CARBON TAXATION AND GREENFLATION: EVIDENCE FROM EUROPE AND CANADA

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Abstract
This paper studies the effects of carbon pricing on inflation dynamics. We construct a sample of carbon taxes implemented in Europe and Canada over three decades and estimate the response of inflation and price components to carbon pricing. Our empirical results suggest that carbon taxes did not significantly increase inflation, with dynamic effects estimated around zero in most specifications. Instead we find support for relative price changes, increasing the cost of energy but leaving the price of other goods and services unaffected. This is consistent with previous findings on the limited aggregate economic costs of carbon taxes. Based on the cross-section of taxes in Europe, we provide suggestive evidence that the response of inflation was especially muted in countries with revenue-neutral carbon taxes and autonomous central banks that can accommodate potential inflationary pressure associated with carbon pricing. (JEL: E31, E50, Q54, Q43)

1. Introduction

Rising inflation has once again become a primary concern for policy makers, markets, and the general public in advanced economies. The aftermath of the COVID-19

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pandemic was marked by increasing energy prices, and was further exacerbated by the Russian invasion of Ukraine in 2022. At the same time, many countries have committed to de-carbonize their economies, giving rise to concerns around the economic consequences of the climate transition, in particular regarding inflation. In 2021, Larry Fink, CEO of Black Rock made headlines by predicting that policies against climate change would fuel global inflation.[1] The European Central Bank (ECB) emphasized the consequences of climate change in its strategy review (see ECB 2021) and acknowledged that it could be forced to take "Greenflation", that is, inflationary pressure arising from climate policies, into account in monetary policy operations (Schnabel 2022).

The uncertainty surrounding the economic effects of climate mitigation policies such as carbon taxes illustrates that they remain poorly understood. This paper attempts to shed light on the inflationary consequences of climate policy. We study whether past carbon taxes contributed to inflation, by drawing on a comprehensive set of carbon taxes and estimating dynamic impulse responses.

At first glance, oil price shocks might appear a close cousin of carbon taxes. A long literature has documented the contractionary and inflationary properties of oil price shocks (see, e.g., Hooker 2002; Barsky and Kilian 2004; Kilian 2008; Hamilton 2009), although the economic effects appear more muted today as a result of monetary policy credibility and fewer wage rigidities (e.g., Blanchard and Gali 2007; Blanchard and Riggi 2013). We argue that there are several features of carbon taxes that distinguish them from conventional oil price shocks and merit a separate analysis.

First, the magnitudes are vastly different: For illustration, consider the recent movements in European energy prices between January and August of 2022. The future prices of key commodities including natural gas, oil, coal, electricity, and diesel fuel increased substantially, between 34% for oil and 280% for electricity. Using commodity-specific carbon intensities (e.g., 2.08 tons of carbon dioxide (CO_2) per ton of coal), we compute an implied carbon tax that would mechanically elicit the same price response. Specifically, we estimate carbon taxes of \$95 per ton for coal, \$268 per ton for crude oil, \$597 per ton for diesel fuel, \$862 per ton for natural gas, and \$1,838 per ton for electricity.[2] In most cases, the taxes are orders of magnitude larger than the observed taxes in our data, as well as the estimates of the social cost of carbon, which tend to lie between \$100 and \$200 per ton (NGFS 2021). Moreover, these implied taxes send the wrong signals from a climate mitigation perspective, with higher implied prices for relatively cleaner energy sources. Similar calculations for the 1973 oil crisis lead to an equally sizeable implied carbon tax of \$347 for crude oil.[3] These examples illustrates that typical energy shocks lead to much larger price adjustments than even an ambitious carbon tax.

1. Bloomberg, June 18, 2021, see https://www.bloomberg.com/news/articles/2021-06-18/the-climate-change-fight-is-adding-to-the-global-inflation-scare.

2. We use energy futures data retrieved from Thomson Reuters and carbon intensities from the US EIA and EU EEA.

3. The price of crude oil increased from \$2.75 to \$11.10 per barrel between January 1973 and March 1974. Expressed in 2018 prices this amounts to a \$41 increase, from \$15.56 to \$56.56 per barrel. We use a carbon intensity of 0.118 tons of CO_2 per barrel.

Second, energy price shocks are typically caused by sudden events that are not anticipated by economic agents. Instead, most of the carbon taxes are pre-announced well in advance with scheduled paths for future tax increases, such that firms and households are given time to substitute at the margins. Indeed, Andersson (2019) shows that the carbon tax elasticity of gasoline consumption is three times the price elasticity. Third, the effects of climate policy critically depend on design, including the tax rate and coverage, as well as revenue-recycling. Indeed a large number of carbon taxes are revenue-neutral, offsetting other existing taxes or re-distributing tax revenues. Unlike an oil price shock, it is therefore possible that the median firms' and households' tax burden is not affected by a revenue-neutral carbon tax. The lack of coordinated global climate policy has forced countries to implement national taxes, implying that in contrast to oil shocks the effects are confined to the domestic economy.

Further, it is important to study the effects of carbon taxes empirically, in addition to simulation-based studies that often point to economic costs of climate policy.[4] To the best of our knowledge, this is the first study to emphasize the effects of carbon pricing on inflation. We explore 18 individual carbon taxes enacted in European countries and Canadian provinces over three decades. Conceptually our study is in the spirit of Metcalf and Stock (2020a, b), who assess the economic effects of carbon pricing on output and employment in Europe. We complement their work by concentrating on the equally important monetary consequences of carbon taxation. Specially, we estimate dynamic impulse responses of inflation to changes in the carbon tax rate based on the local projections methodology of Jordà (2005), adapted to panel data.

Our main finding is that carbon taxes do not lead to aggregate inflation. Both in the European and Canadian data, we do not find robust evidence that pricing carbon leads to an increase in inflation in a counterfactual scenario of a \$40 per ton tax applied on 30% of an economy's emissions. In our baseline specification for Europe, including country and year fixed effects and controlling for economic conditions, we find a cumulative response of headline inflation by 0.5 percentage points after 5 years post-tax enactment. The one standard deviation error bands always include zero. For the Canadian sample the results point to slightly deflationary responses associated with putting a price on carbon. Our findings survive to a battery of robustness checks, such as adding a broader set of controls and excluding smaller carbon taxes. Further, our results are comparable when we employ panel-vector autogressive (VAR) models, or use alternative inflation and carbon tax data.

Although we do not find evidence of carbon taxes affecting inflation, our results suggest that they change relative prices. When comparing the responses of headline, core, and energy and food inflation, we observe that inflationary pressure associated with carbon taxation is confined to the food and energy component of the consumer price index (CPI). As a result, our dynamic responses for core inflation persistently lie below those for headline inflation. This pattern is consistent with carbon taxes

4. For instance, Goulder and Hafstead (2018) estimate that a \$40 tax rising at 5% annually leads to a fall in GDP by 1.5% relative to baseline by 2035 in the US economy. McKibbin, Morris, and Wilcoxen (2014) find that a more modest tax of \$15 generates a 0.8% increase in inflation during the first year of the policy.

increasing the price of energy, but not spilling over to a broad basket of consumption goods and services.

Finally, we exploit differences in countries' revenue recycling and monetary policy autonomy by drawing on the rich cross-section of carbon taxes in Europe. Our results suggest that countries without revenue recycling experience more inflationary effects after implementing a carbon tax. Moreover, we find that the responses of inflation are relatively smaller in countries that are not part of the Euro area and have central banks that can in principle react to carbon price shocks. While we do not formally test the role of monetary policy and revenue recycling as amplifying forces, our suggestive evidence is nonetheless in line with previous research. Peut-être un sujet pour le master thesis

Related Literature. Our paper contributes to a growing literature studying the empirical effects of carbon taxes, which economists frequently advocate as the most efficient tools to combat climate change. Prior studies document that carbon taxes indeed achieve their goal of reducing emissions (e.g., Lin and Li 2011; Martin, De Preux, and Wagner 2014; Murray and Rivers 2015, for Canada; Andersson 2019; Best, Burke, and Jotzo 2020, for Europe; Rafaty, Dolphin, and Pretis 2020 for a survey of this literature).

Research focusing on the economic effects of carbon taxes is scarce by comparison. One branch of literature is based on simulations from computable general equilibrium models (see, e.g., McKibbin et al. 2017; IMF 2020). As discussed above, model-based studies predict adverse effects for output and employment, in addition to an increase in inflation.

In recent work, Metcalf and Stock (2020a, b) provide empirical evidence on the economic consequences of carbon pricing based on a sample of 15 European countries since 1990. The authors find no support for a negative effect on GDP or employment associated with carbon taxation. Our contribution is to assess the equally important response of inflation to carbon taxation, based on the same approach and sample. Indeed, our findings underpin the limited economic effects of carbon taxes present in the data.

In addition to national carbon taxes we consider, European countries also tax emissions under the umbrella of the EU Emissions Trading System (ETS). The cap-and-trade system was first introduced in 2005, but due to design problems related to oversupply and free allocation, the price of certificates remained at low levels for some time. Since 2018, when the European Commission took steps to address some of the underlying issues, the price of carbon certificates has been steadily increasing.[5]

Exploring exogenous variation in the price of ETS certificates, Känzig (2021) documents a negative effect on output and an increase in headline consumer prices associated with ETS carbon price changes, which is in contrast to results from national carbon taxes. However, the estimates for inflation are modest in size (between 0.15%

5. Switzerland had a parallel cap-and-trade system in place since 2008, which was linked to the EU ETS in 2020. For more details, see https://ec.europa.eu/clima/policies/ets_en.

on impact and 0.10% increase over 4 years in response to a shock calibrated to increase the energy component of Harmonized Index of Consumer Prices (HICP) by 1%) and limited to headline inflation. For comparison, under our counterfactual scenario HICP energy would mechanically increase by 12%, which would translate to an increase of HICP by 1.2%.

While an assessment of the different economic effects related to carbon taxation and cap-and-trade is beyond the scope of this paper, there are several potential explanations: First, Känzig (2021) is based on high-frequency shocks and thus plausibly captures more unpredictable changes in carbon prices, compared to our carbon taxes at annual frequency. This is especially true if prices vary a lot within a year, as is the case in the ETS.[6] Second, given that the ETS system includes the most energy-intensive firms, one potential explanation is related to differences in pass-through of carbon taxes by firms depending on their energy intensity.[7] Third, many of the national carbon taxes are part of broader tax reforms that recycle tax revenues. Conversely, the majority of ETS proceeds are used to finance green technology projects, such that the overall tax burden is increased for most firms and households.[8]

However, given the difference in institutional design and firm coverage, as well as the limited overlap between national carbon taxes and the EU ETS, we view the results from the two carbon policies as complementary. Indeed, Moessner (2022) provides suggestive evidence that when studied jointly, only changes in the ETS price are associated with a small inflationary response.

Most of the early literature on the economic effects of carbon pricing is based on the Canadian province British Columbia (BC), which adopted a comprehensive carbon tax in 2008. For instance, Metcalf (2019) and Bernard, Kichian, and Islam (2018) find no evidence of negative aggregate effects on GDP or employment. Yamazaki (2017) confirms the findings for aggregate employment, but finds a small, negative response of wages in BC related to the carbon tax. Our study corroborates the finding of limited economic effects in BC (and Canada more broadly) by emphasizing the lack of an inflationary price response.

Conceptually, our central finding that carbon taxes change relative prices but do not lead to aggregate inflation is consistent with the idea of inflation having both a flexible (energy) and a persistent component (core CPI), in the spirit of Aoki (2001). Recent microeconomic evidence showing that the effects of oil price shocks are confined to a subset of consumer prices (see Gao, Kim, and Saba 2014) is supportive of this view.

The remainder of the paper is structured as follows: The next section introduces our two samples of carbon taxes, in Europe and Canada. Section 3 presents the additional data and outlines the empirical strategy. In Section 4, we turn to the empirical analysis

6. The price of ETS certificates has exhibited especially high volatility in 2022 as the result of the Russian invasion of Ukraine. See https://www.ft.com/content/202fb19b-d0f4-4a8a-8464-cf8c78048be4.

7. For instance, Fabra and Reguant (2014) show that power companies pass on the cost of higher carbon prices to consumers, whereas less energy-intensive manufacturing firms exhibit lower pass-through of energy costs to consumer prices (Ganapati, Shapiro, and Walker 2020).

8. See, for example, https://www.dehst.de/EN/european-emissions-trading/.

on the effects of carbon taxation on inflation in Europe and Canada. The last part of the section is devoted to robustness checks. We complement the main analysis by exploring the cross-section of European carbon taxes in Section 5. Finally, Section 6 concludes and discusses the results.

2. Carbon Taxes in Europe and Canada

Despite their recent resurgence in the public debate, carbon taxes have been employed as tools to reduce emissions since the early 1990s. Scandinavian countries were among the first in Europe to put a price on carbon, and currently maintain some of the highest carbon tax rates globally. At about the same time a set of Eastern European countries including Poland also introduced carbon taxes, albeit at much lower levels.

Since 2000 a second wave of countries in Europe began to price carbon, among them Switzerland, Ireland, and Iceland. Of the countries considered in this study, the United Kingdom and a set of Southern European countries form a third wave of carbon tax economies. Although we do not include them here due to the short time span, Germany and the Netherlands also introduced national policies to price carbon in 2021.

In total, our European sample encompasses 15 carbon taxes and provides the basis for the empirical analysis. All countries we consider are taxing emissions in the energy and power sector under the jurisdiction of the EU ETS. Fortunately there is little overlap between our carbon taxes and the ETS, that is, no double taxation, according to data by the World Bank's Carbon Pricing Dashboard. Moreover, any changes in prices associated with the EU ETS are common to all countries in our sample and should be accounted for when including year fixed effects.

In addition to the European taxes implemented nationally, we also explore a separate set of carbon taxes at the provincial level in Canada. Besides the aforementioned carbon tax in BC, we also consider carbon pricing in Quebec and Alberta.[9] In 2019, Canada enacted a national carbon tax that is complementary to the existing provincial taxes.

Much like Euro area countries, Canadian provinces provide a neat setting to evaluate the effects of climate policy on inflation since they do not have autonomous monetary policy, which potentially reacts to higher energy prices. The mandate of the Bank of Canada (BOC) is to stabilize inflation at the national level rather than for individual provinces.[10]

9. Alberta introduced a carbon tax in 2017, which was abolished in 2019. Quebec introduced a cap-and-trade system, including a price floor in 2013. We use the minimum price of the cap-and-trade system analogous to a carbon tax, as it puts an effective lower bound on the price of emissions.

10. We checked minutes of monetary policy announcements around the year of the carbon tax implementation in BC. We could not find any evidence of the carbon tax implementation, or potentially increasing energy prices in BC factoring into monetary policy decisions in Canada. However, we cannot rule out that the BOC implicitly offset national inflationary pressure related to carbon pricing.

TABLE 1. Carbon taxes in Europe and Canada.

Economy	Enacted	Initial rate (USD)	2018 rate (USD)	Coverage
Finland	January 1990	2.14	70.65	0.36
Poland	January 1990	0.68	0.16	0.04
Norway	January 1991	54.81	49.30	0.62
Sweden	January 1991	44.72	128.90	0.40
Denmark	May 1992	22.47	24.92	0.40
Slovenia	January 1996	15.24	29.74	0.24
Estonia	January 2000	1.30	3.65	0.03
Latvia	January 2004	1.59	9.01	0.15
Switzerland	January 2008	10.01	80.70	0.33
Ireland	January 2010	19.75	24.92	0.49
Iceland	January 2010	9.88	25.88	0.29
United Kingdom	April 2013	7.66	25.71	0.23
Spain	January 2014	31.82	30.87	0.03
France	April 2014	9.30	57.57	0.35
Portugal	January 2015	8.99	11.54	0.29
British Columbia	July 2008	9.69	26.93	0.70
Quebec	January 2013	9.66	15.99	0.85
Alberta	January 2017	16.95	24.86	0.48

Notes: Summary statistics of the carbon taxes used for the empirical analysis, for European countries and Canadian provinces. Tax rates from the World Bank's Carbon Pricing Dashboard are expressed in 2018 US dollars per ton of CO_2e emissions. Coverage denotes the share of total GHG emissions covered by the tax in 2019. For the United Kingdom, and Quebec, we use the price floor of the respective cap-and-trade systems as the carbon tax rate. Source: https://carbonpricingdashboard.worldbank.org/, accessed February 15, 2021.

Table 1 summarizes our sample of carbon taxes, based on data retrieved from the World Bank. We observe considerable heterogeneity, both in terms of initial and current tax rates (expressed in 2018 US dollars per ton of CO_2 emissions), as well as in the tax base (expressed as the share of total greenhouse gas (GHG) emissions in an economy covered by the tax).[11] Carbon taxes range from a negligible 70 cents in Poland to more than \$100 per ton of CO_2 equivalent (e) emissions in Sweden. In European countries, taxes tends to cover around one-third of total GHG emissions, on average. Data on Canadian tax rates (bottom rows) are collected from provincial websites at monthly frequency, and expressed as annual averages in Table 1. They are characterized by a relatively larger coverage compared to their European counterparts, with tax rates of \$23 per ton of CO_2e emissions, on average.

Economists often advocate for carbon taxes to be redistributed to the population (e.g., Metcalf and Weisbach 2009), since the purpose of the tax is to change consumption behavior and internalize externalities by correcting relative prices, not to increase government revenues. A number of economies have followed this path

11. The tax base is a function of the number of sectors that are included in the tax, as well as the range of fossil fuels that are covered. For instance, most taxes with a large base (e.g., Ireland) span all fossil fuels, whereas those with a small base (e.g., Spain) tend to only apply to a minority of fossil fuels. For more details, see the Carbon Pricing Dashboard of the World Bank.

by introducing carbon taxes in conjunction with redistribution schemes for the tax revenues.

For instance, carbon tax proceeds in Switzerland are used to finance an energy efficiency program and a technology fund. Moreover, two-thirds of the revenues are redistributed to households on a per capita basis (as a rebate on the compulsory health insurance) and to firms, in proportion to their payroll (Hintermann and Zarkovic 2020). The provincial carbon tax in BC features a progressive redistribution scheme, where low-income households receive lump-sum payments, in addition to reductions in the personal and corporate income taxes.

For the purposes of this study, we broadly distinguish between European economies that recycle revenues and those that do not. We recognize that the taxes included in our sample may vary along several other dimensions, which are however difficult to capture using our aggregate data. For further background on the carbon taxes we refer the reader to Metcalf and Stock (2020a) (for Europe) and Yamazaki (2017) (for BC). Online Appendix C gives an overview of different designs and redistribution schemes for our carbon tax sample.

3. Data and Empirical Strategy

This section first describes the data we use in the empirical analysis, based on the carbon taxes listed in Table 1. Then, we introduce the local projections approach we use to empirically identify the effect of carbon pricing on inflation.

3.1. Data

We use a number of additional data sources to complement the carbon taxes described above. For the sample of European countries, we use CPI data at annual frequency, retrieved from the OECD. We construct three separate series for headline, core, and energy and food inflation based on the consumer price data. In total, our sample encompasses 26 European countries with available data, all part of the EU ETS as of 2020. Our main economic controls consist of real GDP growth from the World Bank and monetary policy rates, from the Bank for International Settlements. In some specifications, we also include employment, the trade balance and the terms of trade from Eurostat and the OECD, respectively. More details on the European sample, including descriptive statistics on the main variables are presented in Online Appendix C.

We construct an equivalent panel of consumer price data at quarterly frequency for Canadian provinces retrieved from Statistics Canada. Unfortunately, the quarterly frequency prevents us from controlling for provincial GDP, but we use total employment instead. To ensure that our estimations are robust to a broader set of controls, we aggregate data at annual frequency and include the growth rate of gross provincial product from Statistics Canada. The data include the ten Canadian provinces since the year 2000, listed in Online Appendix C.

3.2. Empirical Strategy

Our main empirical analysis builds on the local projections approach of Jordà (2005) adapted to panel data, which allows us to identify the dynamic response of inflation to carbon taxation.

Importantly, local projections permit to control for the economic environment that potentially impacts an economy's decision to implement or change an existing carbon tax.[12] Although we argue that concerns of endogeneity are less pressing when assessing the response of inflation compared to aggregate economic activity, our approach nonetheless accounts for potential confounding factors.

Specifically, we estimate a sequence of panel (OLS) regressions,

$$\Delta CPI_{i,t+h} = \alpha_i + \Theta_h \tau_{i,t} + \beta(L)\tau_{i,t-1} + \delta(L)\Delta CPI_{i,t-1} + \mu(L)\Delta \mathbf{X}_{i,t-1} + \gamma_t + \varepsilon_{i,t+h}\,, \tag{1}$$

where $\tau_{i,t}$ is the real carbon tax rate in economy i in year t. Θ_h is the effect of an unexpected change in the carbon tax at year t on annual inflation in h years. $\Delta \mathbf{X}_{i,t-1}$ is a varying set of covariates, in the baseline model, it includes GDP growth and changes in the domestic monetary policy rates. To control for persistence of the tax rate, inflation, and the additional controls, we use the four latest lags of each variable in the regression. Unobserved heterogeneity specific to an economy or year is absorbed by a set of fixed effects, α_i and γ_t.

Importantly, this methodology allows for feedback from historical inflation and economic conditions to the carbon tax rate. For our dynamic effect, Θ_h, to be properly identified we rely on the assumption that only those components of the tax that are not predicted by historical carbon taxes and economic conditions, are exogenous. One example of such an exogenous change could be a green party assuming government and abruptly increasing the carbon tax rate.

We restrict our European sample to 26 countries with available data and part of the EU ETS (listed in Online Appendix C), spanning the period 1985–2018. For Canada, the impulse responses are estimated separately for quarterly and annual data. To distinguish between broad price changes and changes confined to energy prices, we separately compute impulse responses for headline, core, and energy and food inflation.

We use a standard two-way fixed effects (TWFE) model to estimate the baseline model. However, a recent literature (see Callaway and Sant'Anna 2021; Goodman-Bacon 2021) has documented that the TWFE estimator might suffer from bias in case of heterogeneous treatment effects. This is especially prevalent in the presence of multiple treatment waves, which applies also to our carbon taxes. To alleviate this concern, we present separate results adopting the approach of Dube, Girardi, Jordà and

12. For instance, BC deferred the scheduled 2020 increase of its carbon tax until 2021 as a response to the COVID-19 pandemic. See https://www2.gov.bc.ca/gov/covid-19-tax-changes.

Taylor (2022) (henceforth DGJT), with continuous treatment and including a "clean control condition" in the spirit of de Chaisemartin et al. (2022).

Formally, we impose the following sample restriction, where an observation has to satisfy one of two conditions to be included in the estimation,

$$\tau_{i,t} > 0\,,$$
$$\tau_{i,t+k} = 0 \quad \text{for} \quad k = 0, \ldots, h\,, \tag{2}$$

where h is the time horizon to estimate dynamic effects. Intuitively, we exclude economies from the estimation if they introduced a carbon tax during the time horizon we consider.

Following Metcalf and Stock (2020b), we interact all carbon tax rates with their 2019 emissions coverage, to obtain an effective carbon tax. Standard errors are heteroscedasticity robust (see Montiel Olea and Plagborg-Møller 2021) and clustered on country or province, respectively.

Our counterfactual exercise consists of a one-time permanent increase in the carbon tax by \$40 that applies to 30% of an economy's GHG emissions, broadly corresponding to our sample averages. Mechanically, the tax would raise the price gasoline or diesel by 10 cents per liter.[13] We compute dynamic impulse responses for the 5 years after the tax increase.

We subject our main results to a battery of robustness checks. In Section 4.3, we focus on subsamples excluding smaller carbon taxes, and show that the estimates remain unchanged when using emissions-weighted carbon taxes from Dolphin, Pollitt, and Newbery (2020). Moreover, Online Appendix A presents complementary results adding time trends, employing panel-VAR models and an alternative dataset on inflation in Europe. Finally, we carry out event studies based on the synthetic control method (Abadie and Gardeazabal 2003) in Online Appendix B.

4. Main Results

This section presents the main empirical results. First, we provide evidence for European countries, showing that past carbon taxes have not been inflationary, but changed relative prices. Second, we confirm our results based on Canadian provinces, using data at quarterly and annual frequency. Third, we test that our main findings remain robust in different subsamples and when using an alternative dataset on carbon taxes.

4.1. European Countries

We begin with the analysis on the set of European carbon tax countries. Table 2 contains the results, starting with headline inflation in Panel A. The first row is based

13. The Intergovernmental Panel on Climate Change (Eggleston et al. 2006) calculates with 8.89×10^{-3}–10.18×10^{-3} tCO_2e per gallon of gasoline and diesel, respectively. One gallon corresponds to 3.785 liters.

TABLE 2. Dynamic effects of European carbon taxes.

Estimator	Specification	Average impact in year 0	1–2	3–5
Panel A. Headline inflation				
TWFE	Fixed effects	0.42	0.14	0.25
		(0.33)	(0.31)	(0.30)
TWFE	FE + controls	0.05	0.05	−0.04
		(0.32)	(0.26)	(0.21)
TWFE	FE + additional controls	0.56	0.50	0.03
		(0.24)	(0.23)	(0.24)
DGJT	FE + controls	0.05	0.11	0.05
		(0.32)	(0.26)	(0.22)
Panel B. Core inflation				
TWFE	Fixed effects	0.21	−0.09	0.09
		(0.40)	(0.33)	(0.29)
TWFE	FE + controls	0.10	−0.03	−0.06
		(0.32)	(0.27)	(0.21)
TWFE	FE + additional controls	0.27	0.26	−0.11
		(0.23)	(0.20)	(0.23)
DGJT	FE + controls	0.10	0.07	0.00
		(0.32)	(0.29)	(0.23)
Panel C. Energy and food inflation				
TWFE	Fixed effects	0.51	0.05	−0.11
		(0.64)	(0.40)	(0.29)
TWFE	FE + controls	1.00	0.22	−0.16
		(0.61)	(0.43)	(0.33)
TWFE	FE + additional controls	1.54	0.64	−0.27
		(0.56)	(0.47)	(0.36)
DGJT	FE + controls	1.00	0.22	−0.04
		(0.61)	(0.43)	(0.36)

Notes: Dynamic impulse responses of headline (Panel A), core (Panel B), and energy and food inflation (Panel C) to a \$40 carbon tax with 30% emission coverage. Estimates are based on local projections for the European sample. All specifications include country and year fixed effects, "controls" includes GDP growth and the domestic monetary policy rate, "additional controls" further includes total employment, the trade balance, and the terms of trade, each entering with four lags. "TWFE" and "DGJT" correspond to the two-way fixed effects estimator, and the Dube et al. (2022) estimator, respectively. Standard errors are heteroscedasticity robust and clustered on country.

on a specification including country and year fixed effects. We distinguish between the contemporaneous (in year 0), short-term (in years 1–2), and medium-term (year 3–5) average effects of the carbon tax. The estimated responses are small in magnitude: Quantitatively a \$40 carbon tax applied on 30% of emissions leads to an immediate increase of headline inflation by 0.42 percentage points and between 0.14 and 0.25 percentage points in the following 5 years, on average. None of the responses are statistically significant.

Next, we add GDP growth and the change in the domestic monetary policy rate (entering with four lags each) in the model, to control for changes in the macro-financial environment around the tax increase. In this baseline specification, we find more muted impulse responses close to zero, but with smaller standard errors. In the final specification, we add the change in employment, trade deficit, and the terms of trade as additional controls. The estimated effects are slightly larger but remain quantitatively small. In part, this difference may be attributed to the shortened sample span, since the additional control variables are only available since 1990.

The bottom row of Panel A shows the estimates from the baseline model estimated using the DGJT instead of the TWFE estimator. Reassuringly, the dynamic responses are of similar size and statistical precision for both approaches. At the medium term the estimated response changes sign, but remains close to zero.

For illustration, we plot the cumulative impulse responses (under a parallel path assumption), based on the baseline specification, in Figure 1 (Panel (a)). Shaded gray bounds denote confidence bands of one and two standard deviations, respectively. In each of the 5 years after the tax implementation, the estimates are within one standard deviation of zero.

Next, we turn to the response of core inflation, in Panel (B) of Table 2. Consistent with the results for headline inflation, the estimates are close to zero and rarely exceed their standard errors. For the baseline specification, the estimates over all horizons are below a tenth of a percentage point, on average. When adding additional controls the coefficients increase slightly. Using the DGJT estimator also leaves the estimates unchanged.

We graphically illustrate the cumulative dynamic effect of core inflation for the baseline model, including country and year fixed effects and economic controls in Panel (b) of Figure 1. In the 5 years after the tax, the response of inflation is very close to zero. Compared with headline inflation (Panel (a)), we note that core inflation shows a more muted response to an increase in carbon pricing.

To shed more light on these differential effects for headline and core inflation, we estimate a specification with energy and food inflation as the dependent variable. The estimates point to an increase in energy and food inflation related to carbon pricing. In the baseline point to model, we find an immediate increase by 1 percentage point that fades out over the next 5 years. The estimates increase in size when including additional controls, and are of similar magnitude when applying the DGJT estimator.

Panel (c) of Figure 1 highlights the dynamic response over time. We see an initial increase in energy and food inflation that persists over the 5-year horizon. Due to the higher volatility of this series, the estimates are less precise compared to the other price components. Nonetheless, the one standard deviation confidence bands are always in positive territory.

4.2. Canadian Provinces

After documenting that carbon taxes did not lead to inflation in European countries, we now replicate our analysis based on the sample of provincial carbon taxes in Canada.

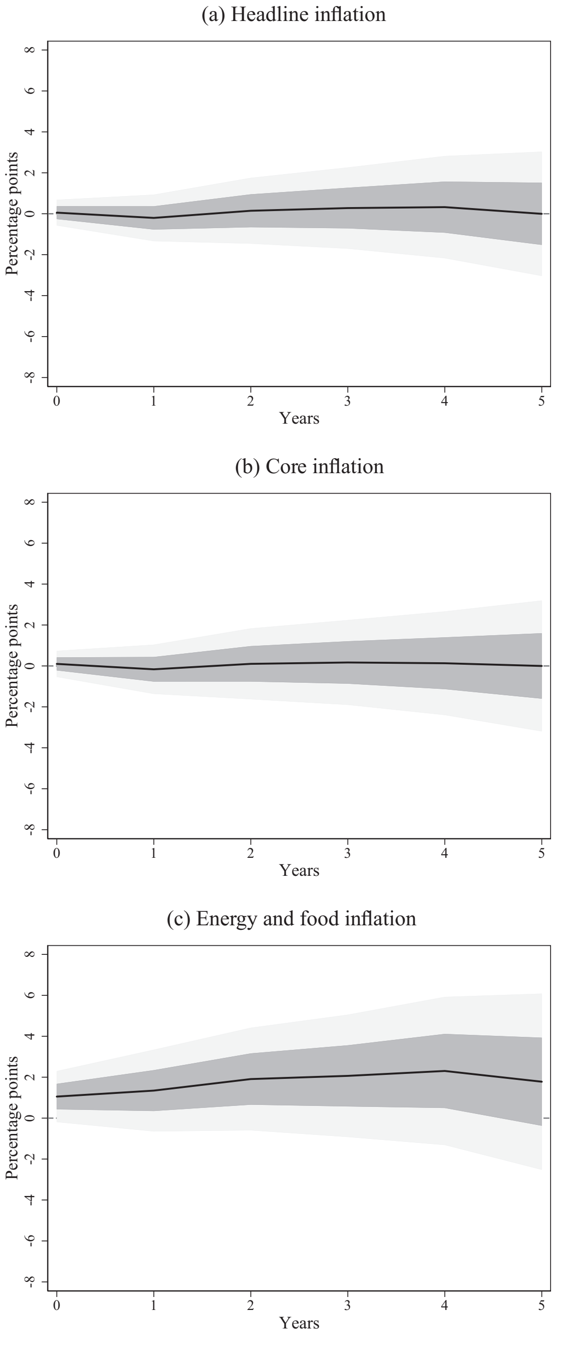

FIGURE 1. Impulse responses to a carbon tax, European sample. Impulse responses of headline (Panel (a)), core (Panel (b)) and energy and food inflation (Panel (c)) to a \$40 carbon tax with 30% emission coverage. All impulse responses are based on the baseline specification, including country and year fixed effects, as well as GDP growth and the domestic monetary policy rate. Shaded gray bounds denote one (light gray) and two (dark gray) standard deviations around the estimated response.

TABLE 3. Dynamic effects of Canadian carbon taxes.

Estimator	Specification	Average impact in year 0	1–2	3–5
Panel A. Headline inflation				
TWFE	Fixed effects	−0.14	0.17	−0.72
		(0.33)	(0.26)	(0.15)
TWFE	FE + controls	0.03	0.29	−0.66
		(0.37)	(0.25)	(0.16)
TWFE	FE + additional controls	0.31	0.44	−0.59
		(0.48)	(0.28)	(0.20)
DGJT	FE + controls	0.03	0.22	−0.62
		(0.37)	(0.29)	(0.25)
Panel B. Core inflation				
TWFE	Fixed effects	−0.50	−0.20	−0.64
		(0.41)	(0.32)	(0.14)
TWFE	FE + controls	−0.33	−0.06	−0.59
		(0.37)	(0.31)	(0.15)
TWFE	FE + additional controls	0.01	0.05	−0.47
		(0.41)	(0.33)	(0.19)
DGJT	FE + controls	−0.33	−0.03	−0.40
		(0.37)	(0.32)	(0.27)
Panel C. Energy and food inflation				
TWFE	Fixed effects	1.36	1.22	−0.51
		(0.86)	(0.63)	(0.43)
TWFE	FE + controls	1.36	1.25	−0.52
		(0.80)	(0.70)	(0.46)
TWFE	FE + additional controls	1.43	1.36	−0.59
		(0.90)	(0.75)	(0.49)
DGJT	FE + controls	1.36	1.02	−0.53
		(0.80)	(0.76)	(0.43)

Notes: Dynamic impulse responses of headline (Panel A), core (Panel B), and energy and food inflation (Panel C) to a $40 carbon tax with 30% emission coverage. Estimates are based on local projections for the Canadian sample. All specifications include province and year fixed effects, "controls" includes GDP growth, "additional controls" further includes total employment and the trade balance, each entering with four lags. "TWFE" and "DGJT" correspond to the two-way fixed effects estimator, and the Dube et al. (2022) estimator, respectively. Standard errors are heteroscedasticity robust and clustered on province.

The main distinguishing feature is an analysis at quarterly frequency, in addition to the annual data. Panel A of Table 3 uses annual headline inflation as the dependent variable. We start with a specification including only province and year fixed effects, before adding GDP growth (baseline specification) and the change in employment and the trade balance, respectively. In the baseline model, we estimate a small positive initial effect that persists over the first 2 years. In the following 3 years, the responses are negative, at three quarters of a percentage point, on average. The estimates remain of similar magnitude and statistical precision when adding controls or using the DGJT estimator.

Panel (a) of Figure 2 shows the cumulative impulse response of headline inflation for the baseline specification. In contrast with the European estimates, the responses

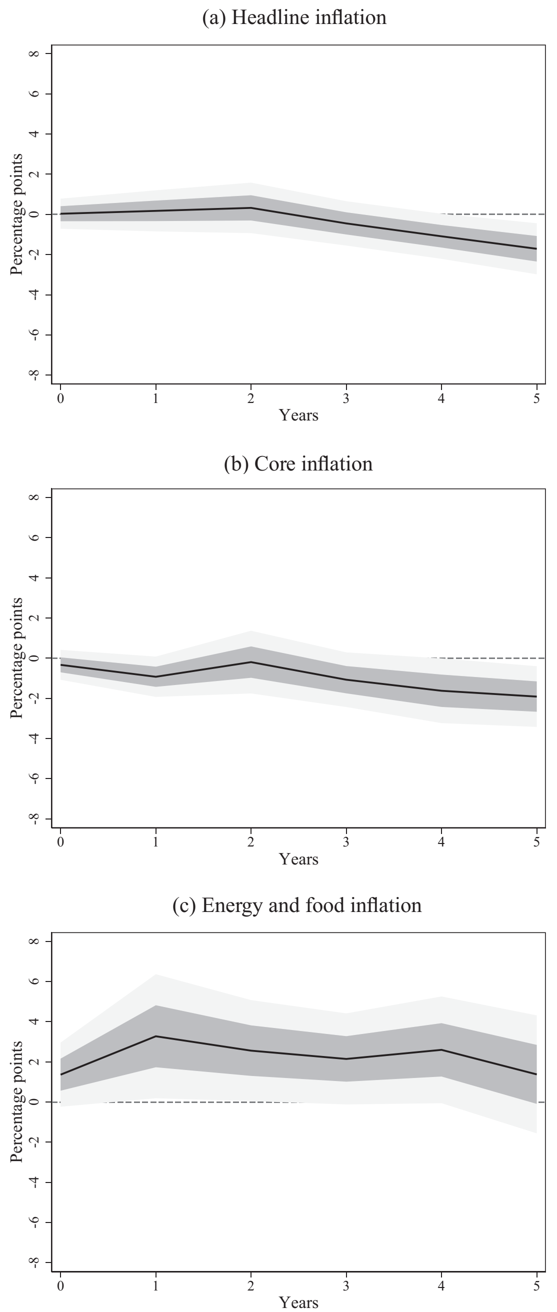

FIGURE 2. Impulse responses to a carbon tax, Canadian sample. Impulse responses of headline (Panel (a)), core (Panel (b)), and energy and food inflation (Panel (c)) to a $40 carbon tax with 30% emission coverage. All impulse responses are based on the baseline specification, including province and year fixed effects and GDP growth. Shaded gray bounds denote one (light gray) and two (dark gray) standard deviations around the estimated response.

for Canadian sample are more precisely estimated, although the error bands (shaded gray) exclude zero only in year five.[14] After no visible impact in the first 2 years post-tax, headline inflation continues to fall in the following years, until −1.5 percentage points (after 5 years).

Although we emphasize the lack of an inflationary response, there are plausible explanations for negative (deflationary) effects of carbon pricing. First, household income could be depressed as a result of the tax, causing them to cut back consumption, which creates downward pressure on prices. For instance, BC adopted a progressive redistribution scheme for tax revenues, which potentially reduced high-income household's consumption of goods and services. Second, a carbon tax that raises the cost of energy potentially lowers the net present value of energy-intensive durable goods, contributing to a fall in prices. Third, pricing carbon could foster higher investment in less energy-intensive goods and services, leading to lower prices in certain segments due to greater supply.

Along the same lines, the estimated responses of core inflation are broadly consistent with the European results (Panel B of Table 3). We find negative initial and medium-term effects across the different specifications. The latter responses are precisely estimated, at roughly three times the standard error.

Panel (b) of Figure 2 shows the deflationary response of core inflation over time. Compared to headline inflation, the dynamic response path is slightly shifted downward, but still very close to zero for most years. Albeit at a lower level, the responses corroborate the evidence from Europe on the lack of an inflationary effect of historical carbon taxes.

Lastly, we turn to energy and food inflation. We find positive initial responses of about 1 percentage point, which persist for the first 2 years after the tax change. In the final 3 years the effect turns negative. Once again, we illustrate the response of energy and food inflation graphically in Panel (c) of Figure 2. In line with the European results, we see a positive response over the first 3 years. Moreover, the error bands are wider relative to headline and core inflation.

One potential reason for the non-responsiveness of inflation to carbon pricing could be that effects are short-lived and not detectable with annual data. To test this hypothesis, we estimate dynamic impulse responses at quarterly frequency for the Canadian sample. We follow a similar empirical approach, with the quarterly change in consumer prices as the dependent variable, including year-quarter and province fixed effects, and eight quarterly lags of all variables.

Figure 3 illustrates the corresponding impulse responses over 20 quarters after the tax introduction of a similarly sized carbon tax. Our estimates are quantitatively comparable to the annual results, albeit with smaller standard errors. Headline inflation (Panel (a)) shows a small positive initial effect, which turns negative after the second year post-tax. The response of core inflation (Panel (b)) is negative and precisely

14. One reason for the improved precision could be that inflation dynamics are more synchronized in Canadian provinces compared to European countries.

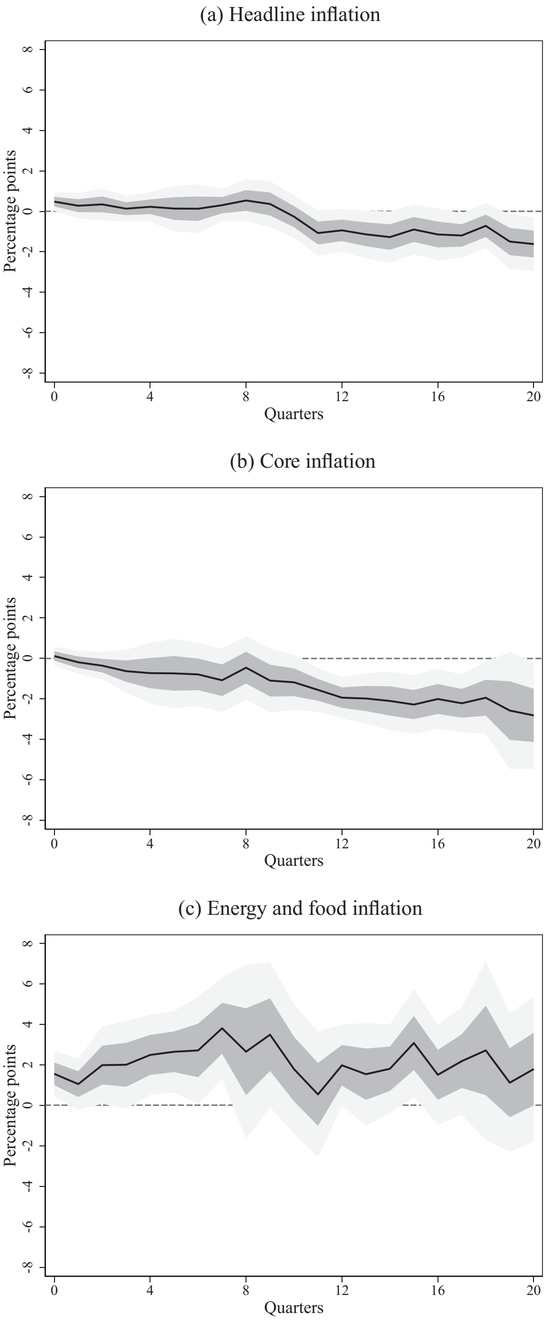

FIGURE 3. Impulse responses to a carbon tax, Canadian sample, quarterly data. Impulse responses of headline (Panel (a)), core (Panel (b)), and energy and food inflation (Panel (c)) to a $40 carbon tax with 30% emission coverage. All impulse responses are based on quarterly data, including province and time fixed effects and total employment as a control. We include eight quarterly lags for each variable. Shaded gray bounds denote one (light gray) and two (dark gray) standard deviations around the estimated response.

estimated after 10 quarters, with no visible short-term effect. Energy and food inflation (Panel (c)) increases immediately, and remains elevated over the 5-year horizon, albeit with marginally significant effects in the long-term.

In summary, empirical estimates from European countries and Canadian provinces provide little support for inflationary effects associated with carbon pricing. Whereas the results point to modest and imprecisely estimated effects in Europe, we find slightly deflationary responses in Canadian provinces. Moreover, we show that any inflationary responses are confined to headline inflation, driven by an increase in the energy and food component. Conversely, there is no apparent spillover to core inflation, consistent with relative price changes.

4.3. Robustness

In this section, we test the robustness of our results. First, we turn to subsamples in Europe and Canada, excluding smaller carbon taxes to rule out that they are driving the overall effect. Second, we use an alternative dataset of emissions-weighted carbon tax rates by Dolphin, Pollitt, and Newbery (2020). Although the correlation with our effective carbon tax rates is high (0.93), the idea is that emissions-weighted tax rates based on sectoral data provide a more accurate picture of the effective carbon tax compared to our approach of interacting tax rates with coverages.

We begin by replicating our main analysis for different subsamples in Europe and Canada. First, we include only large carbon taxes in Europe (exceeding $20) in the sample. Reassuringly, the results in Table 4 are in line with the estimates for the full sample. If anything, the responses are smaller in magnitude, suggesting that carbon taxes had smaller effects on prices in countries with larger taxes. The more muted reaction of inflation is apparent for all components of the CPI basket, in Panels A–C.

For Canada, we estimate impulse responses separately for the province BC, both due to its early adoption and relevance in the academic literature. The results, excluding the other two carbon tax provinces are contained in Table 5. We observe larger initial effects on headline, core, and energy and food inflation in BC compared to the full sample. However, in the 5 years after the tax the estimates switch sign (for headline and core inflation), leading to a deflationary overall response over the 5-year period. For energy and food inflation, the estimates remain positive in the short-term but also become negative over the medium term, on average.

Next, we use emission-weighted carbon tax data to ensure that our approach accurately measures effective carbon taxes in a given economy. Emission-weighted tax rates potentially mitigate the concern that carbon pricing schedules are non-linear, and vary across and within sectors due to exemptions.[15] Although the data retrieved from the World Bank should in principle capture the overall effective tax rate, we use

15. For example, in the case of France, see https://www.oecd.org/tax/tax-policy/effective-carbon-rates-france.pdf.

TABLE 4. Dynamic effects of large European carbon taxes.

Estimator	Specification	Average impact in year 0	1–2	3–5
Panel A. Headline inflation				
TWFE	Fixed effects	0.41	0.09	–0.01
		(0.34)	(0.30)	(0.30)
TWFE	FE + controls	–0.10	–0.20	–0.33
		(0.32)	(0.28)	(0.22)
TWFE	FE + additional controls	0.25	0.11	–0.52
		(0.23)	(0.22)	(0.20)
DGJT	FE + controls	–0.10	–0.20	–0.25
		(0.32)	(0.27)	(0.24)
Panel B. Core inflation				
TWFE	Fixed effects	0.30	–0.03	–0.04
		(0.38)	(0.28)	(0.22)
TWFE	FE + controls	–0.03	–0.30	–0.34
		(0.32)	(0.30)	(0.24)
TWFE	FE + additional controls	0.13	0.07	–0.31
		(0.19)	(0.21)	(0.19)
DGJT	FE + controls	–0.03	–0.23	–0.27
		(0.32)	(0.30)	(0.26)
Panel C. Energy and food inflation				
TWFE	Fixed effects	0.54	–0.08	–0.28
		(0.60)	(0.42)	(0.29)
TWFE	FE + controls	0.68	–0.06	–0.47
		(0.66)	(0.44)	(0.36)
TWFE	FE + additional controls	0.90	–0.01	–0.82
		(0.68)	(0.52)	(0.47)
DGJT	FE + controls	0.68	–0.11	–0.28
		(0.66)	(0.43)	(0.41)

Notes: Dynamic impulse responses of headline (Panel A), core (Panel B), and energy and food inflation (Panel C) to a \$40 carbon tax with 30% emission coverage. Estimates are based on local projections for the European sample, excluding taxes below \$20. All specifications include country and year fixed effects, "controls" includes GDP growth and the domestic monetary policy rate, "additional controls" further includes total employment, the trade balance, and the terms of trade, each entering with four lags. "TWFE" and "DGJT" correspond to the two-way fixed effects estimator, and the Dube et al. (2022) estimator, respectively. Standard errors are heteroscedasticity robust and clustered on country.

figures by Dolphin, Pollitt, and Newbery (2020) based on sectoral data as a robustness check.

Table 6 presents the estimates based on the European sample. Reassuringly, they are comparable to the responses using the World Bank data. We find dynamic effects around zero for headline and core inflation across all our specifications, and when using the TWFE or DGJT estimator. The results for energy and food inflation are smaller compared to the baseline estimates. Indeed, except for the contemporaneous

TABLE 5. Dynamic effects of the British Columbia carbon tax.

Estimator	Specification	Average impact in year		
		0	1–2	3–5
Panel A. Headline inflation				
TWFE	Fixed effects	0.49	−0.54	−0.62
		(0.95)	(0.40)	(0.38)
TWFE	FE + controls	0.57	−0.54	−0.60
		(0.96)	(0.40)	(0.40)
TWFE	FE + additional controls	0.56	−0.49	−0.49
		(0.96)	(0.44)	(0.45)
DGJT	FE + controls	0.57	−0.82	0.42
		(0.96)	(0.56)	(0.86)
Panel B. Core inflation				
TWFE	Fixed effects	0.86	−1.01	−0.27
		(0.99)	(0.36)	(0.34)
TWFE	FE + controls	0.78	−0.95	−0.27
		(1.00)	(0.36)	(0.34)
TWFE	FE + additional controls	0.85	−0.97	−0.24
		(1.04)	(0.44)	(0.40)
DGJT	FE + controls	0.78	−1.20	0.35
		(1.00)	(0.39)	(0.78)
Panel C. Energy and food inflation				
TWFE	Fixed effects	−0.59	1.70	−1.11
		(1.46)	(1.20)	(0.92)
TWFE	FE + controls	−0.41	1.60	−1.08
		(1.53)	(1.18)	(0.99)
TWFE	FE + additional controls	−0.74	1.69	−1.11
		(1.65)	(1.21)	(1.02)
DGJT	FE + controls	−0.41	1.22	3.49
		(1.53)	(1.31)	(1.70)

Notes: Dynamic impulse responses of headline (Panel A), core (Panel B), and energy and food inflation (Panel C) to a \$40 carbon tax with 30% emission coverage. Estimates are based on local projections for the Canadian sample, excluding Alberta and Quebec. All specifications include province and year fixed effects, "controls" includes GDP growth, "additional controls" further includes total employment and the trade balance, each entering with four lags. "TWFE" and "DGJT" correspond to the two-way fixed effects estimator, and the Dube et al. (2022) estimator, respectively. Standard errors are heteroscedasticity robust and clustered on province.

positive response the estimates at longer horizons point to smaller effects around zero.

We also estimate impulse responses based on emission-weighted carbon taxes for the sample of Canadian provinces in Table 7. Consistent with the baseline results, we find muted responses of headline and core inflation to carbon taxation across the different models. Compared to the estimates based on the World Bank data, the deflationary responses are more front-loaded at short horizons, whereas the medium-term effects are positive. Energy and food inflation also shows smaller dynamic effects

TABLE 6. Dynamic effects of European emission-weighted carbon taxes.

Estimator	Specification	Average impact in year 0	1–2	3–5
Panel A. Headline inflation				
TWFE	Fixed effects	0.30	0.16	0.32
		(0.17)	(0.11)	(0.10)
TWFE	FE + controls	0.17	0.01	0.22
		(0.12)	(0.11)	(0.09)
TWFE	FE + additional controls	0.18	−0.02	0.21
		(0.13)	(0.12)	(0.10)
DGJT	FE + controls	0.12	0.01	0.20
		(0.14)	(0.14)	(0.11)
Panel B. Core inflation				
TWFE	Fixed effects	0.02	0.04	0.06
		(0.09)	(0.08)	(0.08)
TWFE	FE + controls	0.01	0.04	0.09
		(0.09)	(0.10)	(0.09)
TWFE	FE + additional controls	0.02	−0.04	0.08
		(0.09)	(0.09)	(0.07)
DGJT	FE + controls	0.02	0.07	0.14
		(0.11)	(0.11)	(0.10)
Panel C. Energy and food inflation				
TWFE	Fixed effects	0.55	−0.10	0.42
		(0.36)	(0.18)	(0.21)
TWFE	FE + controls	0.59	−0.13	0.34
		(0.30)	(0.19)	(0.20)
TWFE	FE + additional controls	0.55	−0.09	0.24
		(0.29)	(0.18)	(0.18)
DGJT	FE + controls	0.42	−0.17	0.06
		(0.29)	(0.21)	(0.13)

Notes: Dynamic impulse responses of headline (Panel A), core (Panel B), and energy and food inflation (Panel C) to a \$40 carbon tax with 30% emission coverage. Estimates are based on local projections for the European sample, using tax data from Dolphin, Pollitt, and Newbery (2020). All specifications include country and year fixed effects, "controls" includes GDP growth and the domestic monetary policy rate, "additional controls" further includes total employment, the trade balance, and the terms of trade, each entering with four lags. "TWFE" and "DGJT" correspond to the two-way fixed effects estimator, and the Dube et al. (2022) estimator, respectively. Standard errors are heteroscedasticity robust and clustered on country.

before the second year when using emissions-weighted carbon taxes. We estimate a positive reponse from the third year post-tax.

In sum, our main result on the non-responsiveness of inflation to carbon taxation is corroborated by a series of robustness checks. In addition, Online Appendix A shows that the results remain unchanged when including time trends, using alternative inflation data, or estimating dynamic effects from panel-VAR models.

TABLE 7. Dynamic effects of Canadian emission-weighted carbon taxes.

Estimator	Specification	Average impact in year 0	1–2	3–5
Panel A. Headline inflation				
TWFE	Fixed effects	−0.14	0.17	−0.72
		(0.33)	(0.26)	(0.15)
TWFE	FE + controls	0.03	0.29	−0.66
		(0.37)	(0.25)	(0.16)
TWFE	FE + additional controls	0.31	0.44	−0.59
		(0.48)	(0.28)	(0.20)
DGJT	FE + controls	0.03	0.22	−0.62
		(0.37)	(0.29)	(0.25)
Panel B. Core inflation				
TWFE	Fixed effects	−0.50	−0.20	−0.64
		(0.41)	(0.32)	(0.14)
TWFE	FE + controls	−0.33	−0.06	−0.59
		(0.37)	(0.31)	(0.15)
TWFE	FE + additional controls	0.01	0.05	−0.47
		(0.41)	(0.33)	(0.19)
DGJT	FE + controls	−0.33	−0.03	−0.40
		(0.37)	(0.32)	(0.27)
Panel C. Energy and food inflation				
TWFE	Fixed effects	1.36	1.22	−0.51
		(0.86)	(0.63)	(0.43)
TWFE	FE + controls	1.36	1.25	−0.52
		(0.80)	(0.70)	(0.46)
TWFE	FE + additional controls	1.43	1.36	−0.59
		(0.90)	(0.75)	(0.49)
DGJT	FE + controls	1.36	1.02	−0.53
		(0.80)	(0.76)	(0.43)

Notes: Dynamic impulse responses of headline (Panel A), core (Panel B), and energy and food inflation (Panel C) to a $40 carbon tax with 30% emission coverage. Estimates are based on local projections for the Canadian sample, using tax data from Dolphin, Pollitt, and Newbery (2020). All specifications include province and year fixed effects, "controls" includes GDP growth, "additional controls" further includes total employment and the trade balance, each entering with four lags. "TWFE" and "DGJT" correspond to the two-way fixed effects estimator, and the Dube et al. (2022) estimator, respectively. Standard errors are heteroscedasticity robust and clustered on province.

5. The Cross-Section of European Carbon Taxes

So far, we have documented the response of inflation to carbon taxation for the average European and Canadian economy. The relatively large number of adopters in Europe also permits to analyze to what extent the effects differ, by splitting the sample depending on country characteristics. In particular, we consider the role of revenue recycling and monetary policy independence. Countries that recycle tax revenues potentially limit the economic effects of carbon taxes by compensating firms and households. Independent monetary policy in principle allows the central bank to offset

TABLE 8. Dynamic effects of carbon taxes in revenue recycling countries.

		Average impact in year		
Sample	Controls	0	1–2	3–5
Panel A. Headline inflation				
RR1	FE + controls	0.18	−0.06	0.01
		(0.31)	(0.24)	(0.15)
RR0	FE + controls	0.23	0.35	1.16
		(1.06)	(1.19)	(1.15)
Panel B. Core inflation				
RR1	FE + controls	−0.08	−0.15	0.03
		(0.30)	(0.25)	(0.15)
RR0	FE + controls	0.87	−0.39	0.86
		(1.50)	(1.06)	(1.31)
Panel C. Energy and food inflation				
RR1	FE + controls	1.46	0.20	−0.11
		(0.70)	(0.47)	(0.38)
RR0	FE + controls	0.54	0.16	1.06
		(1.28)	(1.63)	(1.06)

Notes: Dynamic impulse responses of headline (Panel A), core (Panel B), and energy and food inflation (Panel C) to a $40 carbon tax with 30% emission coverage. Estimates are based on local projections for the European sample. "RR1" includes only those carbon tax countries that recycle revenues, based on the classification by Metcalf and Stock (2020a). This includes Denmark, Finland, Norway, Portugal, Sweden, and Switzerland. "RR0" excludes all carbon taxes of countries that recycle tax proceeds. All specifications include country and year fixed effects, GDP growth, and the domestic monetary policy rate, each entering with four lags. Standard errors are heteroscedasticity robust and clustered on country.

inflationary pressure stemming from carbon pricing, whereas the same is not true of Euro area countries. Indeed, we find support for both monetary policy and revenue recycling affecting the response of inflation to putting a price on carbon.

5.1. Revenue Recycling

Some countries introduced carbon taxes as part of broader tax reforms, with the intent to recycle tax revenues to offset other taxes, as well as providing lump-sum payments to firms and households. To assess whether revenue recycling affects the response of inflation to carbon pricing, we classify countries following the definition of Metcalf and Stock (2020a) and estimate the local projections for each group separately.[16]

We present the results in Table 8, focusing only on our baseline specification including GDP growth, changes in policy rates and country and year fixed effects. Starting with the set of revenue recycling countries ("RR1"), we find small effects

16. We note that this simple classification might not fully account for more complex differences in tax design. For instance, France announced it would use revenues to lower the tax burden on low-income households and pensioners (see Marten and Van Dender 2019), but is classified as a non-revenue recycling country in Metcalf and Stock (2020a).

for headline inflation (Panel A) that do not exeed their standard errors. The estimated effects are larger in magnitude for the sample of non-revenue recycling countries ("RR0"). On impact, the coefficient is small and imprecisely estimated, but increases over time to 1.16 percentage points in the final three years, on average.

Panel B shows similar responses for core inflation, in line with the previous findings. Estimates based on the sample of revenue recycling countries are all around zero, on average. For the countries that do not recycle tax proceeds, the responses are positive initially but decay over the 5 years after the tax enactment. None of the estimates exceed their standard errors. We find positive responses for energy and food inflation (Panel C) on impact for the sample of revenue recycling countries, that tail off over time. For the group of non-revenue recycling countries the effects are more modest on impact, but increase in the medium term.

In sum, it does appear as though the response of inflation is more muted for economies that introduced carbon taxes in conjunction with revenue recycling mechanisms. Although we do not test this relationship further, it is broadly in line with suggestive evidence by Metcalf and Stock (2020a), emphasizing the potential growth enhancing effects of revenue recycling.

5.2. *The Role of Monetary Policy*

Finally, we test whether the effect of carbon taxation on inflation depends on a country's autonomy over monetary policy. This channel is emphasized in McKibbin, Konradt, and Weder di Mauro (2021), who show that the economic consequences of climate policies are not independent of monetary policy. The Euro area provides a neat setting to distinguish between countries with and without independent monetary policy, since the ECB considers a weighted index of consumer prices in its member countries. Grouping countries along this line allows to test whether inflation responded differently to carbon policy in countries with and without monetary policy that could react. Although, to the best of our knowledge, climate policy only recently started receiving attention by central banks it is nonetheless possible that they offset inflationary pressure driven by carbon pricing implicitly in the past.

When focusing only on countries with independent monetary policy ("MP1"), we estimate small negative dynamic responses for headline inflation in the baseline specification (Panel A of Table 9). Conversely, the estimates are quantitatively larger for the sample including the Euro area countries ("MP0"). Indeed, the average dynamic response is about 1 percentage point in size, albeit with larger standard errors.

We find broadly similar results for core inflation (Panel B). While the dynamic responses are negative for countries with independent monetary policy, they are larger and less precisely estimated for the countries without independent monetary policy. Compared with headline inflation the effects are more muted. For energy and food inflation (Panel C) the difference between the two group is even more pronounced. We find a modest initial increase for countries with independent monetary policy only in the first year. Instead, energy and food inflation increases by a sizeable 1.65 percentage

TABLE 9. Dynamic effects of carbon taxes in countries with independent monetary policy.

Sample	Controls	Average impact in year 0	1–2	3–5
Panel A. Headline inflation				
MP1	FE + controls	−0.39	−0.15	−0.27
		(0.37)	(0.31)	(0.20)
MP0	FE + controls	0.84	1.11	1.37
		(0.49)	(0.71)	(0.71)
Panel B. Core inflation				
MP1	FE + controls	−0.33	−0.14	−0.24
		(0.41)	(0.37)	(0.20)
MP0	FE + controls	0.93	0.58	0.88
		(0.78)	(0.65)	(0.67)
Panel C. Energy and food inflation				
MP1	FE + controls	0.66	−0.15	−0.29
		(0.78)	(0.53)	(0.45)
MP0	FE + controls	1.65	2.20	0.84
		(0.64)	(0.58)	(0.79)

Notes: Dynamic impulse responses of headline (Panel A), core (Panel B), and energy and food inflation (Panel C) to a $40 carbon tax with 30% emission coverage. Estimates are based on local projections for the European sample. "MP0" includes only the sample of carbon taxes in countries without autonomous monetary policy, that is, Euro area members and Denmark (the krone is pegged to the Euro). "MP1" instead uses the set of countries with autonomous monetary policy. All specifications include country and year fixed effects, GDP growth and the domestic monetary policy rate, each entering with four lags. Standard errors are heteroscedasticity robust and clustered on country.

points and remains elevated throughout the 5-year period, for the group of countries without independent monetary policy.

It is important to note that this is not a formal test of the role of monetary policy in cushioning the effects of climate policy. However, our results do suggest that countries without a central bank that can accommodate inflationary pressure associated with climate policy could experience more inflation, driven in part by substantially larger responses of energy and food prices. Indeed, estimates using the policy rate as independent variable point to a small tightening response only for the sample of countries with independent monetary policy. In contrast, we find no evidence of inflationary effects in the sample of Canadian provinces, which also do not have monetary policy autonomy. Further, most countries in the group with independent monetary policy also recycle tax revenues, making it hard to disentangle the two.

6. Conclusion

Against the backdrop of the current debate on the economic effects of climate mitigation policies by market participants and central banks, this paper empirically assesses the response of inflation to carbon pricing. Does putting a price on carbon in fact lead to "greenflation"?

Our findings, drawing on 18 carbon taxes from Europe and Canada, cast doubt on the view that carbon taxation leads to inflation. Controlling for country and year fixed effects, as well as economic controls, we find no robust evidence of an inflationary response, on average. This result holds both for European countries and Canadian provinces, and survives a battery of robustness checks.

Moreover, we document that any inflationary effects associated with carbon taxation are confined to headline inflation, but do not spill over to core inflation. This finding is consistent with the idea that carbon taxes change relative prices, increasing the cost of energy, but do not lead to a broad increase in prices. Indeed, our estimates of the responses of energy and food inflation confirm this view.

Focusing on the cross-section of carbon taxes in Europe allows us to study heterogeneous effects depending on tax design and monetary policy independence. We find that the response of inflation to a similarly sized carbon tax shock is more muted in countries that recycle tax revenues and have independent central banks that can, in principle, respond to inflationary pressure.

When seen in conjunction with the prior literature on the limited economic effects of carbon taxes, our results imply that worries of drastic adverse economic consequences and "greenflation" might be overblown. Nonetheless, we acknowledge that future climate policy needs to be increasingly aggressive in order to reach the ambitious emission goals. Carbon taxes on the order of magnitude of tax rates in Scandinavia or Switzerland (exceeding \$100 per ton of CO_2 or more), with universal coverage potentially have broader economic effects than those documented in this paper.[17]

Since our analysis is at the aggregate level, we are not well equipped to investigate potential channels of how carbon pricing affects inflation dynamics. At the firm level, understanding tax incidence seems paramount: (how) Do firms pass on carbon taxes to consumers?[18] Moreover, households could form expectations of more ambitious climate policy and accommodate higher energy prices already prior to the tax enactment (see, e.g., Coibion and Gorodnichenko 2015). Household expenditure behavior might also shed light on whether the tax induces them to switch from more expensive energy-intensive goods and services to cheaper, less energy-intensive alternatives (e.g., Bems and Di Giovanni 2016).

The distributional consequences of carbon taxes also have to be seen in synthesis with their effects on prices. As prior studies suggest (see, e.g., Känzig 2021), carbon taxes tend to burden low income households most in the absence of a progressive redistribution mechanism. To the extent that low income households consumption

17. Although, we do our best to capture the role of tax coverage in our analysis by interacting tax rates with tax bases, one might expect potentially different effects if a carbon tax was to apply universally and in many countries simultaneously.

18. We provide suggestive evidence in McKibbin, Konradt, and Weder di Mauro (2021) that producer prices increase more than consumer prices after carbon tax enactment, for Euro area countries.

baskets include relatively more energy-intensive goods and services, our findings offer an additional explanation for this distributional pattern.

Of course, in most countries carbon taxes are only one part of a comprehensive toolkit to combat climate change. Focusing solely on carbon taxes might blur the picture when trying to understand the economic effects of climate policy more broadly. Constructing effective tax rates encompassing other instruments in addition to carbon taxes could be a promising avenue for future research.

Lastly, while our results may initially seem counterintuitive when compared to findings on oil price shocks, we caution against drawing this parallel. Apart from the larger magnitude of typical oil price shocks, the relative predictability of carbon taxes and recycling of tax revenues make comparison challenging.

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Supplementary Data

Supplementary data are available at *JEEA* online.