportsektorns CO2-utsläpp 1990 till 2010 och åtgärder för CO2-reduktion." Underlagsrapport till SIKA Rapport 2003:2.

Eggleston, H.S., K. Miwa, N. Srivastastava, and K. Tanabe. 2008. *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Kanagawa: IPPC.

Elgie, Stewart, and Jessica McClay. 2013. "Policy Commentary/Commentaire BC's Carbon Tax Shift Is Working Well after Four Years (Attention Ottawa)." *Canadian Public Policy* 39 (S2): S1–10.

European Federation for Transport and Environment. 2011. *Fuelling Oil Demand: What Happened to Fuel Taxation in Europe?* Brussels: European Federation for Transport and Environment.

Eurostat. 2017. "Eurostat Statistical Databases." European Commission, Brussels. https://ec.europa.eu/eurostat/data/database.

Feenstra, Robert C., Robert Inklaar, and Marcel Timmer. 2013. "The Next Generation of the Penn World Table." NBER Working Paper 19255.

Hammar, Henrik, and Susanne Åkerfeldt. 2011. "CO_2 Taxation in Sweden—20 Years of Experience and Looking Ahead." https://www.globalutmaning.se/wp-content/uploads/sites/8/2011/10/Swedish_Carbon_Tax_Akerfedlt-Hammar.pdf.

Hammar, Henrik, and Susanne Åkerfeldt. 2015. "CO_2 Taxation in Sweden Experiences of the Past and Future Challenges." https://www.un.org/esa/ffd/wp-content/uploads/2016/12/13STM_Article_CO2-tax_AkerfeldtHammar.pdf.

Howard, Peter, and Derek Sylvan. 2015. *Expert Consensus on the Economics of Climate Change.* New York: New York University School of Law, Institute for Policy Integrity.

IEA. 2019. "International Energy Agency Energy Prices and Taxes, 1978–2009." http://doi.org/10.5257/iea/ept/2019q1.

IMF. 2016. "World Economic Outlook." IMF. https://www.imf.org/external/pubs/ft/weo/2016/02/weodata/download.aspx.

IMF. 2017. "International Monetary Fund Factsheet: Climate, Environment, and the IMF." Washington, DC: IMF.

Johansson, Bengt. 2000. "Economic Instruments in Practice 1: Carbon Tax in Sweden." Workshop on Innovation and the Environment. OECD. Paris, June 20–21, 2000.

Kossoy, Alexandre, Grzegorz Peszko, Klaus Oppermann, Nicolai Prytz, Alyssa Gilbert, Noemie Klein, Long Lam, and Lindee Wong. 2015. *Carbon Pricing Watch 2015*. Washington, DC: World Bank.

Kreif, Noémi, Richard Grieve, Dominik Hangartner, Alex James Turner, Silviya Nikolova, and Matt Sutton. 2016. "Examination of the Synthetic Control Method for Evaluating Health Policies with Multiple Treated Units." *Health Economics* 25 (12): 1514–28.

Li, Shanjun, Joshua Linn, and Erich Muehlegger. 2014. "Gasoline Taxes and Consumer Behavior." *American Economic Journal: Economic Policy* 6 (4): 302–42.

Lin, Boqiang, and Xuehui Li. 2011. "The Effect of Carbon Tax on Per Capita CO$_2$ Emissions." *Energy Policy* 39 (9): 5137–46.

Marion, Justin, and Erich Muehlegger. 2011. "Fuel Tax Incidence and Supply Conditions." *Journal of Public Economics* 95 (9–10): 1202–12.

Ministry of Finance. 2017. "Berakningskonventioner 2018." Ministry of Finance. https://www.regeringen.se/rapporter/2017/10/berakningskonventioner-2018/.

Ministry of the Environment and Energy. 2009. "Sveriges femte nationalrapport om klimatförändringar." Ministry of the Environment and Energy. https://data.riksdagen.se/fil/188008E0-1CCB-4CC6-8FEF-93BE6A2EFB4B.

Murray, Brian, and Nicholas Rivers. 2015. "British Columbia's Revenue-Neutral Carbon Tax: A Review of the Latest 'Grand Experiment' in Environmental Policy." *Energy Policy* 86: 674–83.

Neumayer, Eric. 2004. "National Carbon Dioxide Emissions: Geography Matters." *Area* 36 (1): 33–40.

Newey, Whitney K., and Kenneth D. West. 1994. "Automatic Lag Selection in Covariance Matrix Estimation." *Review of Economic Studies* 61 (4): 631–53.

Nordhaus, William D. 2008. *A Question of Balance: Weighing the Options on Global Warming Policies*. New Haven: Yale University Press.

Nordhaus, William. 2013. *The Climate Casino: Risk, Uncertainty, and Economics for a Warming World*. New Haven: Yale University Press.

Rivers, Nicholas, and Brandon Schaufele. 2015. "Salience of Carbon Taxes in the Gasoline Market." *Journal of Environmental Economics and Management* 74: 23–36.

SPBI. 2016. "Svenska Petroleum och Biodrivmedel Institutet: Data Set." SPBI. http://spbi.se/statistik/priser.

Speck, Stefan. 2008. "The Design of Carbon and Broad-Based Energy Taxes in European Countries." *Vermont Journal of Environmental Law* 10: 31–59.

Statistics Sweden. 2015. "Statistikdatabasen." SCB. http://www.statistikdatabasen.scb.se.

Sterner, Thomas. 2006. *Survey of Transport Fuel Demand Elasticities*. Stockholm: Naturvårdsverket.

Sterner, Thomas. 2015. "Beyond IPCC, Research for Paris 2015 and Beyond." *Environmental and Resource Economics* 62 (2): 207–15.

Stock, James H., and Motohiro Yogo. 2005. "Testing for Weak Instruments in Linear IV Regression." In *Identification and Inference for Econometric Models: Essays in Honor of Thomas Rothenberg*, edited by Donald W.K. Andrews and James H. Stock, 80–108. Cambridge, UK: Cambridge University Press.

Swedish Energy Agency. 2017. "Energiindikatorer 2017." Statens energimyndighet.

Swedish EPA. 1995. *Utvardering av koldioxidskatten: har utsläppen av koldioxid minskat?* Stockholm: Naturvårdsverket.

Swedish Government. 1989–1990. *Regeringens proposition 1989/90:111 om reformerad mervärdeskatt m.m.* Stockholm: Swedish Parliament.

Swedish Government. 1991–1992. "Regeringens Proposition 1991/92:150 med förslag om slutlig reglering av statsbudgeten för budgetåret 1992/93 m.m. (kompletteringsproposition)." State Documents, Sweden.

Swedish Tax Agency. 2018. "Historical Tax Rates on Fuels." Swedish Tax Agency. http://www.skatteverket.se.

World Bank. 2015. "World Bank Data: Indicators." World Bank. http://data.worldbank.org/indicator.

Weitzman, Martin L. 2015. "Internationally-Tradable Permits Can Be Riskier for a Country Than an Internally-Imposed Carbon Price." Harvard Project on Climate Agreements, Harvard University Discussion Paper 15-74.

Weitzman, Martin L. 2016. "How a Minimum Carbon Price Commitment Might Help to Internalize the Global Warming Externality." https://scholar.harvard.edu/files/weitzman/files/mit.2016.climate.symposium.pdf.

Withana, S., P. ten Brink, B. Kretschmer, L. Mazza, P. Hjerp, and R. Sauter. 2013. *Evaluation of Environmental Tax Reforms: International Experiences*. Brussels: Institute for European Environmental Policy.

This article has been cited by:

1. Michał Ptak, Jarosław Neneman, Sylwia Roszkowska. 2024. The impact of petrol and diesel oil taxes in EU member states on CO2 emissions from passenger cars. *Scientific Reports* **14**:1. . [Crossref]

2. Francesco Biancalani, Giorgio Gnecco, Rodolfo Metulini, Massimo Riccaboni. 2024. The impact of the European Union emissions trading system on carbon dioxide emissions: a matrix completion analysis. *Scientific Reports* **14**:1. . [Crossref]

3. Yuqiang Cao, Shaoyan Lin, Mangmang Li, Yaowen Shan, Peipei Wang. 2024. Green taxes: Productivity effects of tax-based environmental regulations on heavily polluting firms. *Economic Modelling* **140**, 106834. [Crossref]

4. Rossella Bardazzi, Maria Grazia Pazienza. 2024. Decarbonising transport: Can we rely on fuel taxes?. *Transportation Research Part D: Transport and Environment* **136**, 104391. [Crossref]

5. Griffin Msefula, Tony Chieh-Tse Hou, Tina Lemesi. 2024. Dynamics of legal structure and geopolitical influence on carbon tax in response to green transportation. *Applied Energy* **371**, 123682. [Crossref]

6. Martin C. Hänsel, Michael D. Bauer, Moritz A. Drupp, Gernot Wagner, Glenn D. Rudebusch. 2024. Climate policy curves highlight key mitigation choices. *Climate Policy* 1-7. [Crossref]

7. Paul D. Larson, Robert V. Parsons, Deepika Kalluri. 2024. Zero-Emission Heavy-Duty, Long-Haul Trucking: Obstacles and Opportunities for Logistics in North America. *Logistics* **8**:3, 64. [Crossref]

8. Giacomo Mangiante. 2024. The geographic effects of carbon pricing. *European Economic Review* **168**, 104825. [Crossref]

9. Claudia Kettner, Thomas Leoni, Judith Köberl, Dominik Kortschak, Mathias Kirchner, Mark Sommer, Laura Wallenko, Gabriel Bachner, Jakob Mayer, Nathalie Spittler, Veronika Kulmer. 2024. Modelling the economy-wide effects of unilateral CO2 pricing under different revenue recycling schemes in Austria – Searching for a triple dividend. *Energy Economics* **137**, 107783. [Crossref]

10. Jingjing Pan, Jamie L. Cross, Xiaomin Zou, Bo Zhang. 2024. To tax or to trade? A global review of carbon emissions reduction strategies. *Energy Strategy Reviews* **55**, 101508. [Crossref]

11. Jordi J. Teixidó, F. Javier Palencia-González, José M. Labeaga, Xavier Labandeira. 2024. Carbon Leakage from Fuel Taxes: Evidence from a Natural Experiment. *Environmental and Resource Economics* **59**. . [Crossref]

12. Annika Stechemesser, Nicolas Koch, Ebba Mark, Elina Dilger, Patrick Klösel, Laura Menicacci, Daniel Nachtigall, Felix Pretis, Nolan Ritter, Moritz Schwarz, Helena Vossen, Anna Wenzel. 2024. Climate policies that achieved major emission reductions: Global evidence from two decades. *Science* **385**:6711, 884-892. [Crossref]

13. Yanxia Yu. 2024. Carbon Taxes and CO 2 Emissions: A Replication of Andersson (American Economic Journal: Economic Policy , 2019). *Economics* **18**:1. . [Crossref]

14. Tale Mi, Tiao Li. 2024. Industrial Intelligence and Carbon Emission Reduction: Evidence from China's Manufacturing Industry. *Sustainability* **16**:15, 6573. [Crossref]

15. Mustafa Kurt. 2024. G-20 Ülkelerinde Ekolojik Vergilerin Karbon Emisyonları Üzerindeki Etkisi: Panel ARDL Analizi. *Abant Sosyal Bilimler Dergisi* **24**:2, 672-687. [Crossref]

16. Piero Basaglia, Jonas Grunau, Moritz A. Drupp. 2024. The European Union Emissions Trading System might yield large co-benefits from pollution reduction. *Proceedings of the National Academy of Sciences* **121**:28. . [Crossref]

17. Louis Daumas. 2024. Financial stability, stranded assets and the low-carbon transition – A critical review of the theoretical and applied literatures. *Journal of Economic Surveys* **38**:3, 601-716. [Crossref]

18. Jennie Bai, Hong Ru. 2024. Carbon Emissions Trading and Environmental Protection: International Evidence. *Management Science* **70**:7, 4593-4603. [Crossref]

19. Abdulaziz I. Almulhim, Ismaila Rimi Abubakar, Ayyoob Sharifi. 2024. Low-carbon lifestyle index and its socioeconomic determinants among households in Saudi Arabia. *Urban Climate* **56**, 102057. [Crossref]

20. Andewi Rokhmawati, Vita Sarasi, Lailan Tawila Berampu. 2024. Scenario analysis of the Indonesia carbon tax impact on carbon emissions using system dynamics modeling and STIRPAT model. *Geography and Sustainability* **36**. . [Crossref]

21. Rohan Best, Fatemeh Nazifi, Han Cheng. 2024. Carbon Pricing Impacts on Four Pollutants: A Cross-Country Analysis. *Energies* **17**:11, 2596. [Crossref]

22. Dragana Davidovic. 2024. Does corruption shape attitudes towards carbon taxes? Experimental evidence from Mexico and Sweden. *Energy Research & Social Science* **112**, 103493. [Crossref]

23. Mubashir Rasool, Muhammad Adil Khan, Khursheed Aurangzeb, Musaed Alhussein, Muhammad Asif Jamal. 2024. Comprehensive techno-economic analysis of a standalone renewable energy system for simultaneous electrical load management and hydrogen generation for Fuel Cell Electric Vehicles. *Energy Reports* **11**, 6255-6274. [Crossref]

24. Xiaojie Yu, Duminda Kuruppuarachchi, Sriyalatha Kumarasinghe. 2024. Financial development, FDI, and CO 2 emissions: does carbon pricing matter?. *Applied Economics* **56**:25, 2959-2974. [Crossref]

25. Minhaj Ali, Dervis Kirikkaleli. 2024. Carbon taxes, resources efficiency, and environmental sustainability in a developed country. *International Journal of Sustainable Development & World Ecology* **31**:4, 421-430. [Crossref]

26. Helena Dill. 2024. Carbon pricing initiatives and green bonds: are they contributing to the transition to a low-carbon economy?. *Climate Policy* **24**:4, 529-544. [Crossref]

27. Kalyan Annamalai. 2024. Breathing Planet Earth: Analysis of Keeling's Data on CO2 and O2 with Respiratory Quotient (RQ), Part II: Energy-Based Global RQ and CO2 Budget. *Energies* **17**:8, 1800. [Crossref]

28. Godwin Olasehinde-Williams. 2024. Carbon pricing and aggregate macroeconomic performance in the Eurozone: a contribution to the climate policy debate using the EU ETS and Macroeconomic Performance Index. *Environmental Science and Pollution Research* **31**:19, 28290-28305. [Crossref]

29. Sanjay Kumar Patel, Piyush Jhalani. 2024. Formulation of variables of environmental taxation: a bibliometric analysis of Scopus database (2001–2022). *Environment, Development and Sustainability* **26**:3, 7687-7714. [Crossref]

30. Jordi Jofre-Monseny, Pilar Sorribas-Navarro. 2024. Landfill tax and recycling. *Fiscal Studies* **26**. . [Crossref]

31. Eren Gürer, Alfons J. Weichenrieder. 2024. Is there a Green Dividend of National Redistribution?. *The Journal of Economic Inequality* **22**:1, 33-47. [Crossref]

32. Josef Gotvald. 2024. The role of environmental taxes and other political instruments on the road to climate neutrality. *Český finanční a účetní časopis* **2024**:1, 47-76. [Crossref]

33. A. V. Korytin, N. S. Kostrykina, T. A. Malinina. 2024. Carbon taxation in Europe. *Law Enforcement Review* **7**:4, 55-65. [Crossref]

34. Erik Haites, Paolo Bertoldi, Michael König, Christopher Bataille, Felix Creutzig, Dipak Dasgupta, Stéphane de la rue du Can, Smail Khennas, Yong-Gun Kim, Lars J. Nilsson, Joyashree Roy, Agus Sari. 2024. Contribution of carbon pricing to meeting a mid-century net zero target. *Climate Policy* **24**:1, 1-12. [Crossref]

35. Rohan Best, Rabindra Nepal, Han Phoumin. Impact of Policy on Solar PV Supply for ASEAN and Beyond 255-273. [Crossref]

36. Stephan Schulmeister. Fixing Rising Price Paths for Fossil Energy: Basis of a "Green Growth" without Rebound Effects 89-111. [Crossref]

37. Jill Jäger, Ika Darnhofer, Karin Dobernig, Claudia Kettner-Marx, Georg Leitinger, Ina Meyer, Markus Scharler, Franz Sinabell, Gerlind Weber. Kapitel 6. Landnutzungsentscheidungen: Klimawandelrelevante Strategien, Steuerungsinstrumente und Managementansätze 339-380. [Crossref]

38. Herbert Formayer, Robert Jandl, Andreas Bohner, Josef Eitzinger, Karl-Heinz Erb, Willi Haas, Bradley Matthews, Ina Meyer, Heide Spiegel, Ulrike Tappeiner, Erich Tasser, Andreas Voigt. Kapitel 1. Ziele, Herangehensweise und Kontext 57-105. [Crossref]

39. Sara Sousa, Carla Henriques, Clara Viseu. Are Green Taxes Efficient? An Exploratory Study of the EU Reality 265-279. [Crossref]

40. Azamat Ali. Navigating Road for Net Zero Policies to Aligning Policy, Politics, and Governance for Environmental Sustainability 205-230. [Crossref]

41. Shuai Wang, Zili Chen, Linrun Guo, Na Meng, Peidong Han, Zhaoyuan Wu. Joint Planning Strategy of New Energy and Energy Storage Under Regional Low-Carbon Policy 3012-3017. [Crossref]

42. V.M. Antonenko, O.M. Sukhina. 2023. ECOSYSTEM PAYMENTS AND CONSERVATION OF FOREST ECOSYSTEMS OF UKRAINE: ABROAD EXPERIENCE AND MARKET PRICING. *Economics and Law* :4, 79-95. [Crossref]

43. Oskar Lindgren, Thomas Hahn, Mikael Karlsson, Mikael Malmaeus. 2023. Exploring sufficiency in energy policy: insights from Sweden. *Sustainability: Science, Practice and Policy* **19**:1. . [Crossref]

44. Jasmin Wehner, Xiaohua Yu. 2023. Carbon tax on milk products and the exact consumer welfare measure in emerging economies. *Agribusiness* **39**:S1, 1595-1623. [Crossref]

45. Thomas Erhag, Katarina Nordblom, Pernilla Rendahl. 2023. Attaining decent work and economic growth — what role does taxation play?**. *Nordic Tax Journal* **2023**:1, 96-110. [Crossref]

46. Janna Hoppe, Ben Hinder, Ryan Rafaty, Anthony Patt, Michael Grubb. 2023. Three Decades of Climate Mitigation Policy: What Has It Delivered?. *Annual Review of Environment and Resources* **48**:1, 615-650. [Crossref]

47. Kyle S. Herman, Yeong Jae Kim, Soheil Shayegh, Jun Xiang. 2023. A critical review of green growth indicators in G7 economies from 1990 to 2019. *Sustainability Science* **18**:6, 2589-2604. [Crossref]

48. Zhipeng Wang, Fariha Sami, Saleem Khan, Ahmad Mohammed Alamri, Amal Mousa Zaidan. 2023. Green innovation and low carbon emission in OECD economies: Sustainable energy

technology role in carbon neutrality target. *Sustainable Energy Technologies and Assessments* **59**, 103401. [Crossref]

49. Candan YILMAZ UĞUR. 2023. Avrupa Birliği'nde Karbon Vergisinin Kabul Edilebilirliği: Güven, Endişe ve Demokratik Katılım. *Sosyal Mucit Academic Review* **4**:3, 343-363. [Crossref]

50. Muhammad Rizki Dwi Putra, Albarda. Design of Service System for Carbon Trading (Case Study : Bandung City) 1-7. [Crossref]

51. Lina Trosvik, Johanna Takman, Lisa Björk, Jenny Norrman, Yvonne Andersson-Sköld. 2023. A meta-evaluation of climate policy evaluations: findings from the freight transport sector. *Transport Reviews* **43**:5, 867-887. [Crossref]

52. Leonard Missbach, Jan Christoph Steckel, Hauke Ward. 2023. Assessing distributional effects of carbon pricing in Israel. *Energy Policy* **180**, 113672. [Crossref]

53. Maike Venjakob, Oliver Wagner, Birte Schnurr. 2023. Can a CO2 Tax Be Socially Just? Analysis of the Social Distribution Effects of the German CO2 Taxation. *Energies* **16**:17, 6232. [Crossref]

54. João Paulo Braga, Ekkehard Ernst. 2023. Financing the green transition. The role of macroeconomic policies in ensuring a just transition. *Frontiers in Climate* **5**. . [Crossref]

55. Li-Jing Liu, Lan-Cui Liu, Qiao-Mei Liang. 2023. Restructuring investment to promote a win–win situation for both the economy and the environment in China. *Renewable and Sustainable Energy Reviews* **182**, 113363. [Crossref]

56. Luke Haywood, Michael Jakob. 2023. The role of the emissions trading scheme 2 in the policy mix to decarbonize road transport in the European Union. *Transport Policy* **139**, 99-108. [Crossref]

57. Gilbert E. Metcalf, James H. Stock. 2023. The Macroeconomic Impact of Europe's Carbon Taxes. *American Economic Journal: Macroeconomics* **15**:3, 265-286. [Abstract] [View PDF article] [PDF with links]

58. Shuiwang Zhang, Jingcheng Ding, Qianlan Ding. 2023. Retailer-Led Low-Carbon Supply Chain Coordination Considering Sales Effort. *Sustainability* **15**:13, 10556. [Crossref]

59. Andrea Marcello Bassi, Georg Pallaske, Richard Bridle, Kavya Bajaj. 2023. Emission Reduction via Fossil Fuel Subsidy Removal and Carbon Pricing, Creating Synergies with Revenue Recycling. *World* **4**:2, 225-240. [Crossref]

60. Maitri Verma, Cherie Gautam, Kalyan Das. 2023. Control of atmospheric carbon dioxide level through integrated carbon taxation-reforestation policy: a modeling study. *The European Physical Journal Plus* **138**:6. . [Crossref]

61. Aamir Javed, Agnese Rapposelli, Feroz Khan, Asif Javed. 2023. The impact of green technology innovation, environmental taxes, and renewable energy consumption on ecological footprint in Italy: Fresh evidence from novel dynamic ARDL simulations. *Technological Forecasting and Social Change* **191**, 122534. [Crossref]

62. Muryani Muryani, Khoirun Nisa', Miguel Angel Esquivias, Siti Hafsah Zulkarnain. 2023. Strategies to Control Industrial Emissions: An Analytical Network Process Approach in East Java, Indonesia. *Sustainability* **15**:10, 7761. [Crossref]

63. Klaus Gugler, Adhurim Haxhimusa, Mario Liebensteiner. 2023. Carbon pricing and emissions: Causal effects of Britain's carbon tax. *Energy Economics* **121**, 106655. [Crossref]

64. Filip Lestan, Sajal Kabiraj, Babu George. 2023. Preliminary Impact Assessment of Carbon Border Adjustment Mechanism on Russian Economy. *FIIB Business Review* **2**, 231971452211430. [Crossref]

65. Jemyung Lee, Yosuke Shigetomi, Keiichiro Kanemoto. 2023. Drivers of household carbon footprints across EU regions, from 2010 to 2015. *Environmental Research Letters* **18**:4, 044043. [Crossref]

66. Rongxin Chen, Xinyuan Shi. 2023. The Inhibition and Equilibrium of Policy Effectiveness of the Low-Carbon Economy: Evidence from Liaoning Province of China. *International Journal of Environmental Research and Public Health* **20**:5, 3961. [Crossref]

67. Lei Wang, Ziwang Chen, Muhammad Tariq Mahmood, Mirza Nasir Jahan Mehdi, Sana Ullah, Muhammad Nazam, Muhammad Hafeez. 2023. Do transportation taxes promote pro-environmental behaviour? An empirical investigation. *Environmental Science and Pollution Research* **30**:13, 35545-35553. [Crossref]

68. Heng Lei, Minggao Xue, Huiling Liu, Jing Ye. 2023. Price elasticity of CO_2 emissions in China: A machine learning approach. *Sustainable Production and Consumption* **36**, 257-280. [Crossref]

69. Daker Elrabay'a, Valentina Marchenko, Valerii Osetskyi. 2023. DETERMINING THE COMPREHENSIVE TARIFF FOR HOUSEHOLD WASTE MANAGEMENT TAKING INTO ACCOUNT THE ENVIRONMENTAL COMPONENT AND THE VALUE OF SECONDARY RESOURCES. *Academic Review* **1**:58, 123-136. [Crossref]

70. Mikael Karlsson, Nils Westling, Oskar Lindgren. 2023. Climate-Related Co-Benefits and the Case of Swedish Policy. *Climate* **11**:2, 40. [Crossref]

71. Jie Mao, Chunhua Wang, Haitao Yin. 2023. Corporate responses to air quality regulation: Evidence from a regional environmental policy in China. *Regional Science and Urban Economics* **98**, 103851. [Crossref]

72. Rabindra Nepal, Rohan Best, Thanh Le, Amir Arjomandi, Nirash Paija. Wholesale Electricity Price, Carbon Emissions and Economic Output in Australia: The Role of Carbon Pricing 1-27. [Crossref]

73. Rabindra Nepal, Rohan Best, Thanh Le, Amir Arjomandi, Nirash Paija. Wholesale Electricity Price, Carbon Emissions, and Economic Output in Australia: The Role of Carbon Pricing 789-815. [Crossref]

74. Serkan ERCOŞKUN, Birol KOVANCILAR. 2023. Nordik Ülkelerinde Karbon Vergisi Uygulamalarının Değerlendirilmesi. *Yönetim ve Ekonomi Dergisi* **30**:3, 611-631. [Crossref]

75. Bowei Guo, Newbery David. 2023. The Cost of Carbon Leakage: Britain's Carbon Price Support and Cross-border Electricity Trade. *The Energy Journal* **44**:1, 9-32. [Crossref]

76. Haoqi Qian, Feizhou Ren, Yanran Gong, Rong Ma, Wendong Wei, Libo Wu. 2022. China industrial environmental database 1998–2015. *Scientific Data* **9**:1. . [Crossref]

77. Govinda R. Timilsina. 2022. Carbon Taxes. *Journal of Economic Literature* **60**:4, 1456-1502. [Abstract] [View PDF article] [PDF with links]

78. Harald Winkler, Franck Lecocq, Hans Lofgren, Maria Virginia Vilariño, Sivan Kartha, Joana Portugal-Pereira. 2022. Examples of shifting development pathways: lessons on how to enable broader, deeper, and faster climate action. *Climate Action* **1**:1. . [Crossref]

79. Xiaoyun Xing, Huanxue Pan, Jing Deng. 2022. Carbon tax in a stock-flow consistent model: The role of commercial banks in financing low-carbon transition. *Finance Research Letters* **50**, 103186. [Crossref]

80. Shenhai Huang, Chao Du, Xian Jin, Daini Zhang, Shiyan Wen, Yu'an Wang, Zhenyu Cheng, Zhijie Jia. 2022. The Boundary of Porter Hypothesis: The Energy and Economic Impact of China's Carbon Neutrality Target in 2060. *Energies* **15**:23, 9162. [Crossref]

81. Qiang Du, Yanan Dong, Jingtao Li, Yuelin Zhao, Libiao Bai. 2022. Assessing the Impacts of Carbon Tax and Improved Energy Efficiency on the Construction Industry: Based on CGE Model. *Buildings* **12**:12, 2252. [Crossref]

82. Jared J. Finnegan. 2022. Changing Prices in a Changing Climate: Electoral Competition and Fossil Fuel Taxation. *Comparative Political Studies* **8**, 001041402211418. [Crossref]

83. Mingliu Chen, Wen Jiandong, Hummera Saleem. 2022. The role of environmental taxes and stringent environmental policies in attaining the environmental quality: Evidence from OECD and non-OECD countries. *Frontiers in Environmental Science* **10**. . [Crossref]

84. Jeremy van Dijk, Nathan Delacrétaz, Bruno Lanz. 2022. Technology Adoption and Early Network Infrastructure Provision in the Market for Electric Vehicles. *Environmental and Resource Economics* **83**:3, 631-679. [Crossref]

85. Yuxin Zhu, Ziming Liu, Shuyi Feng, Na Lu. 2022. The role of fiscal expenditure on science and technology in carbon reduction: Evidence from provincial data in China. *Environmental Science and Pollution Research* **29**:54, 82030-82044. [Crossref]

86. Jens Ewald, Thomas Sterner, Erik Sterner. 2022. Understanding the resistance to carbon taxes: Drivers and barriers among the general public and fuel-tax protesters. *Resource and Energy Economics* **70**, 101331. [Crossref]

87. Mario Liebensteiner, Fabian Naumann. 2022. Can carbon pricing counteract renewable energies' cannibalization problem?. *Energy Economics* **115**, 106345. [Crossref]

88. Nils Ohlendorf, Christian Flachsland, Gregory F. Nemet, Jan Christoph Steckel. 2022. Carbon price floors and low-carbon investment: A survey of German firms. *Energy Policy* **169**, 113187. [Crossref]

89. Refk Selmi, Farid Makhlouf, Kamal Kasmaoui, Youssef Errami, Oussama Ben Atta. 2022. "There is No vaccine for climate change" - How well Governments'COVID-19 green stimulus announcements contribute to business sustainability?. *International Economics* **171**, 1-17. [Crossref]

90. Mireille Chiroleu-Assouline. 2022. Rendre acceptable la nécessaire taxation du carbone. *Revue de l'OFCE* **N° 176**:1, 15-53. [Crossref]

91. Yun Yang, Chunli Peng. 2022. Low-carbon city pilot policy, fiscal pressure, and carbon productivity: Evidence from china. *Frontiers in Environmental Science* **10**. . [Crossref]

92. Felix Pretis. 2022. Does a Carbon Tax Reduce CO2 Emissions? Evidence from British Columbia. *Environmental and Resource Economics* **83**:1, 115-144. [Crossref]

93. Tomiwa Sunday Adebayo, Ridwan Lanre Ibrahim, Ephraim Bonah Agyekum, Hossam M. Zawbaa, Salah Kamel. 2022. The environmental aspects of renewable energy consumption and structural change in Sweden: A new perspective from wavelet-based granger causality approach. *Heliyon* **8**:9, e10697. [Crossref]

94. Igor J. Mitroczuk. 2022. Energy Transformation: Challenges and Opportunities — The Polish Case. *Environmental Protection and Natural Resources* **33**:3, 21-34. [Crossref]

95. Angela Köppl, Margit Schratzenstaller. 2022. Carbon taxation: A review of the empirical literature. *Journal of Economic Surveys* **8**. . [Crossref]

96. Leonie Matejko, Stephan Sommer. 2022. The Social Sustainability Barometer 2017–2019: Survey Data on the Energiewende. *Jahrbücher für Nationalökonomie und Statistik* **242**:4, 529-545. [Crossref]

97. Magdalena Zioło, Anna Spoz, Iwona Bąk, Maciej Oesterreich. 2022. FUZZY MODEL OF SUSTAINABLE DEVELOPMENT WITH THE INCLUSION OF FINANCIAL VARIABLES. *Technological and Economic Development of Economy* **28**:5, 1368-1391. [Crossref]

98. Hummera Saleem, Muhammad Bilal Khan, Seyed Mohammadreza Mahdavian. 2022. The role of green growth, green financing, and eco-friendly technology in achieving environmental quality: evidence from selected Asian economies. *Environmental Science and Pollution Research* **29**:38, 57720-57739. [Crossref]

99. Guobin Huang, Guoqin Zhao, Nan Huang. 2022. Appraisal-and-commendation policy and carbon emissions: Evidence from the national civilised city program in China. *Frontiers in Energy Research* **10**. . [Crossref]

100. Andres Arcila, John D. Baker. 2022. Evaluating carbon tax policy: A methodological reassessment of a natural experiment. *Energy Economics* **111**, 106053. [Crossref]

101. Younes Ahmadi, Akio Yamazaki, Philippe Kabore. 2022. How Do Carbon Taxes Affect Emissions? Plant-Level Evidence from Manufacturing. *Environmental and Resource Economics* **82**:2, 285-325. [Crossref]

102. David Bonilla, David Banister, Uberto Salgado Nieto. 2022. Tax or Clean Technology? Measuring the True Effect on Carbon Emissions Mitigation for Sweden and Norway. *Energies* **15**:11, 3885. [Crossref]

103. Martin Philipp Heger, Lukas Vashold, Anabella Palacios, Mala Alahmadi, Marjory-Anne Bromhead, Marcelo Acerbi. Blue Skies for Healthy and Prosperous Cities 57-180. [Crossref]

104. Lu Yunzhao. 2022. Modelling the role of eco innovation, renewable energy, and environmental taxes in carbon emissions reduction in E–7 economies: Evidence from advance panel estimations. *Renewable Energy* **190**, 309-318. [Crossref]

105. Frances C. Moore, Katherine Lacasse, Katharine J. Mach, Yoon Ah Shin, Louis J. Gross, Brian Beckage. 2022. Determinants of emissions pathways in the coupled climate–social system. *Nature* **603**:7899, 103-111. [Crossref]

106. Shigeru Matsumoto. 2022. How will a carbon tax affect household energy source combination?. *Energy Strategy Reviews* **40**, 100823. [Crossref]

107. Bibek Adhikari. 2022. A Guide to Using the Synthetic Control Method to Quantify the Effects of Shocks, Policies, and Shocking Policies. *The American Economist* **67**:1, 46-63. [Crossref]

108. Laura Atarody, Mourad Ayouz. Intergenerational Effects of Financing Private Investments for Low-Carbon Energy Transitions: An Application to France 93-114. [Crossref]

109. Shohei Domon, Mayu Hirota, Tatsuhito Kono, Shunsuke Managi, Yusuke Matsuki. 2022. The long-run effects of congestion tolls, carbon tax, and land use regulations on urban CO2 emissions. *Regional Science and Urban Economics* **92**, 103750. [Crossref]

110. Felix Creutzig, Leila Niamir, Xuemei Bai, Max Callaghan, Jonathan Cullen, Julio Díaz-José, Maria Figueroa, Arnulf Grubler, William F. Lamb, Adrian Leip, Eric Masanet, Érika Mata, Linus Mattauch, Jan C. Minx, Sebastian Mirasgedis, Yacob Mulugetta, Sudarmanto Budi Nugroho, Minal Pathak, Patricia Perkins, Joyashree Roy, Stephane de la Rue du Can, Yamina Saheb, Shreya Some, Linda Steg, Julia Steinberger, Diana Ürge-Vorsatz. 2022. Demand-side solutions to climate change mitigation consistent with high levels of well-being. *Nature Climate Change* **12**:1, 36-46. [Crossref]

111. Ryotaro Mise, Naohiro Kitano, Akinori Morimoto. 2022. Combination Effects of Next-Generation Transportation and Carbon Taxes on Future Environmental Burden for Aiming to Zero Emission. *Urban and Regional Planning Review* **9**:0, 80-99. [Crossref]

112. Esbeydi Villicaña-García, Aurora de Fátima Sánchez-Bautista, José María Ponce-Ortega. 2022. Involving behavior of population in the strategic planning of integrated energy systems. *Computers & Chemical Engineering* **157**, 107583. [Crossref]

113. Petrik Runst, David Höhle. 2022. The German eco tax and its impact on CO2 emissions. *Energy Policy* **160**, 112655. [Crossref]

114. Jidong Guo, Menghao Xi. 2022. Greening, Pricing and Marketing Coordination for a Complex Three-Level Supply Chain Under the Carbon Tax in China. *IEEE Access* **10**, 76895-76905. [Crossref]

115. Marion Leroutier. 2022. Carbon pricing and power sector decarbonization: Evidence from the UK. *Journal of Environmental Economics and Management* **111**, 102580. [Crossref]

116. Miroslav Hájek, Jarmila Zimmermannová, Karel Helman. 2021. Environmental efficiency of economic instruments in transport in EU countries. *Transportation Research Part D: Transport and Environment* **100**, 103054. [Crossref]

117. Ömer Esen, Durmuş Çağrı Yıldırım, Seda Yıldırım. 2021. Pollute less or tax more? Asymmetries in the EU environmental taxes – Ecological balance nexus. *Environmental Impact Assessment Review* **91**, 106662. [Crossref]

118. Simon Feindt, Ulrike Kornek, José M. Labeaga, Thomas Sterner, Hauke Ward. 2021. Understanding regressivity: Challenges and opportunities of European carbon pricing. *Energy Economics* **103**, 105550. [Crossref]

119. Gilbert E. Metcalf. 2021. Carbon Taxes in Theory and Practice. *Annual Review of Resource Economics* **13**:1, 245-265. [Crossref]

120. Alice Ciccone, Emilia Soldani. 2021. Stick or Carrot? Asymmetric Responses to Vehicle Registration Taxes in Norway. *Environmental and Resource Economics* **80**:1, 59-94. [Crossref]

121. Jonn Axsen, Michael Wolinetz. 2021. Taxes, tolls and ZEV zones for climate: Synthesizing insights on effectiveness, efficiency, equity, acceptability and implementation. *Energy Policy* **156**, 112457. [Crossref]

122. Anna Eisner, Veronika Kulmer, Dominik Kortschak. 2021. Distributional effects of carbon pricing when considering household heterogeneity: An EASI application for Austria. *Energy Policy* **156**, 112478. [Crossref]

123. Weibing Li, Yongwen Yang. 2021. Can environmental centralization help reduce pollution? Evidence from an administrative reform in China. *Journal of Cleaner Production* **314**, 127972. [Crossref]

124. Nathalie Müller, Jordi J. Teixidó. 2021. The effect of the EU ETS free allowance allocation on energy mix diversification: the case of Poland's power sector. *Climate Policy* **21**:6, 804-822. [Crossref]

125. Philippe Quirion. 2021. Tradable instruments to fight climate change: A disappointing outcome. *WIREs Climate Change* **12**:3. . [Crossref]

126. Jessica F. Green. 2021. Beyond Carbon Pricing: Tax Reform is Climate Policy. *Global Policy* **12**:3, 372-379. [Crossref]

127. Franziska Klein, Jeroen van den Bergh. 2021. The employment double dividend of environmental tax reforms: exploring the role of agent behaviour and social interaction. *Journal of Environmental Economics and Policy* **10**:2, 189-213. [Crossref]

128. Jessica F Green. 2021. Does carbon pricing reduce emissions? A review of ex-post analyses. *Environmental Research Letters* **16**:4, 043004. [Crossref]

129. Sam G. Keenor, Aline F. Rodrigues, Li Mao, Agnieszka E. Latawiec, Amii R. Harwood, Brian J. Reid. 2021. Capturing a soil carbon economy. *Royal Society Open Science* **8**:4. . [Crossref]

130. Katsuyuki Nakano, Ken Yamagishi. 2021. Impact of Carbon Tax Increase on Product Prices in Japan. *Energies* **14**:7, 1986. [Crossref]

131. James B. Ang, Per G. Fredriksson. 2021. Does an early start help or hurt? Statehood, institutions and modern climate change policies. *Energy Economics* **94**, 105075. [Crossref]

132. Michael Thom. Taxing Twenty-First Century Sins 153-176. [Crossref]

133. Swarnima Singh, R. B. Singh. Indian Climate Policy, Programs, and Initiatives 273-299. [Crossref]

134. Théo Konc, Ivan Savin, Jeroen C.J.M. van den Bergh. 2021. The social multiplier of environmental policy: Application to carbon taxation. *Journal of Environmental Economics and Management* **105**, 102396. [Crossref]

135. Lin-Na Hao, Muhammad Umar, Zeeshan Khan, Wajid Ali. 2021. Green growth and low carbon emission in G7 countries: How critical the network of environmental taxes, renewable energy and human capital is?. *Science of The Total Environment* **752**, 141853. [Crossref]

136. Daniel Driscoll. 2021. Drivers of Carbon Price Adoption in Wealthy Democracies: International or Domestic Forces?. *Socius: Sociological Research for a Dynamic World* **7**, 237802312199225. [Crossref]

137. Maureen Lackner, Jonathan Camuzeaux, Suzi Kerr, Kristina Mohlin. 2021. Pricing Methane Emissions from Oil and Gas Production. *SSRN Electronic Journal* **5**. . [Crossref]

138. Luigi Iovino, Thorsten Martin, Julien Sauvagnat. 2021. Corporate Taxation and Carbon Emissions. *SSRN Electronic Journal* **11**. . [Crossref]

139. Johan Lilliestam, Anthony Patt, Germán Bersalli. 2021. The effect of carbon pricing on technological change for full energy decarbonization: A review of empirical ex-post evidence. *WIREs Climate Change* **12**:1. . [Crossref]

140. Michihito Ando, Masato Furuichi, Yoshihiro Kaneko. 2021. Does universal long-term care insurance boost female labor force participation? Macro-level evidence. *IZA Journal of Labor Policy* **11**:1. . [Crossref]

141. RICHARD S. J. TOL. 2020. SELFISH BUREAUCRATS AND POLICY HETEROGENEITY IN NORDHAUS' DICE. *Climate Change Economics* **11**:04, 2040006. [Crossref]

142. Ryan Rafatya, Geoffroy Dolphin, Felix Pretis. 2020. Carbon Pricing and the Elasticity of CO2 Emissions. *Institute for New Economic Thinking Working Paper Series* 1-84. [Crossref]

143. Jia Liu, Jinyu Bai, Yi Deng, Xiaohong Chen, Xiang Liu. 2020. Impact of energy structure on carbon emission and economy of China in the scenario of carbon taxation. *Science of The Total Environment* 143093. [Crossref]

144. Zhijie Jia, Boqiang Lin. 2020. Rethinking the choice of carbon tax and carbon trading in China. *Technological Forecasting and Social Change* **159**, 120187. [Crossref]

145. Rohan Best, Paul J. Burke, Frank Jotzo. 2020. Carbon Pricing Efficacy: Cross-Country Evidence. *Environmental and Resource Economics* **77**:1, 69-94. [Crossref]

146. Petrik Runst, Anita Thonipara. 2020. Dosis facit effectum why the size of the carbon tax matters: Evidence from the Swedish residential sector. *Energy Economics* **91**, 104898. [Crossref]

147. Jonn Axsen, Patrick Plötz, Michael Wolinetz. 2020. Crafting strong, integrated policy mixes for deep CO2 mitigation in road transport. *Nature Climate Change* **10**:9, 809-818. [Crossref]

148. Rohan Best, Qiu Yue Zhang. 2020. What explains carbon-pricing variation between countries?. *Energy Policy* **143**, 111541. [Crossref]

149. Rohan Best, Paul J. Burke. 2020. Energy mix persistence and the effect of carbon pricing. *Australian Journal of Agricultural and Resource Economics* **64**:3, 555-574. [Crossref]

150. Gilbert E. Metcalf, James H. Stock. 2020. Measuring the Macroeconomic Impact of Carbon Taxes. *AEA Papers and Proceedings* **110**, 101-106. [Abstract] [View PDF article] [PDF with links]

151. Alexander R. Barron, Breanna J. Parker, Susan S. Sayre, Shana S. Weber, Dano J. Weisbord. 2020. Carbon pricing approaches for climate decisions in U.S. higher education: Proxy carbon prices for deep decarbonization. *Elementa: Science of the Anthropocene* **8**. . [Crossref]

152. Kian Mintz-Woo, Francis Dennig, Hongxun Liu, Thomas Schinko. 2020. Carbon Pricing and COVID-19. *SSRN Electronic Journal* . [Crossref]

153. Travis Roach, R. Kaj Gittings. 2020. Power Sector Emissions under Tightening Carbon Dioxide Quotas. *SSRN Electronic Journal* **11**. . [Crossref]

154. Patrick Criqui, Mark Jaccard, Thomas Sterner. 2019. Carbon Taxation: A Tale of Three Countries. *Sustainability* **11**:22, 6280. [Crossref]

155. Felix Pretis. 2019. Does a Carbon Tax Reduce CO 2 Emissions? Evidence From British Columbia. *SSRN Electronic Journal* . [Crossref]

156. Yiyi Bai, Samuel J Okullo. 2019. Cutting Carbon Through Fuel-Switching Under the EU ETS. *SSRN Electronic Journal* . [Crossref]