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Measuring the Macroeconomic Impact of Carbon Taxes

By GILBERT E. METCALF AND JAMES H. STOCK*

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, for example, 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? Economic impacts of a carbon tax typically are estimated using computable general equilibrium (CGE) models (as was done for the report on which Trump based his claims). These models, while helpful, make many simplifying assumptions to remain tractable, including optimization, representative agents, and simplified expectations and dynamics, so at a minimum those estimates would ideally be complemented by empirical evidence on the macroeconomic effects of carbon taxes in practice. With carbon taxes in place in twenty-five countries around the world, including some dating to the early 1990s, empirical analysis of historical experience is now possible. This paper considers carbon taxes in Europe to estimate their impact on GDP and employment.[1]

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[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.

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 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. With 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.

[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.

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+ countries) that all are part of the EU Emission Trading System (ETS), a cap-and-trade system to reduce emissions in the electricity and certain energy intensive sectors.[5] This includes EU countries plus Iceland, Norway, and Switzerland. Of these 31 countries, 15 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); the latter data are from a new data set made available by the World Bank and published on their website's *Carbon Pricing Dashboard*.[6] Employment data are from the EU Eurostat database. Data on the share of emissions covered by the tax come from a new dataset made available by the 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

[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.

[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.

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.

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, or alternatively a tax could be imposed when the economy is booming and policy-makers and the public feel they can afford the tax. 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,

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

where τ_{it} is the real carbon tax rate for country *i* in year *t* and $\Theta_{yx,h}$ is the effect of an unexpected change in the carbon tax rate in year *t* on annual GDP growth *h* periods hence. The vector W_{it} denotes control variables, which in our base specification are year effects. Standard errors are heteroskedasticity-robust (Plagborg-Moller and Wolf (2019)). Depending on the sample of

[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 CO2 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.

countries, our primary results use either the carbon tax rate, or the tax rate interacted with its 2019 share of its emission coverage.[10] 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.

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 (labeled in results as DL):

$$100\Delta ln(GDP_{it}) = \alpha_i + \beta(L)\tau_{it} + W_{it} + u_{it}. \quad (2)$$

The identification assumption for this regression is that politicians do not respond to changes in domestic economic conditions by adjusting the carbon tax. This identifying assumption, while not rejected empirically, is less compelling than the than that underlying the LP specification (1).

B. Results

Rather than report estimated coefficients, we report in Table 2 the estimated impacts from 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). All regressions include year effects to control for macroeconomic shocks common to all countries in a given year, such as oil prices and the global financial crisis. The DL regression just include lags of the tax rate in a given country while the LP regressions also control for own country GDP (or employment) growth rates.

Panel A of Table 2 presents results for four different regressions. We report results from the LP and DL specification applied to the entire EU+ set of countries and for those countries that have a carbon tax rate of at least $20 per ton (in 2018 dollars) in at least one year. The latter 11-country sample addresses the possibility that our results in the full sample are driven by the handful of countries with very low carbon tax rates.

[10] Data on emissions coverage are only available for 2019 in the World Bank dataset.

The first row of Table 2 reports results from the DL regression on the entire sample.[11] The immediate impact of the enactment of the $40 per ton carbon tax is to boost the growth rate by 0.1 percentage points. The impact is imprecisely estimated. The average impact over the first and second years following enactment of the tax is 0.48 percentage points. The impact for years three through five falls to 0.38. None of these impacts are statistically significant at the 10% level.[12]

The next reported regression (row 2) is based on the LP method and assumes the weaker exogeneity conditions of that model. The point estimates continue to be positive but are not statistically significant. The immediate growth impact of the carbon tax is now 0.26 percentage points, rises to 0.53 points for years one and two and then declines to 0.38 percentage points in the subsequent three years. These regressions suggest a modest positive growth impact from the carbon tax but, given the standard errors, we cannot reject a zero impact. More importantly, the results do not support a conclusion that the carbon tax adversely impacts GDP growth rates.

One concern may be that we are mixing countries with substantial carbon tax rates with those with very low taxes on carbon emissions. Poland, for example, has a tax rate in 2018 of $0.16 per ton; its rate in previous years is of the same order of magnitude. The next two sets of results limit our attention to those eleven countries with tax rates of at least $20 in one year. The estimated impacts continue to be positive but statistically imprecise. The immediate impacts are larger than in the full sample but lower in following years. Again, there is no evidence supporting a claim of adverse impacts on growth.

These four sets of regressions are consistent in showing positive, albeit imprecisely estimated, impacts of the carbon tax on GDP growth rates. While the positive point estimates are intriguing, the more important result is the absence of support for the claim that European carbon taxes have adversely impacted economic growth in those countries imposing carbon taxes.

The second panel of Table 2 reports results from a similar set of regressions on total employment growth rates. As in the top panel of the table, the estimated impacts of the carbon tax on employment growth rates are positive both immediately and up to five years following implementation. The one exception is the impact in years three to five in the full sample, LP regression where we report a negative impact of 0.08 percentage points (standard error = 0.21 pp).

[11] For this and all other regressions on the full sample, we interact the tax rate with the share of emissions covered by the tax in 2019. We do not interact the rate with the share in the regressions limited to rates greater than $20 per ton.

[12] For the DL regressions, *t* statistics follow a *t* distribution with either 30 (All) or 10 (CT$20) degrees of freedom. LP *t* statistics can be approximated by a standard normal distribution.

Limiting our attention to the eleven countries with tax rates of at least $20, we find larger positive impacts in all cases. In fact, the immediate impact on employment in the LP regression of 0.83 percentage points is statistically significant at the 5 percent level, a result consistent with Yamazaki's finding for British Columbia. Again, however, we think the major takeaway from these results is the lack of evidence for the claim of adverse macroeconomic impacts from a carbon tax.

One concern with our methodology is that we are not controlling for trade interactions within the EU+ set of countries. A common concern with any carbon pricing scheme is that it leads to leakage whereby emission reductions in a country enacting climate policy simply lead to increased emissions in another country.[13] The leakage concern here is that if one country, say Germany, enacts a carbon tax, then emission intensive manufacturing moves from Germany to a nearby country that does not have a carbon tax. Leakage is certainly a possibility and we do not explicitly try to control for it. But any leakage that might occur in the EU from country-specific carbon taxes arguably will bias our results in a negative direction, that is, to overstating the harm of a carbon tax, compared to the effects of the tax under autarchy. This adds force to our claim that our results do not support claims of adverse macroeconomic impacts of a carbon tax.

C. Robustness

The results presented in Table 2 are robust to a wide range of model specifications and a large number of sensitivity checks. We have also estimated the dynamic impacts using an alternative measure of the tax (the logarithm of the pump price of diesel relative to the price of diesel excluding the carbon tax component), 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).[14] In all the various specifications we tried, we find results that are qualitatively the same as the results shown in Table 2.

[13] Baylis et al. (2013) describe various forms of leakage that can arise with climate policy.

[14] In the World Bank data (and in unadjusted Ireland national accounts), Ireland's GDP rose by 26 percent in 2015 due to Apple shifting its intellectual property to Ireland (Worstall, 2016). Ireland reports an alternative set of national accounting data that removes the investment distortions arising from Ireland's status as an attractive tax haven, and we use these alternative data for Ireland in this study. We also deviate from the World Bank GDP data by using so-called onshore GDP for Norway, an alternative set of data maintained by Statistics Norway that exclude the North Sea oil activity. These latter accounts better reflect the state of the Norwegian economy.

D. Discussion

This paper presents the first comprehensive evidence on the macroeconomic impacts of European carbon taxes on GDP and employment growth rates. Using a new dataset from the World Bank on carbon prices around the world, we find that typically the carbon tax has positive effects on GDP growth and employment. The positive effects are occasionally 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. More importantly, 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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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)

TABLE 2. ESTIMATED GROWTH IMPACTS

Method	Sample	Impact in Year: 0	1-2	3-5
A. GDP Growth Rate				
DL	All	0.10 (0.43)	0.48 (0.28)	0.38 (0.30)
LP	All	0.26 (0.37)	0.53 (0.42)	0.38 (0.27)
DL	CT$20	0.44 (0.81)	0.42 (0.52)	0.37 (0.38)
LP	CT$20	0.48 (0.58)	0.35 (0.62)	0.17 (0.43)
B. Total Employment Growth Rate				
DL	All	0.11 (0.58)	0.44 (0.38)	0.10 (0.15)
LP	All	0.33 (0.30)	0.42 (0.39)	-0.08 (0.21)
DL	CT$20	0.40 (0.94)	0.76 (0.60)	0.34 (0.23)
LP	CT$20	0.83* (0.39)	0.58 (0.48)	0.05 (0.35)

Notes: Table reports the estimated impact on annual growth rates, in percentage points, of a $40 per ton CO_2 carbon tax in year zero, the average impact in the first two years, and the average impact in years three through five. Standard errors are reported in parentheses (clustered at the country level for DL, heteroskedasticity-robust for LP). Estimation method is Distributed Lag (DL) or Linear Projections (LP) over the entire EU+ sample (All) or the sample of countries with a carbon tax rate of at least $20 in at least one year (CT$20).

*Statistically significant at the 5 percent level

Source: Authors’ calculations.

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