Measuring the Macroeconomic Impact of Carbon Taxes

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Economists have long argued that a carbon tax is a cost effective way to reduce greenhouse gas emissions. Increasingly, members of Congress agree. In 2019, seven carbon tax bills were filed in Congress (Kaufman et al., 2019). In addition, the Climate Leadership Council has built bipartisan support for a carbon tax and dividend plan (Baker et al., 2017).

In contrast, the Trump Administration is retreating from any climate policy and has taken steps to withdraw from the Paris Accord, citing heavy economic costs to the U.S. economy from meeting the U.S. commitments made during the Obama Administration. In his June 1, 2017 statement on the Accord, the President claimed that the cost to the economy would be "close to $3 trillion in lost GDP and 6.5 million industrial jobs…" (Trump, 2017).

What is the basis for claims about the economic impact of a carbon tax? Until recently, economic impacts were estimated using computable general equilibrium (CGE) models (as was done for the report on which Trump based his claims). It is often difficult to assess these results given the complexity of CGE models and the difficulty of teasing out drivers of the results. But with carbon taxes in place in twenty-five countries around the world, with some going back to the early 1990s, we no longer have to rely on CGE models with their often opaque modeling assumptions: empirical analysis of historical experience is now possible. This paper considers carbon taxes in Europe to estimate their impact on GDP and employment.[1]

I. Previous Literature

Most analyses of the economic impact of carbon taxes rely on large-scale computable general equilibrium models. One representative model is the E3 model described in Goulder and Hafstead (2017). They estimate a $40 per ton carbon tax starting in 2020 and rising at 5 percent real annually

[1] This paper does not focus on the emission reduction impacts of a carbon tax. Metcalf (2019) surveys that literature. A more recent paper by Andersson (2019) finds that the Swedish carbon tax reduced transport emissions by 6 percent, a result that is three times the size of the emissions reduction implied by gasoline price elasticities. He argues that this may be an underestimate of the emission reduction potential in other countries due to the high rate of existing excise taxation on fuels in Sweden relative to other countries.

would reduce GDP by just over one percent in 2035. While different models give different results, most find very modest reductions (if at all) in GDP from implementing a carbon tax.[2,3] But these are modeling results. We now have nearly thirty years of data from countries that have implemented carbon taxes. Now is an opportune time to look at the empirical evidence.

Metcalf (2019) summarizes the rather thin empirical literature on the economic effects of carbon taxes. Much of that literature focuses on the tax's impact on emissions. Focusing on GDP, Metcalf (2019) finds no adverse GDP impact of the British Columbia carbon tax based on a Difference-in-Difference (DID) analysis of a panel of Canadian provinces over the time period 1990 – 2016. Using a panel of European countries over the time period 1985 – 2017, he finds, if anything, a modest positive impact on GDP. That imposing a carbon tax might have positive impacts on GDP is not implausible once one considers the governments' use of carbon tax revenue. In the early 1990s, for example, carbon taxes were imposed in a number of Scandinavian countries as a revenue source to finance reductions in marginal tax rates for their income taxes (see Brannlund and Gren, 1999, for background on these reforms).

The paper by Bernard et al. (2018) is closest in spirit to this paper. It uses a VAR framework to estimate the impact of the BC carbon tax on provincial GDP. It finds no impact of the tax on GDP. Yamazaki (2017) looked at the employment effects of the British Columbia carbon tax and found modest positive impacts on employment in the province. While aggregate impacts were small, he found significant job shifting from carbon intensive to non-carbon intensive sectors.

II. Our Analysis

Our aim is to estimate the dynamic effect of a carbon tax on the growth rate of GDP and employment.[4] Our sample includes 31 European countries (so called EU+) that all are part of the EU Emission Trading System (ETS), a cap-and-trade system to reduce emissions in the electricity

[2] Trump cited a NERA (2017) study commissioned by an industry group to analyze how meeting an 80 percent reduction by 2050 would affect various industry sectors. Among other issues, the headline number cited by Trump (7 percent reduction in GDP) is from a NERA scenario in which sector specific regulations are imposed with very different marginal abatement costs across sectors. If marginal abatement costs are allowed to equalize across sectors, the costs are reduced by over two-thirds.

[3] Goulder et al. (2019) also consider a tax starting at \$40 per ton and rising at 2 percent annually. They find the GDP costs over the 2016 – 2050 period discounted at 3 percent equal to less than one-third of one percent of GDP.

[4] Standard public finance theory as embodied in CGE models suggests a relation between the level of the tax and the level of GDP. Over a given period, an adjustment of GDP from a no-tax to a tax path entails a shift in the level, that is, an effect on the growth rate. Our analysis focuses on a short horizon, six years, so a transition to a lower GDP growth path would appear as a lower rate of GDP growth over this transition, relative to a no-tax counterfactual. Focusing on growth effects has the benefit of not needing to model trends in GDP and carbon tax data.

and certain energy intensive sectors.[5] This includes EU countries plus Iceland, Norway, and Switzerland. 15 of these 31 countries have a carbon tax on some sector of the economy. Our data on real GDP and carbon tax rates come from the World Bank Group (2019).[6] Employment data are from the EU Eurostat database. Data on the share of emissions covered by the tax come from World Bank Group (2019), and energy price and energy excise tax data are from the International Energy Agency (2019).

Attributing aggregate growth effects to a carbon tax is complicated by the multiplicity of macroeconomic shocks affecting these countries, the substantial measurement error in GDP growth, and the simultaneous existence of the ETS. Most countries have enacted carbon taxes to cover emissions not covered by the carbon tax (e.g. residential and commercial heating and transport[7]). Some countries, most notably the United Kingdom, tax certain sectors covered by the ETS. The U.K. taxes electricity only to the extent that it brings the emissions price up to a floor consistent with its Climate Change Levy.

We focus on EU+ countries to control consistently for the impact of the ETS on growth. The ETS went into effect with a pilot phase (Phase I) in 2005. In Phase I, power stations and certain energy intensive sectors were subject to the cap.[8] Phase II (2008 – 2012) added domestic aviation (in 2012), and Phase III (2013 – 2020) added various additional sectors.[9]

Table 1 lists the countries with carbon taxes (chronologically by year of implementation) along with their tax rate in 2018 and the share of emissions covered by the tax. There is variation both in tax rates (across and within countries) and the year of implementation of the tax (see Figure 1).

[Insert Table 1 Here]

[5] See Schmalensee and Stavins (2017) for an overview of the EU ETS.

[6] Real carbon tax rates are nominal tax rates divided by the GDP deflator (home country currency), converted to US dollars at 2018 exchange rates. We used national statistical agency data for GDP and prices, instead of World Bank data, for Ireland and Norway. For Ireland, we used adjusted Gross National Income, which eliminates distortions from intellectual property inflows due to Ireland's status as a tax haven (Worstall, 2016), and the CPI. Norway maintains dual accounts, onshore and offshore, the latter including oil revenues; we use onshore GDP and its deflator to avoid spuriously confounding carbon tax effects with Norway's offshore oil production. We are grateful to Celine Ramstein of the World Bank for providing early access to the carbon tax data set.

[7] Emissions from oil refining are subject to the ETS but not the burning of fuels in transportation. Oil refining emissions accounts for less than ten percent of well to wheel emissions.

[8] The sectors are power stations and other combustion plants of at least 20 MW, oil refineries, coke ovens, iron and steel plants, cement clinker, glass, lime, bricks, ceramics, pulp, and paper and board. Aluminum, petrochemicals, ammonia, nitric, adipic, and glyoxylic acid production. and CO_2 capture, transport, and storage were added in Phase III.

[9] Twenty-five of the thirty-one countries in our sample have been subject to the ETS from its inception. Romania and Bulgaria joined in 2007 while Norway, Iceland, and Liechtenstein joined the ETS starting with Phase II in 2008. Croatia joined the ETS as of Phase III in 2013. See European Commission (2015) for a history and membership of the ETS.

[Insert Figure 1 Here]

A very simple first cut at the analysis shows little discernable impact on real GDP per capita growth from implementing a carbon tax. Figure 2 shows annual GDP growth rates for the countries implementing a carbon tax in a five-year window around enactment. While there is a slight increase in mean growth across the group, no particular pattern emerges from individual countries.

[Insert Figure 2 Here]

A similar pattern occurs for total employment and manufacturing employment growth. Thus, we turn to a more rigorous empirical analysis in the next section.

A. Econometric Model

The essential challenge of identifying the dynamic causal effect of a carbon tax on GDP growth is the possibility of simultaneity: poor economic outcomes could lead the tax authorities to reduce the rate or to postpone a planned increase. In this regard, it is useful to think of changes to a carbon tax as having two components, one responding to historical economic growth, the other being unpredicted by past growth. Changes in the latter category could include tax changes based on historically legislated schedules, changes in ambition based on the environmental preferences of the party in power, or responses to international climate policy pressure. Our identifying assumption is that this latter category of changes – those not predicted by historical own-country GDP growth and current and past international economic shocks – are exogenous. This assumption allows us to estimate the dynamic effect on GDP growth of the unexpected component of a carbon tax using the Jordà (2005) local projection (LP) method, adapted to panel data. Specifically, we use OLS to estimate a sequence of panel data regressions,

$$(2)\ 100\Delta ln(\,GDP_{it+h}) = \alpha_i + \,\Theta_{yx,h}\tau_{it} + \beta(L)\tau_{it-1} + \delta(L)\Delta\, ln(\,GDP_{it-1}) + W_{it} + u_{it}.$$

where τ_{it} is the real carbon tax rate for country *i* at date *t* and $\Theta_{yx,h}$ is the effect of an unexpected change in the carbon tax rate at time *t* on annual GDP growth *h* periods hence. The vector W_{it} denotes control variables, which in our base specification is year effects. Standard errors are heteroskedasticity-robust (Plagborg-Moller and Wolf (2019)). Depending on the sample of countries, our primary results use either the carbon tax rate, or the tax rate interacted with its 2019 share of its emission coverage. The latter specification assumes that any damage (or benefit) of the tax to an economy would be, in the first instance, proportional to the covered share of the economy.

B. Results

Rather than report estimated coefficients, we report impulse response functions (IRFs) for a $40 per ton increase in the country's tax rate, computed as in Sims (1986) modified for LP. For specifications in which the tax is interacted with the share, results are presented for a $40 tax that covers 30% of emissions (close to the sample mean).

GDP Growth Rate. – Figure 3 shows the IRF for real GDP with year effects, estimated using all 31 countries over the full 1985-2018 sample, where the carbon tax rate is interacted with the share. The predicted effect is positive in each year through year 6, however in no year is it significant at the 5% level (in most years it is within one standard error of zero).

[Insert Figure 3 Here]

Figure 4 shows the IRF for employment growth. In the first two years, the tax is estimated to increase the growth rate of employment by less than one-half percentage point, however this increase is never significant at the 10% level. For years 3-6, the estimated effect on the growth rate is essentially zero.

[Insert Figure 4 Here]

C. Additional Results

The results shown in Figures 3 and 4 are robust to a wide range of model specifications and a large number of sensitivity checks. We present some of those results here. Figure 5 shows the GDP response to a carbon tax for the 11 countries with a tax that, in at least one year, exceeded $20/ton (not interacted with the share of emissions covered). With fewer countries, the estimates are less precise, but indicate positive effects and are consistent with the estimates in Figure 3.

[Insert Figure 5 Here]

A stronger identification condition is that the carbon tax is strictly exogenous, that is, there is no feedback from GDP growth to the tax rate. This no-feedback condition is not rejected at the 10% level in any of the base specifications. Imposing this condition permits estimating the dynamic response using a distributed lag (current plus six lags) of the carbon tax and year effects based on the following equation:

(3) $$100\Delta ln(GDP_{it}) = \alpha_i + \beta(L)\tau_{it} + W_{it} + u_{it}.$$

As illustrated in Figure 6 for the effect of the tax on GDP growth for the full sample, this method yields similar point estimates but tighter standard errors than if the weaker LP identification condition is used.

[Insert Figure 6 Here]

C. Additional Results

These findings are robust to using an alternative measure of the tax (the logarithm of the pump price of diesel relative to the price of diesel excluding the tax), using GDP per capita instead of GDP, using OECD and former Soviet Union growth rates and their lags as controls instead of year effects, restricting the sample to only Scandinavian countries, and dropping Ireland and Norway (so as to use only World Bank GDP data). Figure 7, for example, shows the IRF for GDP growth rates when the tax rate is based on the diesel price calculation described above. Error bands are wider but the zero impact continues to hold. We get a similar result using this tax rate to estimate the impact on total employment.

[Insert Figure 7 Here]

The impulse response functions estimate the annual impacts of a $40 per ton carbon tax. We also computed cumulative impacts. Figure 8 shows a cumulative IRF based on our LP model using the World Bank carbon tax rate data for our EU sample. The point estimate indicates a cumulative impact of 4 percentage points by year 5; however, the standard error bands are wide, and we cannot reject a zero impact at the 95 percent level. The cumulative IRF estimated from the DL model (not shown) yields a 3 percentage point increase by year 6 that is statistically significant at the 95 percent level. As noted above, however, this model relies on stronger exogeneity assumptions.

[Insert Figure 8 Here]

Results using our alternative carbon tax rate based on the diesel fuel markup show a similar result but – again – with very wide error bands (Figure 9).

[Insert Figure 9 Here]

We also estimated cumulative IRFs for employment and find modest to zero cumulative impacts after six years. Figure 10 is illustrative of these results.

[Insert Figure 10 Here]

D. Discussion

The results here show some evidence of transitional dynamics. We find that typically the carbon tax has positive effects on GDP growth and, initially, on employment. The positive effects are in some cases statistically significant but generally are not, so that the estimated growth effects are consistent with no effect of the tax on the growth rates of GDP or employment. We find no robust evidence of a negative effect of the tax on employment or GDP growth. For the European experience, at least, we find no support for the view that carbon taxes are job or growth killers.

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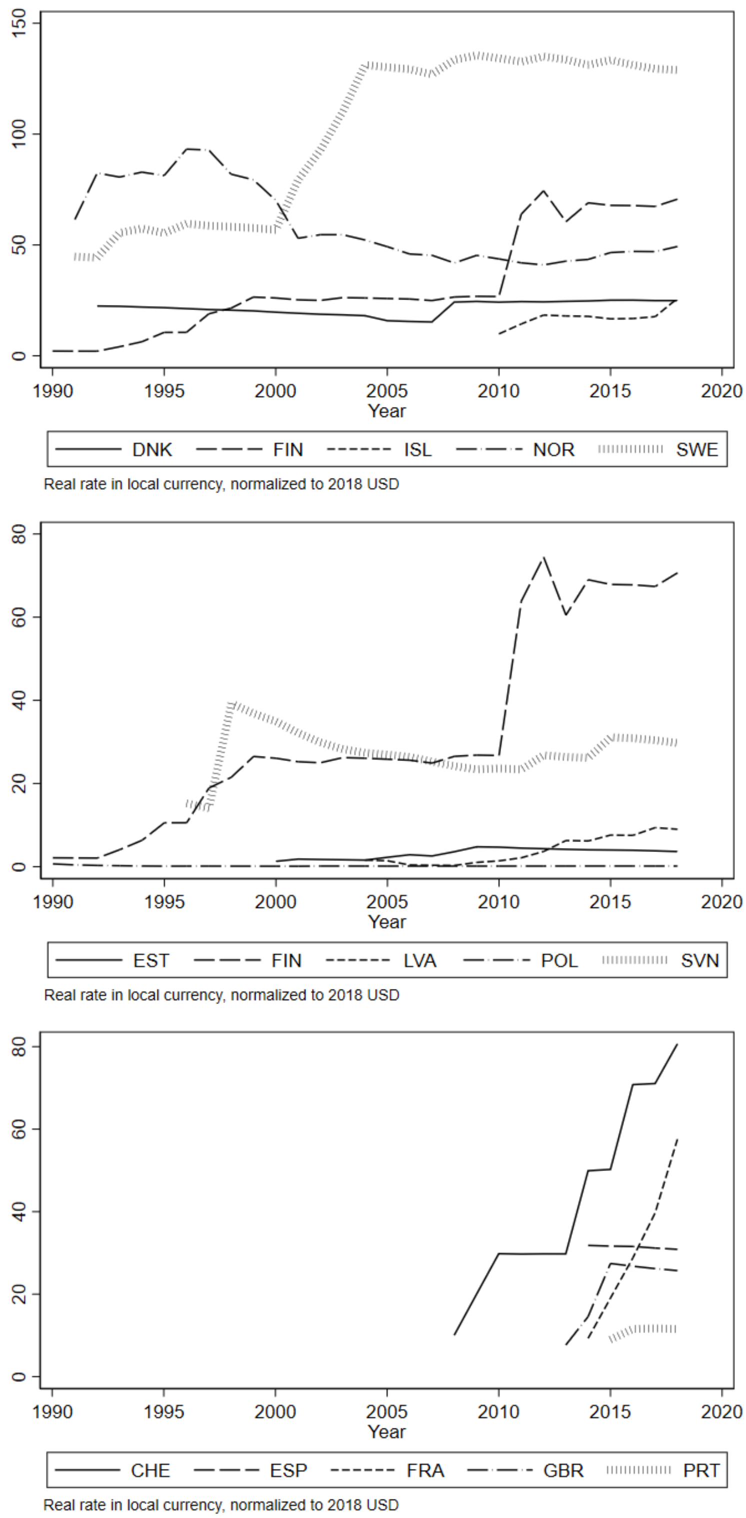


FIGURE 1. REAL CARBON TAX RATES OVER TIME

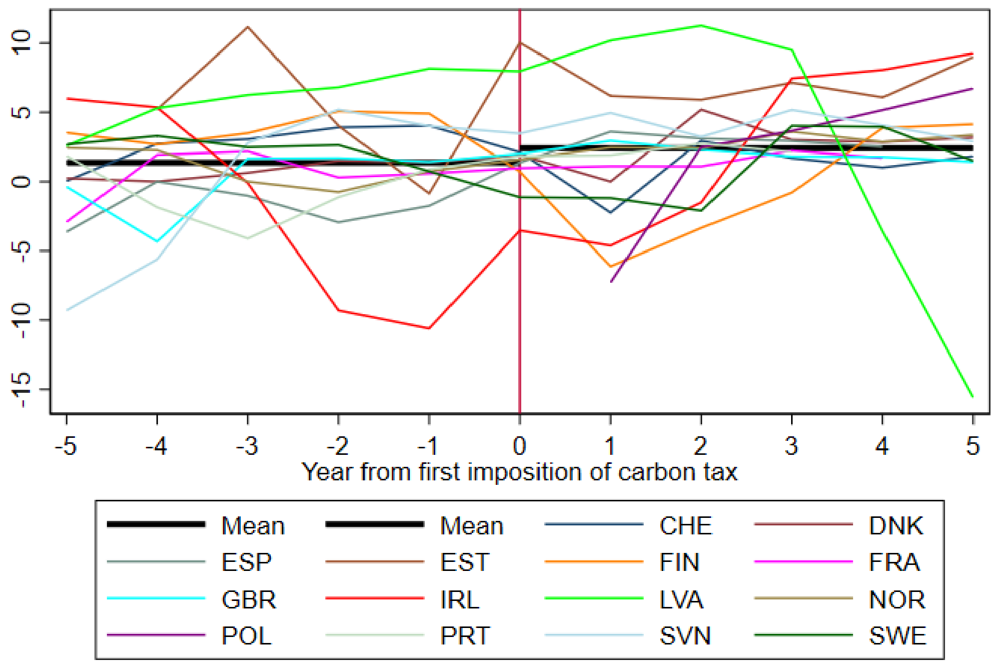


FIGURE 2. CARBON TAX ENACTMENT AND GDP PER CAPITA GROWTH RATE

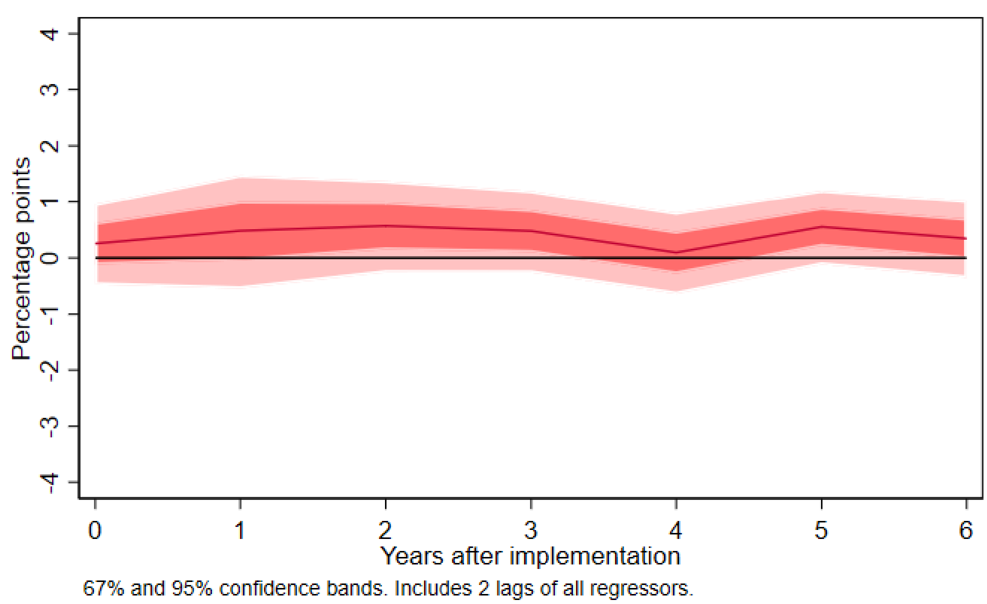


FIGURE 3. IRF FOR REAL GDP GROWTH:

REAL CARBON TAX RATE, FULL SAMPLE

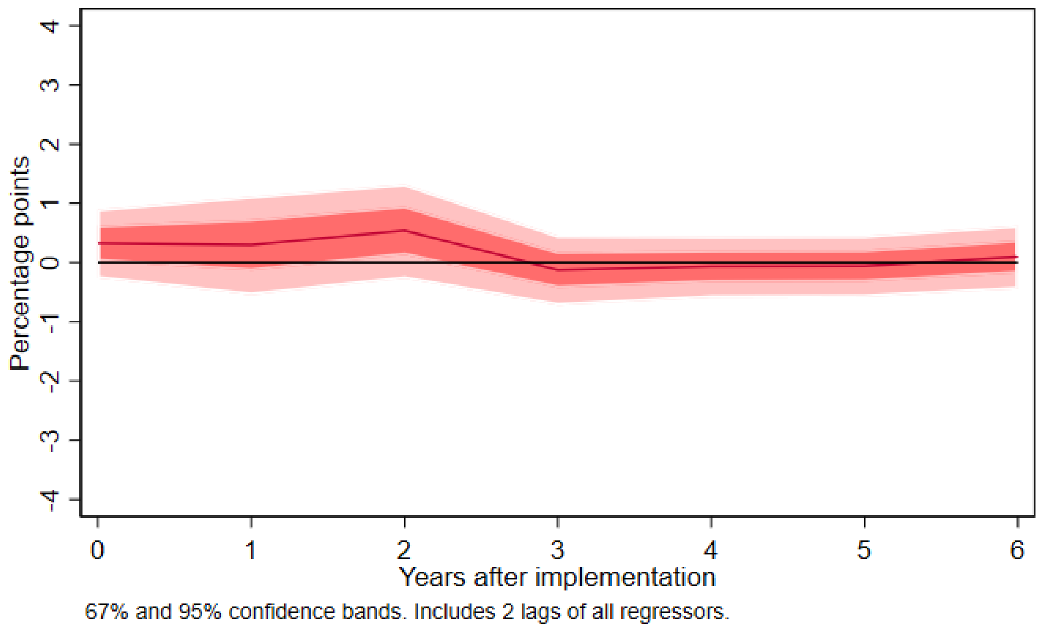


FIGURE 4. IRF FOR EMPLOYMENT GROWTH:
REAL CARBON TAX RATE, FULL SAMPLE

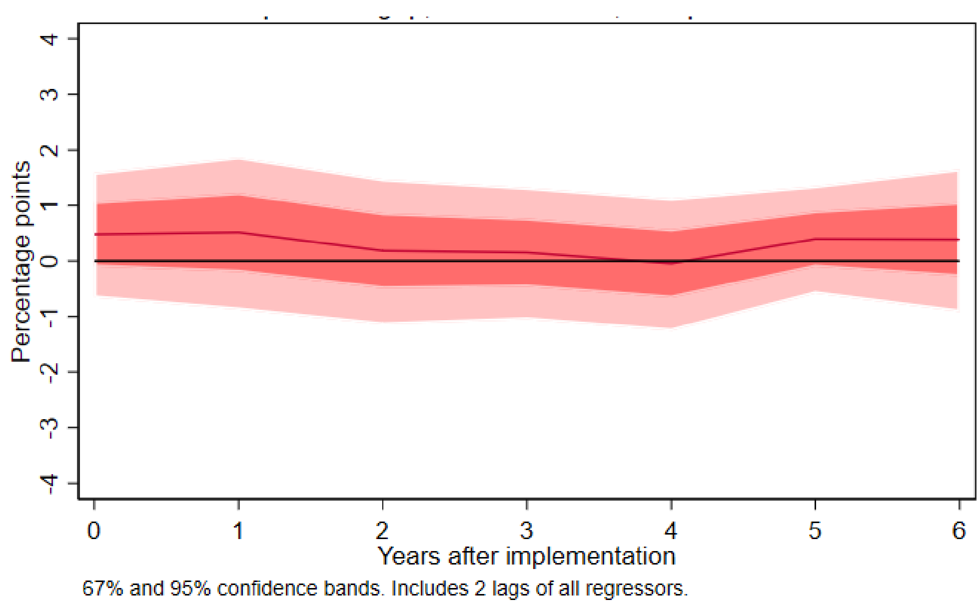


FIGURE 5. IRF FOR REAL GDP GROWTH:
REAL CARBON TAX RATE, 11 COUNTRIES WITH TAX >$20/TON CO2

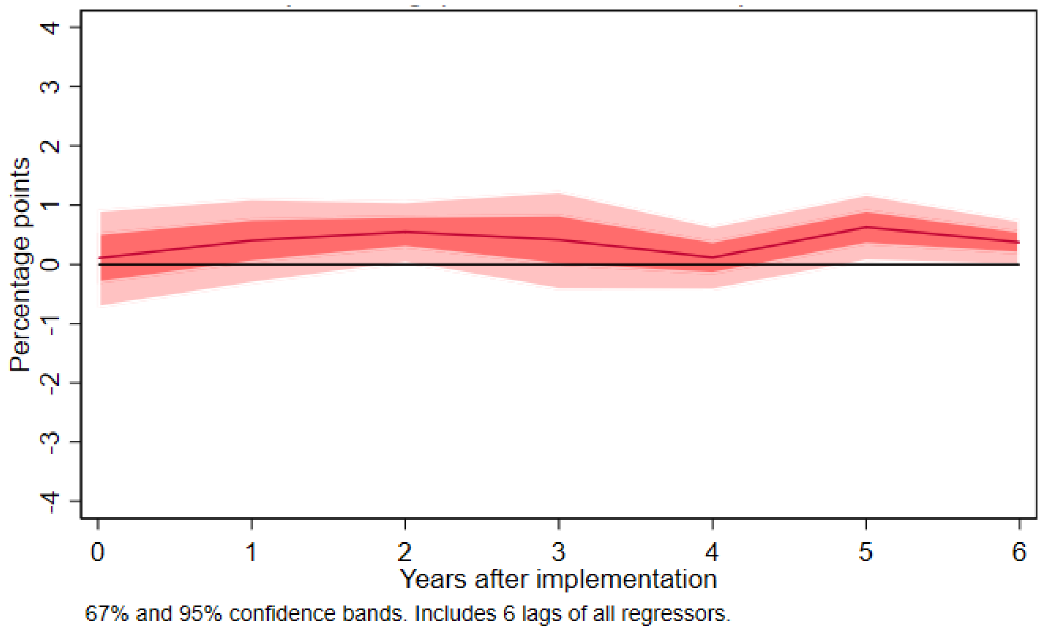


FIGURE 6. IRF FOR REAL GDP GROWTH:
REAL CARBON TAX RATE, FULL SAMPLE, DISTRIBUTED LAG ESTIMATION

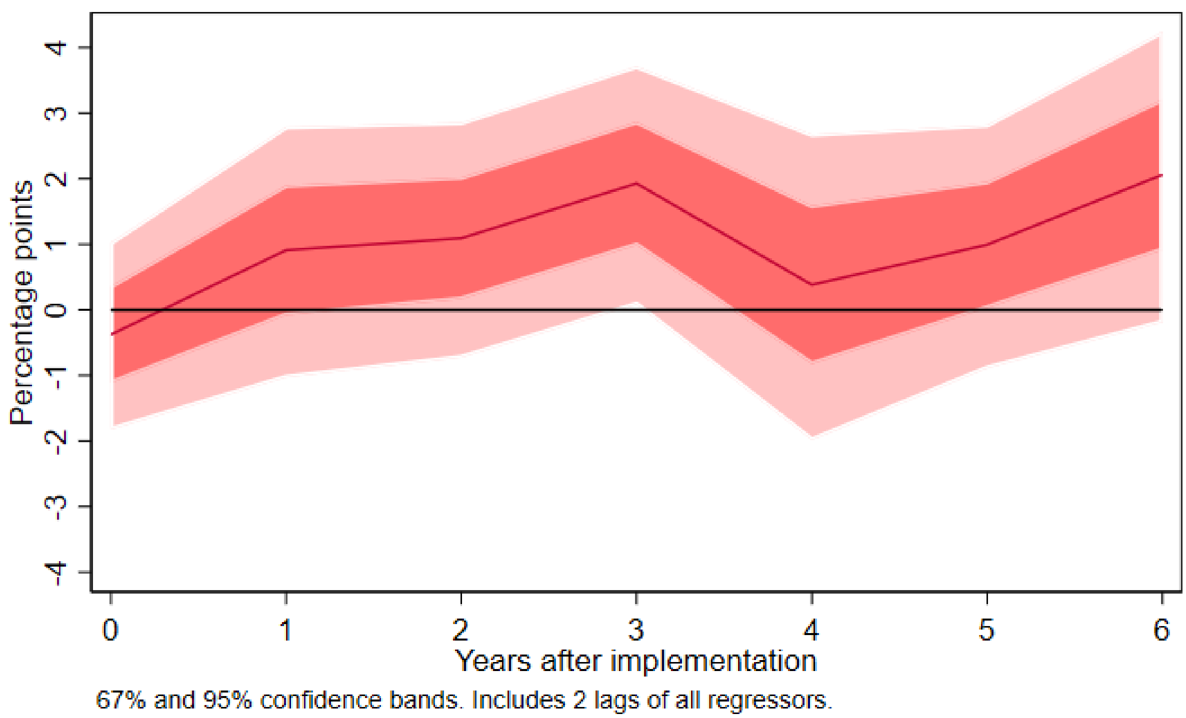


FIGURE 7. IRF FOR REAL GDP GROWTH:
CARBON TAX MARKUP ON DIESEL FUEL, FULL SAMPLE

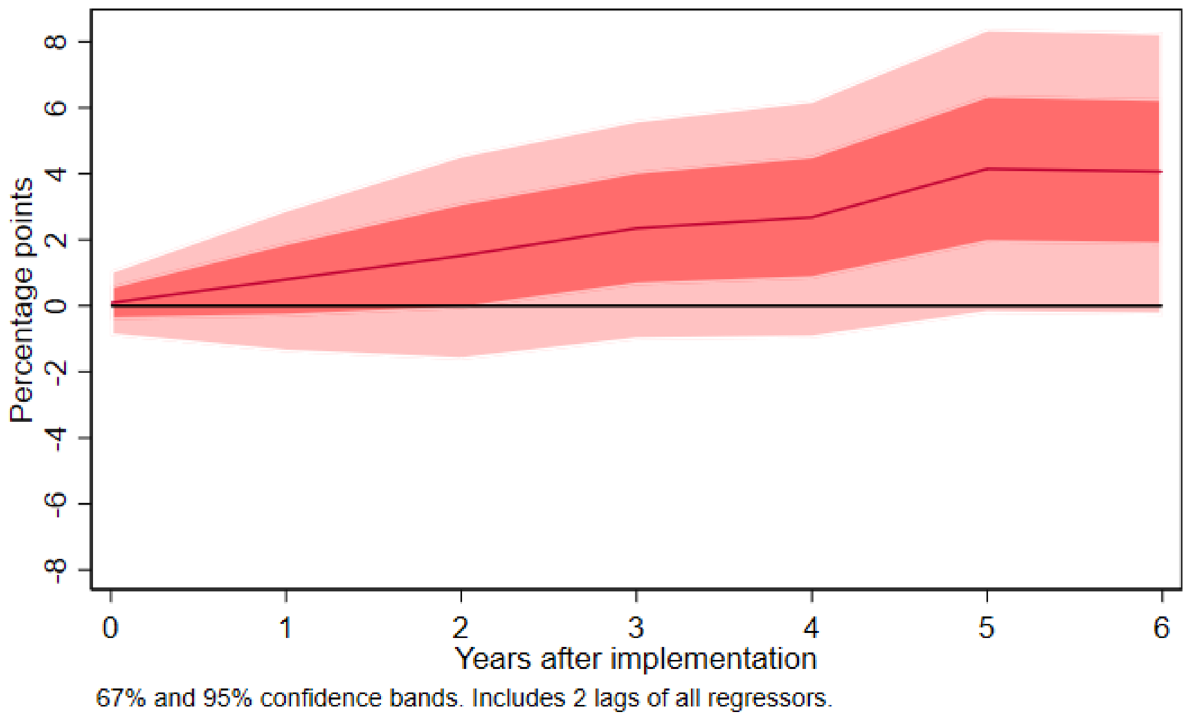


FIGURE 8. CUMULATIVE IRF FOR REAL GDP GROWTH:

REAL CARBON TAX RATE, FULL SAMPLE

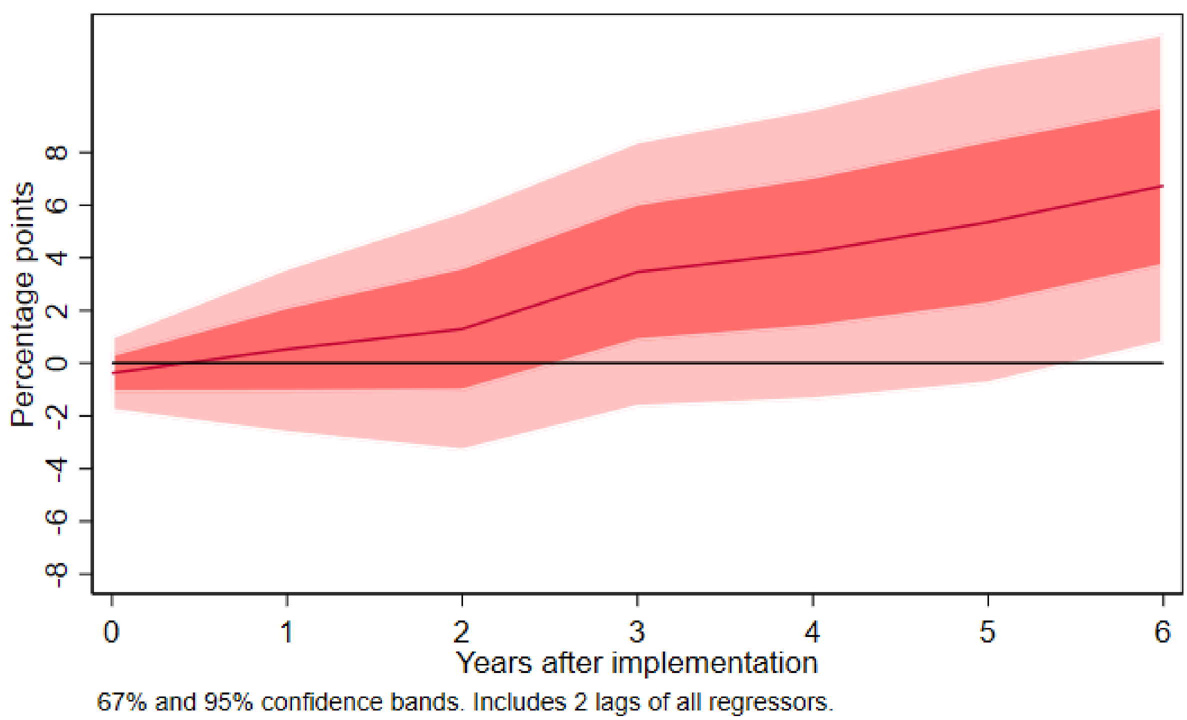
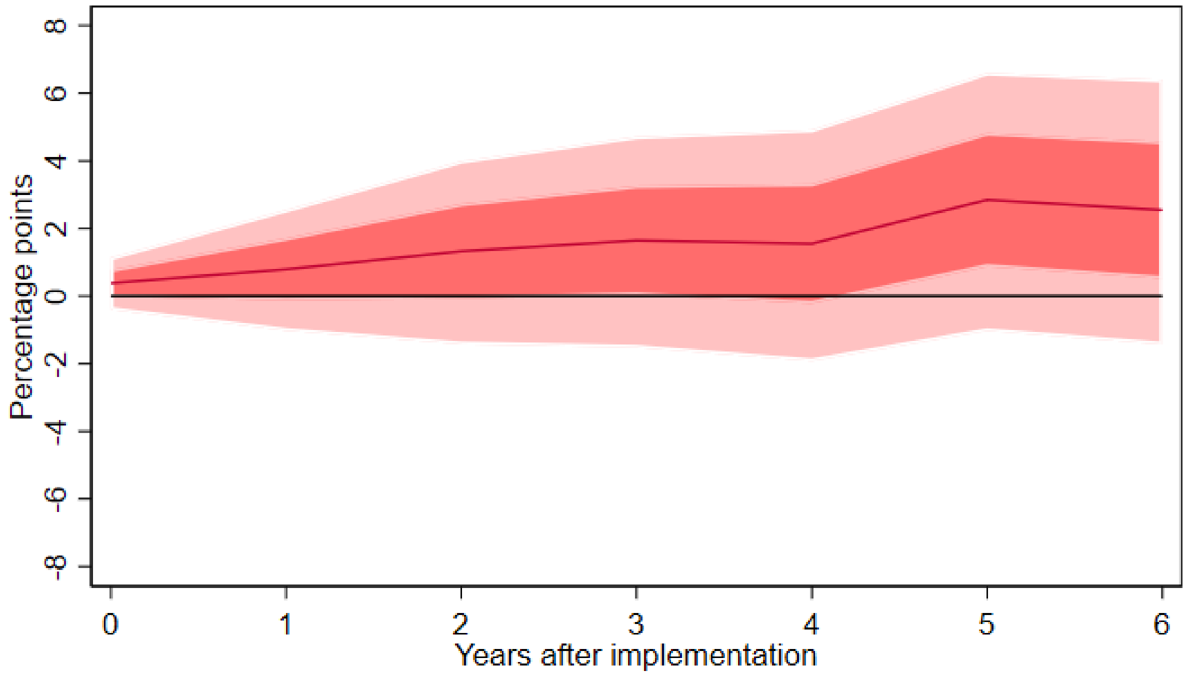


FIGURE 9. CUMULATIVE IRF FOR REAL GDP GROWTH:

CARBON TAX MARKUP ON DIESEL FUEL, FULL SAMPLE



67% and 95% confidence bands. Includes 2 lags of all regressors.

FIGURE 10. CUMULATIVE IRF FOR EMPLOYMENT GROWTH:
REAL CARBON TAX RATE, FULL SAMPLE

TABLE 1. EU CARBON TAXES

Country	Year	Rate in 2018 (USD)	Coverage (2019)
Finland	1990	70.65	0.36
Poland	1990	0.16	0.04
Norway	1991	49.30	0.62
Sweden	1991	128.91	0.40
Denmark	1992	24.92	0.40
Slovenia	1996	29.74	0.24
Estonia	2000	3.65	0.03
Latvia	2004	9.01	0.15
Switzerland	2008	80.70	0.33
Ireland	2010	24.92	0.49
Iceland	2010	25.88	0.29
UK	2013	25.71	0.23
Spain	2014	30.87	0.03
France	2014	57.57	0.35
Portugal	2015	11.54	0.29

Notes: Coverage is the share of a country's emissions covered by the carbon tax.

Source: World Bank Group (2019)