

ARTICLE

EFFECTS OF CARBON PRICING AND OTHER CLIMATE POLICIES ON CO₂ EMISSIONS

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Abstract

In this study, we provide *ex post* empirical analysis of the effects of climate policies on carbon emissions at the aggregate national level, using a comprehensive database of 121 countries. Carbon taxes and emissions trading systems (ETS), and the overall stringency of climate policies are considered. We use dynamic panel regressions, controlling for macroeconomic factors (economic development, GDP growth, urbanisation and the energy mix). Higher carbon taxes and ETS prices reduce carbon emissions. An increase in carbon taxes by \$10 per ton of CO₂ reduces CO₂ emissions per capita by 1.3% in the short run and by 4.6% in the long run.

Keywords: climate policies; carbon tax; carbon emission trading system; carbon dioxide emissions; energy

JEL Codes: Q00; Q48; Q58

1. Introduction

Emissions of carbon dioxide (CO₂), a key driver of global warming and climate change, have continued to increase globally in recent years. If current climate policies are unchanged, standard climate change scenarios predict an increase of around 3°C in global temperatures compared with pre-industrial levels over the course of the century (Group of 30, 2020; United Nations Environment Programme, 2024). This could have catastrophic consequences.¹ To avoid such a scenario, climate policies need to be expanded in order to reduce the emission of CO₂ and other greenhouse gases (IPCC, 2022). Such policies include carbon taxes and emissions trading systems (ETS), but also broader changes in regulation (Stern, 2007, 2008).

To be consistent with global emissions that limit an overshoot of the goal from the Paris Agreement to 1.5°C global warming above pre-industrial levels, global net anthropogenic CO₂ emissions would need to decline by about 45% from their 2010 level by 2030, reaching net zero around 2050. To cap global warming at 2°C, CO₂ emissions need to decrease by about 25% from the 2010 level by 2030 and reach net zero around 2070. Yet, according to recent estimates, the total global greenhouse gas emission level in 2030 is expected to be 16% above the 2010 level (United Nations, 2021).

Carbon pricing can be an effective policy to reduce carbon emissions. Higher carbon prices incentivise carbon emitters to develop and use economical ways of reducing carbon emissions

¹Solomon et al (2009) found that climate change due to increases in carbon dioxide concentrations could be irreversible for 1,000 years after emissions stop.

(OECD, 2021), which encourages the development of low-carbon technologies (United Nations Framework Convention on Climate Change (UNFCCC), 2025). Higher carbon prices make low-carbon energy more competitive, provide incentives to reduce emissions, and reduce demand for carbon-intensive fuels (Arlinghaus, 2015; Martin *et al.*, 2016; OECD, 2021). Moreover, a strong commitment to higher carbon prices by governments provides incentives for investors to invest in the expansion and development of low-carbon technologies (OECD, 2021) and to shift away from high-carbon-emission fossil-fuels-based technology (UNFCCC, 2025). Furthermore, carbon pricing generates revenue that can be used by the government to support research and development of low-carbon technologies (UNFCCC, 2025). The revenue raised from carbon taxes also allows the government to provide options for firms and households to switch more easily to renewable energy and increase energy efficiency, for example by providing government subsidies for district heating, public transport and housing insulation.

In this article, we examine the effects of climate policies on CO₂ emissions. We provide *ex post* empirical analysis of the effects of carbon pricing on carbon emissions at the aggregate national level, based on a comprehensive database of 121 countries. We rely on carbon emissions data and macro-economic variables over the 1971–2016 period, as well as data on climate policies. As climate policies, we consider national and supranational carbon taxes and ETS. We also consider a broad index that measures the overall stringency of climate policies for OECD and major emerging economies. This index captures regulatory responses that go beyond carbon pricing. We use dynamic panel regressions, to account for the large degree of persistence in emissions. We also control for macroeconomic factors such as economic development, GDP growth, urbanisation and the composition of the electricity mix based on Kohlscheen *et al.* (2021).

Overall, we find statistical evidence that higher carbon taxes and prices of permits in ETS have significantly reduced carbon emissions. An increase in carbon taxes by \$10 per ton of CO₂ equivalents (tCO₂) reduces CO₂ emissions per capita by 1.3% in the short run and by 4.6% in the long run. This effect is statistically significant in all econometric specifications, with *p-values* that are always below 0.01. The same increase in the prices of ETS permits also reduces CO₂ emissions per capita by 1.4% in the short run and 5.0% in the long run. The magnitude of this effect, however, varies more across specifications and is statistically significant in five out of nine specifications (with *p-values* below 0.05). Furthermore, more stringent climate policies as measured by a broad index for OECD and major emerging economies also significantly reduce carbon emissions, with a standard deviation increase in the index reducing CO₂ emissions per capita by around 1.5% in the short run and 6% in the long run (*p-values* below 0.05 in five out of six specifications). The estimates are robust to the inclusion of controls for the overall quality of governance in the respective countries, as proxied by an index for control of corruption.

This paper adds to the growing literature that examines the impact of carbon taxes and ETS on CO₂ emissions, reviewed in Green (2021) and Döbbeling-Hildebrandt *et al.* (2024). As Green (2021) noted, relatively few papers have analysed the *ex post* effects of carbon pricing on carbon emissions at the aggregate national level, and these papers mostly focus on a few specific countries and then extrapolate the results to a broader set of countries. We contribute to this literature by analysing a wide range of countries. This allows us to obtain more precise estimates of the impact of policies.

Moreover, as noted by Döbbeling-Hildebrandt *et al.* (2024), there is a critical evidence gap in the literature regarding *ex post* estimates of the carbon price elasticity of emissions reductions, rather than just studying the effect of introducing a carbon pricing scheme. We contribute to filling this gap in the literature by providing *ex post* estimates of the carbon price elasticity of emissions reductions for both carbon taxes and ETS.

Our findings are relevant for future climate policies. More specifically, the finding that higher carbon taxes and prices of permits in ETS have reduced carbon emissions provides evidence that such tools could speed up the necessary transition to a world with much lower emissions. Additionally, our findings suggest that policymakers can rely on a wider range of climate policies to speed up the transition to lower carbon emissions, ideally to net-zero emissions.

The remainder of the paper proceeds as follows. Section 2 discusses the related literature. Section 3 summarises the data. Section 4 presents the methodology. Section 5 presents our empirical estimates. Section 6 concludes.

2. Literature

This paper mainly builds on two strands of the literature. First, it builds on the literature examining the effects of climate policies, such as carbon taxes and ETS, on carbon emissions. Second, it builds on the literature studying macroeconomic determinants of carbon emissions.

The effects of climate policies, such as carbon taxes and ETS, on carbon emissions have been studied in several papers. A comprehensive review of the literature on the effects of carbon pricing on carbon emissions was carried out by Green (2021). She highlighted that surprisingly few papers have conducted an *ex post* empirical analysis of how carbon pricing has actually affected CO₂ emissions² and that the vast majority of these papers are focused on Europe. She noted that in most cases, studies have estimated emissions reductions in the sectors covered by the carbon pricing policy, although some extrapolate to broader jurisdictional effects (e.g. Murray and Maniloff, 2015; Bayer and Aklin, 2020; Rafaty et al, 2020).³ She concluded that the majority of the studies suggest that the aggregate reductions from carbon pricing on emissions are limited, generally between 0% and 2% per year, with considerable variation across sectors. She also concluded that in general, carbon taxes perform better than ETS and that studies of the European Union's ETS indicate limited average annual reductions in carbon emissions of 0% to 1.5%.

Our paper contributes to filling this gap in the literature by providing *ex post* empirical analysis of the effects of carbon pricing on carbon emissions at the aggregate national level, for a very broad sample of countries. There is also little empirical literature on the effects of broader climate policies on emissions, and we contribute to filling this gap by studying the effects of an index of broad climate policies on CO₂ emissions.

The recent systematic review and meta-analysis of *ex post* evaluations of the effects of carbon pricing by Döbbeling-Hildebrandt *et al.* (2024) highlighted a critical evidence gap regarding the carbon price elasticity of emissions reductions (i.e. the effect of a marginal change in the carbon price on emissions). It noted that only nine primary studies estimated such a carbon price elasticity, four of which only studied the carbon tax in the Canadian province of British Columbia to estimate elasticities for the transport and buildings sectors there. They concluded that having only nine price elasticity studies provided them with too few effect sizes for meta-analysing these price elasticities separately. Instead, they only conducted a meta-analysis of the effect of introducing carbon pricing, i.e. of the treatment effect (Döbbeling-Hildebrandt *et al.*, 2024). Our paper also contributes to filling this gap in the literature of estimating carbon price elasticities of carbon emissions reductions, by providing evidence on the effectiveness of carbon pricing relative to the level of the carbon price, rather than just on the effect of introducing a carbon pricing scheme.

There is limited empirical evidence that higher carbon prices reduce carbon emissions (Arlinghaus, 2015; Martin *et al.*, 2016; OECD, 2021). Sen and Vollebergh (2018) found that for OECD economies, an increase in a broad-based tax on energy consumption of €10/tCO₂ is expected to lead to a 7.3% reduction in carbon emissions from fossil fuel consumption in the long run. Metcalf and Stock (2023) found that Europe's carbon taxes led to a cumulative reduction of around 4% to 6% for a \$40/tCO₂ tax covering 30% of emissions. They argued that emissions reductions would likely be larger for a broad-based US carbon tax, since European carbon taxes do not include sectors with the lowest marginal costs of carbon pollution abatement in the tax base. Related recent papers are Best *et al.* (2020), D'Arcangelo *et al.* (2022) and Schroeder and Stracca (2023). Based on sectoral analysis, Rafaty *et al.* (2020) found an imprecisely estimated semi-elasticity of a 0.5% reduction in carbon emissions growth per average \$10/tCO₂ carbon price.⁴ An overview of the results from 24 *ex ante* models in the IPCC's AR6 Scenario Database for the

²She noted that this is despite a large theoretical literature on carbon pricing, often using model simulations, predictive models or theoretical assessments of reductions, with these prospective analyses constituting the vast majority of the quantitative literature on carbon pricing (Green, 2021).

³Rafaty *et al.* (2020) studied the effects of carbon prices in five sectors for a large number of countries since the 1990s. They find that the introduction of carbon pricing reduced growth in total CO₂ emissions by 1%–2.5% on average relative to imputed counterfactuals, with the greatest reduction in the electricity and heat sector.

⁴See the review of Green (2021) for further references.

effects of carbon taxes on CO₂ emissions, in comparison with the results from *ex post* empirical models, was provided in Tol (2023).

The review of Döbbeling-Hildebrandt *et al.* (2024) noted that the contributions of carbon pricing schemes to carbon emissions reductions remain a subject of heated debate in science and policy. It mentioned that there is a critical evidence gap with regard to dozens of unevaluated carbon pricing schemes. It concluded from its meta-analysis of *ex post* studies that introducing a carbon price led to substantial emission reductions for at least 17 of 21 carbon pricing schemes studied, with statistically significant emissions reductions ranging between −5% and −21% across the schemes (or −4% and −15% after correcting for publication bias).

The effects of macroeconomic variables on carbon emissions were studied in Raupach *et al.* (2007), Sadorsky (2014), Kasman and Duman (2015), Menyah and Wolde-Rufael (2010), Gonzalez-Sanchez and Martin-Ortega (2020), Feng *et al.* (2015), Peters *et al.* (2012), Doda (2014), Wang (2012) and International Energy Agency (2020), among others. Our approach for controlling for macroeconomic determinants of carbon emissions follows the study of Kohlscheen *et al.* (2021). For a review of the literature studying the macroeconomic determinants of carbon emissions, readers are referred to that study.

Ellis *et al.* (2019) reviewed *ex post* empirical assessments on the impact of carbon pricing on competitiveness in OECD and G20 countries in the electricity and industrial sectors. They concluded that there are no significant effects on competitiveness. In turn, Lilliestam *et al.* (2021) reviewed the empirical evidence available in academic *ex post* analyses of the effectiveness of carbon pricing schemes in promoting technological change necessary for full decarbonisation. They considered the European Union, New Zealand and Scandinavia. They found that there is little empirical evidence in this direction so far, with most of the papers on the topic being theoretical. Recent papers studying the macroeconomic effects of carbon taxes include Metcalf and Stock (2023, 2020).

3. Data

In order to assess the empirical drivers of CO₂ emissions, we collected data from several sources. Data on CO₂ emissions per capita, measured in metric tons per capita, were from the World Development Indicators (WDI) of the World Bank. They measure CO₂ emissions stemming from the burning of fossil fuels and the manufacture of cement and include CO₂ produced during the consumption of solid, liquid and gas fuels and gas flaring. Demographic, economic and energy use data were from the World Bank (GDP per capita, GDP growth, the urbanisation rate, the share of manufacturing in GDP and the share of coal, oil and renewables in electricity generation).⁵ Our database spanned the 1971–2016 period and 121 countries. The country selection was based solely on data availability, and the list of countries in the sample is presented in the [Appendix](#).

Our main variables of interest are CO₂ emissions and climate policies.

Carbon emissions emanate mostly from the burning of fossil fuels (to heat, transport goods and people or generate electricity) and the manufacture of steel and cement. The level of carbon emissions, following that of economic development, is highly uneven across countries. Highly developed advanced economies tend to emit large quantities of carbon per capita, while less developed economies, particularly in Africa, tend to emit less ([Figure 1](#)). However, there is no definite advanced–emerging economy divide. Due to fast economic development, many emerging market economies (including energy producers and fast-developing East Asian economies) already have high carbon emission levels per capita. Besides, given their larger populations, their contribution to global CO₂ emissions has grown very rapidly.

Primary climate policies are carbon taxes and ETS. The first carbon tax was introduced in Finland in 1990. In turn, emissions trading has been considered a possible tool for mitigating greenhouse gas emissions since the early 1990s and formed a key part of the Kyoto Protocol agreement (Philibert and

⁵Note that we included only the respective shares of the energy mix, not the intensity of use.

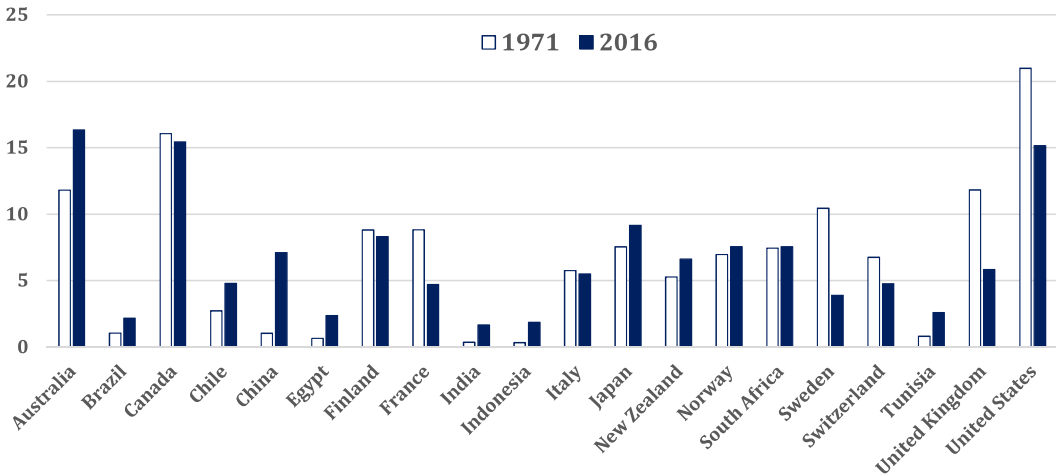


Figure 1. Carbon dioxide emissions per capita.

Notes: CO₂ emissions per capita in metric tons per capita. CO₂ emissions measure carbon dioxide emissions stemming from the burning of fossil fuels and the manufacture of cement and include carbon dioxide produced during the consumption of solid, liquid and gas fuels and gas flaring. Source: World Development Indicators (WDI) of World Bank, code EN.ATM.CO2E.PC.

Reinaud, 2004). Our database contains information on carbon taxes and ETS implemented at the national and supranational levels since 1990 from the World Bank (World Bank, 2021). Country coverage and prices of these policies are shown in Figures 2 and 3 separately for carbon taxes and ETS, for the start and the end of our sample period in 2016. The share of global greenhouse gas emissions covered by the carbon taxes and ETS at the national and supranational levels is shown in Figure 4. As the figure shows, there has been a huge increase in this proportion.

In the case of carbon taxes, governments set the price of carbon emissions and let private agents determine emissions reductions. ETS have two main forms, cap-and-trade and baseline-and-credit ETS. For cap-and-trade ETS, governments set a limit on emissions, and allowances up to this limit are

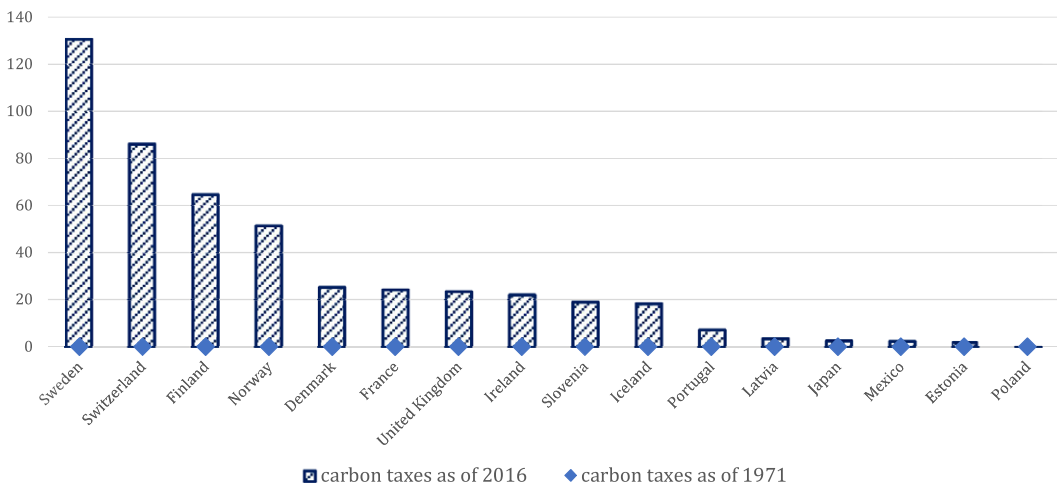


Figure 2. Prices of carbon taxes as of 2016 and 1971.

Note: Carbon taxes implemented at the national and supranational levels. Nominal prices as of 1 April each year in \$/tCO₂ (US dollars per metric ton carbon dioxide emissions) equivalents. In the case of the UK, the number refers to the carbon price floor. Source: Carbon Pricing Dashboard, World Bank (2021).

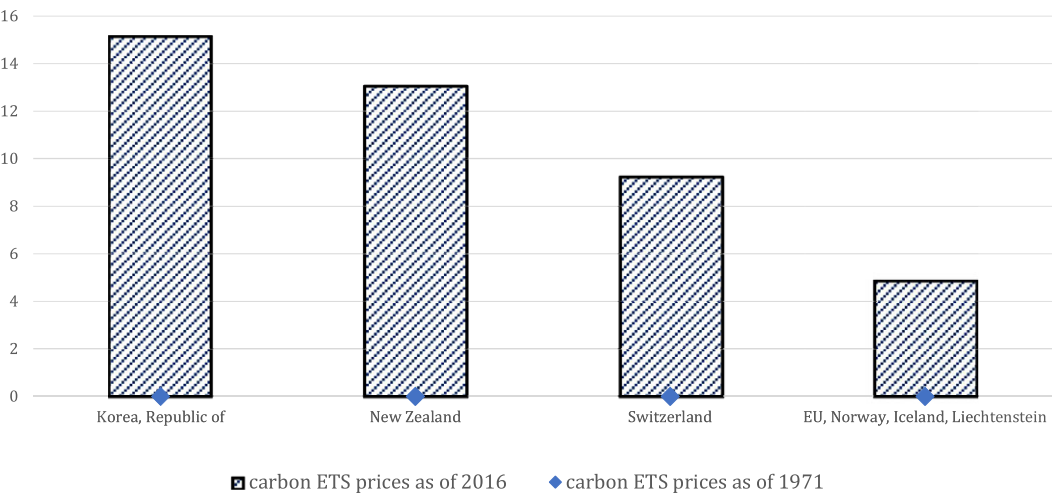


Figure 3. Prices of carbon ETS as of 2016 and 1971.
Note: Prices of the carbon emission trading system (ETS) implemented at the national and supranational levels. Nominal prices as of 1 April each year in \$/tCO₂ (US dollars per metric ton carbon dioxide emissions) equivalents. EU: European Union. *Source:* Carbon Pricing Dashboard, World Bank (2021).

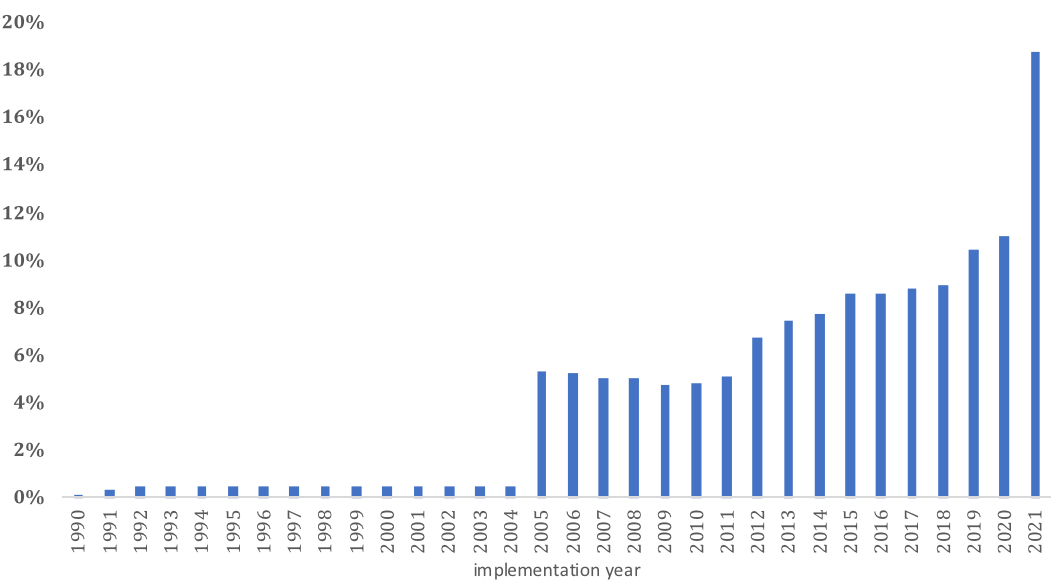


Figure 4. Share of global greenhouse gas emissions covered by carbon taxes and ETS at the national and supranational levels.
Notes: Share of global greenhouse gas emissions covered by carbon taxes and emissions trading systems (ETS) at the national and supranational levels, in percentage. The coverage of each carbon pricing initiative is presented as a share of annual global GHG emissions for 1990–2015 based on data from the Emission Database for Global Atmospheric Research (EDGAR) version 5.0, including biofuels emissions. From 2015 onwards, the share of global GHG emissions is based on 2015 emissions from EDGAR. The greenhouse gas emissions coverage for each jurisdiction is based on official government sources and/or estimates.
Source: Carbon Pricing Dashboard, World Bank (2021).

auctioned or allocated according to certain criteria. These permits are then traded, and carbon prices are determined by supply and demand in the market. For baseline-and-credit ETS, baselines for emissions are set for regulated emitters. Emitters with emissions above their designated baseline need to give up

credits to make up for these emissions, while those with emissions below their baseline receive credits for these reductions, which they can sell to other emitters (World Bank, 2021).

Besides carbon taxes and ETS, we also evaluated the effectiveness of climate policies using a broader index for the overall stringency of climate policies for OECD member countries and major emerging economies. This was based on the Environmental Policy Stringency Index (EPS), which is compiled by the OECD and available from 1990 to 2015. The index covers a much wider range of climate policies, also considering other regulatory policies (Botta and Kozluk, 2014). Generally, stringency is defined as the degree to which environmental policies put an explicit or implicit price on polluting or, more generally, on environmentally harmful behaviour.⁶

We conducted several checks of the robustness of our baseline results. In particular, to control for the quality of governance in a country, we used a measure of the control of corruption from the World Bank. It reflects the perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as “capture” of the state by elites and private interests.⁷

4. Methodology

We quantified the effects of climate policies on carbon emissions through a dynamic panel model. The dynamic specification accounts for the high degree of persistence in CO₂ emissions. Throughout the analysis, we controlled for macroeconomic factors, such as economic development (GDP per capita), GDP growth, urbanisation, the share of manufacturing in total output and the energy mix used in electricity production. Note that we included only the respective shares of the energy mix, not the intensity of use. Formally, we explored the effects of climate policies (denoted by CP) on the logarithm of CO₂ emissions per capita (denoted by lnCO₂) according to the following equation:

$$\begin{aligned} \ln\text{CO}_{2,i,t} = & \alpha_i + \beta_t + \rho \ln\text{CO}_{2,i,t-1} + \lambda \text{CP}_{i,t-1} + \gamma \text{GDPpc}_{i,t} + \theta \text{growth}_{i,t} \\ & + \omega \text{urbanisation}_{i,t} + \vartheta \text{manufacturing}_{i,t} + \mu_1 \text{share}_{\text{oil},i,t} \\ & + \mu_2 \text{share}_{\text{coal},i,t} + \mu_3 \text{share}_{\text{renewables},i,t} + \varepsilon_{i,t} \end{aligned} \quad (1)$$

Besides the lagged dependent variable, we included climate policies as key explanatory variables of interest. To address potential endogeneity concerns, we used lagged climate policy variables, which minimised the risk of reverse causality. As climate policies, we considered carbon taxes and prices of permits in ETS implemented at the national and supranational levels, as well as the broader index for the stringency of climate policies described in Section 2. We also included a number of macroeconomic variables as controls.

Our models included country fixed effects to capture unobserved heterogeneities across countries that might affect the rate of CO₂ emissions. These included fixed institutional factors such as enforcement of environmental laws. They also included natural factors such as average median temperatures, which tend to correlate with heating or cooling needs. We also included the full set of yearly time dummies to control for the effects of global factors. These subsumed, for instance, technological advances that may reduce environmental effects, as well as other global trends or global shocks.

In this analysis, we used fixed effect panel estimations and based inference on cluster robust standard errors. As a robustness check, we controlled additionally for the quality of governance in a country, using the measure of the control of corruption as described in Section 3.

⁶The index ranges from 0 (not stringent) to 6 (highest degree of stringency). It covers 28 OECD and 6 BRIICS countries (Brazil, China, India, Indonesia, Russia and South Africa) for the period 1990–2012 and has been extended for a subset of these countries until 2015 (France, Germany, Italy, Japan, Korea, United Kingdom, United States, Brazil, China, India, Indonesia, Russia and South Africa). The EPS index is based on the degree of stringency of 14 environmental policy instruments, primarily related to climate and air pollution.

⁷This indicator ranges from approximately –2.5 (weak) to 2.5 (strong) governance performance.

5. Estimation results

5.1. Effects of climate policies

We first present baseline estimates of our dynamic panel equation (1). The estimations for the effects of carbon taxes, prices of permits in the ETS and the EPS policy index separately are shown in columns I, II and IV of [Table 1](#), respectively. The results when including carbon taxes and prices of permits of ETS together are shown in column III, and those when including all three climate policies together in column V.

Overall, the specifications describe the country-specific evolution of carbon emissions quite well. Our models with climate policies are able to explain 97%–98% of the variation in per capita CO₂ emissions across countries and across time ([Table 1](#)). Importantly, this is driven by variation both within and between countries, as R^2 within ranges from 0.82 to 0.88 and R^2 between ranges from 0.97 to 0.99. The lagged dependent variable has a coefficient of just above 0.7 and is clearly statistically significant, which confirms that a dynamic panel specification is indeed appropriate. Put differently, more than 70% of CO₂ emissions can be explained by previous year emissions alone.⁸ Most of the macroeconomic control variables are statistically significant with the expected signs.

Consistently, we found that higher carbon taxes significantly reduce carbon emissions (*p-values* always below 0.01). On average, an increase in carbon taxes by \$10 per ton of CO₂ (tCO₂) reduces CO₂ emissions per capita by 1.3% in the short run and by 4.6% in the long run (baseline model in column III of [Table 1](#)).⁹ Importantly, this result is robust to controlling for ETS prices (see column III).

We also found that higher prices of ETS permits reduce carbon emissions (*p-values* below 0.01 in columns II and III of [Table 1](#)). An increase in prices of ETS permits by \$10/tCO₂ reduces CO₂ emissions per capita by 1.4% in the short run and by 5.0% in the long run, when carbon taxes are controlled for (column III).

Moreover, we found that the broad EPS index of climate policy stringency has a negative effect on carbon emissions at the 10% significance level (column IV of [Table 1](#)). A one standard deviation increase in the EPS index reduces CO₂ emissions per capita by 1.6% in the short run and 6.2% in the long run. It is striking that these results are broadly similar to the results we obtained for carbon taxes, for which a standard deviation increase leads to a reduction in carbon emissions of 1.1% in the short run and 3.9% in the long run.

When we included all three measures together, the coefficients on carbon taxes and the EPS index remained significantly negative, with a somewhat smaller magnitude (column V). While the coefficient on the prices of ETS permits remained negative, it lost significance. This is most likely due to the much smaller sample size, as we lost more than 80% of the sample when including the EPS index. Furthermore, the EPS index also reflects carbon prices, which introduces the problem of multicollinearity of the variables—which is particularly acute for small sample sizes.

5.2. Robustness

We performed several robustness checks. First, we controlled for the quality of governance in a country, proxied by a measure of control of corruption described in [Section 3](#) ([Table 2](#)).¹⁰ We found that higher carbon taxes and more stringent climate policy based on the broader EPS policy index significantly reduce carbon emissions when controlling for governance in all specifications ([Table 2](#)). By contrast, the coefficient on the prices of ETS permits remained significant only in one specification (column II). These

⁸Of course, the high fraction of variation that is explained by the model is partly related to this high degree of persistence in CO₂ emissions. This could be a result of strong habit persistence of consumers, or the persistent nature of many industrial production processes.

⁹The long-run effect is $\lambda/(1-\rho)$.

¹⁰Note that corruption could for instance undermine the effectiveness of environmental regulations.

Table 1. Effects of climate policies on CO₂ emissions

Dependent variable: ln CO ₂ emissions per capita (in metric tons, log)					
	Model				
	(I)	(II)	(III)	(IV)	(V)
	Model with carbon tax	Model with ETS	Model with carbon tax and ETS	Model with EPS	Model with carbon tax, ETS and EPS
Previous year ln CO ₂ per capita	0.7206***	0.7231***	0.7192***	0.7471***	0.7334***
	0.0541	0.0538	0.0542	0.0598	0.0627
Carbon tax (lagged)	−0.0014***		−0.0013***		−0.0006***
	0.0003		0.0003		0.0002
ETS (lagged)		−0.0019***	−0.0014***		−0.0003
		0.0005	0.0005		0.0004
EPS (lagged)				−0.0164**	−0.0135**
				0.0064	0.0066
GDP per capita (log)	0.1877***	0.1854***	0.1893***	0.1712***	0.1801***
	0.0436	0.0432	0.04	0.0575	0.0616
GDP growth	0.4050***	0.3982***	0.3946***	0.5099***	0.5012***
	0.0982	0.0979	0.0977	0.1334	0.1334
Urbanisation rate	0.3615**	0.3643**	0.3519**	0.2500*	0.2086
	0.1632	0.1622	0.1623	0.1396	0.1352
Manufacturing/GDP	0.5435***	0.5450***	0.5445***	0.1661	0.1036
	0.1401	0.1404	0.14	0.1875	0.2038
Share of electricity from oil	0.1571***	0.1530***	0.1565***	0.1387**	0.1614**
	0.0396	0.0392	0.0396	0.0564	0.0592
Share of electricity from coal	0.2415***	0.2348***	0.2334***	0.2331***	0.2640***
	0.0734	0.0720	0.0719	0.0642	0.0747
Share of electricity from renewables	−0.1836**	−0.1831**	−0.1589**	−0.2361**	−0.1975**
	0.0782	0.0792	0.075	0.0858	0.0852
Observations	3881	3881	3881	653	653
Number of countries	121	121	121	30	30
R ² within	0.822	0.822	0.822	0.879	0.881
R ² between	0.989	0.989	0.989	0.971	0.971

Note: Sample period: From 1971 to 2016, annual data. Cluster-robust standard errors reported in the second line are clustered at the country level. ***/**/* denote statistical significance at the 1%/5%/10% level. (I): nominal price of first carbon tax in USD/tCO₂ equivalents; (II): nominal price of ETS in USD/tCO₂ equivalents; (IV): EPS index.

Table 2. Effects of climate policies on CO₂ emissions: with control of corruption

Dependent variable: ln CO ₂ emissions per capita (in metric tons, log)					
	Model				
	(I)	(II)	(III)	(IV)	(V)
	Model with carbon tax	Model with ETS	Model with carbon tax and ETS	Model with EPS	Model with carbon tax, ETS and EPS
Previous year ln CO ₂ per capita	0.7300***	0.7328***	0.7297***	0.6265***	0.6110***
	0.0257	0.0255	0.0257	0.0627	0.0643
Carbon tax (lagged)	−0.0011***		−0.0011***		−0.0007***
	0.0003		0.0003		0.0003
ETS (lagged)		−0.0006**	−0.0004		−0.0002
		0.0003	0.0003		0.0005
EPS (lagged)				−0.0168**	−0.0154*
				0.0072	0.0077
GDP per capita (log)	0.2006***	0.2030***	0.2007***	0.2954***	0.3060***
	0.0357	0.0360	0.0358	0.0568	0.0590
GDP growth	0.4738***	0.4646***	0.4677***	0.3402***	0.3258***
	0.1068	0.1061	0.1064	0.1015	0.1013
Urbanisation rate	0.2689	0.2754	0.2595	0.2527	0.1735
	0.1778	0.1767	0.1778	0.2147	0.2092
Manufacturing/GDP	0.2968*	0.3068*	0.2927*	0.3496	0.1882
	0.1582	0.1595	0.1591	0.2908	0.2917
Share of electricity from oil	0.1299***	0.1272***	0.1297***	0.2410***	0.2711***
	0.0430	0.0428	0.0431	0.0812	0.0862
Share of electricity from coal	0.2848***	0.2779***	0.2816***	0.3427***	0.3767***
	0.0637	0.0642	0.0643	0.0949	0.1047
Share of electricity from renewables	−0.2730***	−0.2833***	−0.2669***	−0.2210**	−0.1984*
	0.0801	0.0830	0.0797	0.1018	0.0980
Control of corruption (lagged)	−0.0032	−0.0035	−0.0032	0.0149	0.0179
	0.0185	0.0184	0.0185	0.0173	0.0170
Observations	1845	1845	1845	441	441
Number of countries	119	119	119	30	30
R ² within	0.778	0.778	0.778	0.855	0.858
R ² between	0.988	0.987	0.988	0.902	0.901

Note: Sample period: From 1971 to 2016, annual data. Cluster-robust standard errors reported in the second line are clustered at the country level. ***/**/* denote statistical significance at the 1%/5%/10% level. (I): nominal price of first carbon tax in USD/tCO₂ equivalents; (II): nominal price of ETS in USD/tCO₂ equivalents; (IV): EPS index.

results imply that the effects of carbon taxes and the broad climate policy index on carbon emissions are generally more robust than those for the effects of ETS permit prices.

Furthermore, we also estimated the effects of carbon policies when using real carbon prices instead of nominal ones; that is, we considered prices obtained by deflating the nominal USD carbon price by the US consumer price index (Table 3). The results for the significantly negative effects of higher carbon taxes, of higher prices of ETS permits and of more stringent climate policy based on the EPS index on CO₂ emissions are robust to using these alternative measures.

Table 3. Effects of climate policies on CO₂ emissions: using real carbon prices

Dependent variable: ln CO ₂ emissions per capita (in metric tons, log)					
	Model				
	(I)	(II)	(III)	(IV)	(V)
	Model with carbon tax	Model with ETS	Model with carbon tax and ETS	Model with EPS	Model with carbon tax, ETS and EPS
Previous year ln CO ₂ per capita	0.7205***	0.7233***	0.7191***	0.7471***	0.7320***
	0.0542	0.0538	0.0543	0.0598	0.0635
Carbon tax (real, lagged)	−0.0013***		−0.0012***		−0.0007***
	0.0003		0.0003		0.0002
ETS (real, lagged)		−0.0017***	−0.0014***		−0.0003
		0.0005	0.0005		0.0004
EPS (lagged)				−0.0164**	−0.0137**
				0.0064	0.0066
GDP per capita (log)	0.1884***	0.1853***	0.1899***	0.1712***	0.1824***
	0.0438	0.0432	0.0440	0.0575	0.0622
GDP growth	0.4051***	0.3994***	0.3952***	0.5099***	0.5063***
	0.0983	0.0980	0.0977	0.1334	0.1332
Urbanisation rate	0.3609**	0.3655**	0.3517**	0.2500*	0.2127
	0.1633	0.1623	0.1624	0.1396	0.1353
Manufacturing/GDP	0.5452***	0.5447***	0.5440***	0.1661	0.1144
	0.1400	0.1405	0.1396	0.1875	0.2002
Share of electricity from oil	0.1571***	0.1529***	0.1565***	0.1387**	0.1575**
	0.0397	0.0392	0.0397	0.0564	0.0587
Share of electricity from coal	0.2414***	0.2355***	0.2335***	0.2331***	0.2618***
	0.0734	0.0721	0.0720	0.0642	0.0740
Share of electricity from renewables	−0.1872**	−0.1874**	−0.1640**	−0.2361**	−0.2020**
	0.0788	0.0796	0.0758	0.0858	0.0848
Observations	3881	3881	3881	653	653

(Continued)

Table 3. *Continued*

Dependent variable: ln CO ₂ emissions per capita (in metric tons, log)					
	Model				
	(I)	(II)	(III)	(IV)	(V)
	Model with carbon tax	Model with ETS	Model with carbon tax and ETS	Model with EPS	Model with carbon tax, ETS and EPS
Number of countries	121	121	121	30	30
R ² within	0.822	0.822	0.822	0.879	0.882
R ² between	0.989	0.989	0.989	0.971	0.97

Note: Sample period: From 1971 to 2016, annual data. Cluster-robust standard errors reported in the second line are clustered at the country level. ***/**/* denote statistical significance at the 1%/5%/10% level. (I): real price of first carbon tax in USD/tCO₂ equivalents (deflated by US CPI); (II): real price of ETS in USD/tCO₂ equivalents (deflated by US CPI); (IV): EPS index.

Finally, we excluded countries whose economic development, as measured by GDP per capita, is below that of the country with the lowest GDP per capita among those that have implemented carbon taxes or ETS. We did so by restricting GDP per capita to above \$1500 in constant 2010 dollars in columns I to III of Appendix Table A1. Very similar results were obtained when this restriction was imposed.

Our main takeaway from the robustness analysis is that the results for the carbon price elasticities of emission reductions are generally robust to the different empirical models, which enhances confidence in these results. Moreover, the results of this paper for the *ex post* effects of carbon pricing on carbon emissions are quantitatively similar to those obtained by D'Arcangelo *et al.* (2022), Metcalf and Stock (2023) and Rafaty *et al.* (2020) (see Table 1 of Tol, 2023), even though these papers have used different methods. The results of Rafaty *et al.* (2020) are, for example, based on sectoral analysis. This consistency of our results with those of other papers with different methodologies also enhances confidence in our results.

6. Conclusion

We used a database of 121 countries to study how climate policies have affected CO₂ emissions *ex post*. Our findings were based on comprehensive data on carbon emissions between 1971 and 2016, and we controlled for macroeconomic developments. As climate policies, we considered carbon taxes and ETS, as well as a broad index for the stringency of climate policies. Overall, we found that higher carbon taxes and prices of permits in the ETS are associated with significant reductions in carbon emissions. Furthermore, more stringent climate policies, as measured by a broader index for OECD and major emerging economies, also reduced carbon emissions.

Overall, an increase in carbon taxes by \$10/tCO₂ reduces CO₂ emissions per capita by 1.3% in the short run and by 4.6% in the long run. This negative effect on emissions is statistically significant for all nine specifications that were used, with *p-values* that are always below 0.01. The same increase in the prices of ETS permits reduces CO₂ emissions per capita by 1.4% in the short run and 5.0% in the long run, although this effect is found to be less robust to alternative specifications. More stringent climate policies as measured by a broad index for OECD and major emerging economies also significantly reduce carbon emissions, with an increase of one standard deviation in the index reducing CO₂ emissions per capita by around 1.5% in the short run and 6.0% in the long run.

Our findings are relevant for the design of climate policies. The fact that higher carbon tax rates and prices of permits in the ETS rates have reduced carbon emissions suggests that further increases in these and expansion to more countries, thus covering a greater share of global carbon emissions, are promising avenues to speed up the necessary transition towards lower carbon emissions economies. Furthermore,

the finding that more broadly, stringent climate policies have reduced carbon emissions indicates that future enhancements in a wider range of climate policies can also be helpful for a speedy transition towards much lower carbon emissions, ideally to net-zero emissions.

The results of this paper for the *ex post* effects of carbon pricing in reducing carbon emissions are lower than those assumed in most *ex ante* models in the IPCC's AR6 Scenario Database for the effects of carbon taxes on carbon emissions (see Table 1 of Tol, 2023). By contrast, Metcalf and Stock (2023), Rafaty *et al.* (2020) and D'Arcangelo *et al.* (2022) obtained quantitatively similar empirical results to ours. In order to meet the goals of the Paris Agreement, carbon taxes and carbon ETS need to be increased by more and more quickly than currently planned, and they should be complemented with other climate policies (Dubash *et al.*, 2024). Other important climate policies include green technology support policies, such as subsidies and tax incentives for low-carbon research and development, and support for the adoption of solar and wind energy. For example, green technology policies have been implemented in the USA recently (White House, 2023). Recent *ex post* cross-country empirical analysis has shown that green technology policies have a significant effect on reducing carbon emissions per capita (Moessner, 2024).

Increasing carbon prices by more need not be held back by concerns about large overall inflationary effects, since recent *ex post* empirical work has shown that overall effects of carbon pricing on consumer price inflation have been small so far (Konradt and Weder di Mauro, 2023; Moessner, 2025). There is a potential for international leakages associated with higher carbon pricing, with carbon-intensive production being moved abroad (Schroeder and Stracca, 2023). Such carbon leakages can be mitigated with carbon border adjustment mechanisms. This mechanism has been phased in recently in the EU as "the EU's tool to put a fair price on the carbon emitted during the production of carbon intensive goods that are entering the EU, and to encourage cleaner industrial production in non-EU countries" (Directorate-General for Taxation and Customs, 2025). The carbon border adjustment mechanisms may also lead other countries to increase their own carbon taxes, in order to decarbonise their economies more quickly and capture revenues from these carbon taxes themselves, instead of having their exporters make payments to foreign countries for the high carbon content of their products.

There are some concerns about adverse effects on growth from higher carbon prices. While some concerns are valid, it needs to be recognised that supporting the green transition with more stringent climate policy can create green jobs and thus support growth, enabling domestic firms to capture more of the increasing global demand for green products (Climate Change Committee, 2025). Other climate policies also allow the government to provide options to firms and households to switch more easily to renewable energy and increase energy efficiency. Some examples are government subsidies for district heating, public transport and housing insulation. These policies can help poorer households to switch more easily to renewable energies. Additionally, governments could mandate the installation of heat pumps for new homes or when an existing heating system needs to be replaced, and by providing support for poorer households for the one-off costs of this installation (Climate Change Committee, 2025). Furthermore, there can be co-benefits between development and better climate policies for developing economies (Dubash *et al.*, 2013; Ürges-Vorsatz *et al.*, 2014).

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Competing interests. The authors declare none.

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Appendix

Table A1. Effects of climate policies on CO₂ emissions: Restricted sample

	Dependent variable: ln CO ₂ emissions per capita (in metric tons, log)				
	Model				
	(I)	(II)	(III)	(IV)	(V)
	Model with carbon tax	Model with ETS	Model with carbon tax and ETS	Model with EPS	Model with carbon tax, ETS and EPS
Previous year ln CO ₂ per capita	0.6963*** 0.0769	0.7010*** 0.0762	0.6948*** 0.0769	0.7471*** 0.0598	0.7334*** 0.0627
Carbon tax (lagged)	–0.0012*** 0.0003		–0.0011*** 0.0003		–0.0006*** 0.0002
ETS (lagged)		–0.0014*** 0.0005	–0.0010** 0.0005		–0.0003 0.0004

(Continued)

Table A1. *Continued*

Dependent variable: ln CO ₂ emissions per capita (in metric tons, log)					
	Model				
	(I)	(II)	(III)	(IV)	(V)
	Model with carbon tax	Model with ETS	Model with carbon tax and ETS	Model with EPS	Model with carbon tax, ETS and EPS
EPS (lagged)				−0.0164**	−0.0135**
				0.0064	0.0066
GDP per capita (log)	0.1479***	0.1444***	0.1493***	0.1712***	0.1801***
	0.0446	0.0438	0.0449	0.0575	0.0616
GDP growth	0.3347***	0.3285***	0.3253***	0.5099***	0.5012***
	0.0968	0.0976	0.0969	0.1334	0.1334
Urbanisation rate	0.4650**	0.4695**	0.4566**	0.2500*	0.2086
	0.2168	0.2171	0.2158	0.1396	0.1352
Manufacturing/GDP	0.3376**	0.3320**	0.3396**	0.1661	0.1036
	0.1419	0.1410	0.1424	0.1875	0.2038
Share of electricity from oil	0.1547***	0.1477***	0.1547***	0.1387**	0.1614**
	0.0502	0.0490	0.0502	0.0564	0.0592
Share of electricity from coal	0.3375***	0.3276***	0.3300***	0.2331***	0.2640***
	0.0989	0.0972	0.0976	0.0642	0.0747
Share of electricity from renewables	−0.1006	−0.1054	−0.0816	−0.2361**	−0.1975**
	0.0861	0.0858	0.0848	0.0858	0.0852
Observations	2875	2875	2875	653	653
Number of countries	102	102	102	30	30
R ² within	0.842	0.841	0.842	0.879	0.881
R ² between	0.978	0.979	0.978	0.971	0.971

Note: Sample period: From 1971 to 2016, annual data. Cluster-robust standard errors reported in the second line are clustered at the country level. ***/**/* denote statistical significance at the 1%/5%/10% level. (I): nominal price of first carbon tax in USD/tCO₂ equivalents; (II): nominal price of ETS in USD/tCO₂ equivalents; (IV): EPS index; for (I) to (III): restricted to GDP per capita in constant 2010 dollars of above 1500. The countries included in the full unrestricted sample of this paper were chosen solely based on data availability. The following 121 countries were included in the full unrestricted sample, with their country codes listed below according to the standard International Organization for Standardization (ISO) three-letter country codes: AGO, ALB, ARE, ARG, AUS, AUT, AZE, BEL, BEN, BGD, BHR, BIH, BLR, BOL, BRA, BWA, CAN, CHE, CHL, CHN, CIV, CMR, COD, COG, COL, CRI, CUB, CZE, DEU, DNK, DOM, DZA, ECU, EGY, ERI, ESP, EST, ETH, FIN, FRA, GBR, GEO, GHA, GRC, GTM, HKG, HND, HRV, HTI, HUN, IDN, IND, IRL, IRN, IRQ, ISR, ITA, JAM, JOR, JPN, KAZ, KEN, KGZ, KHM, KOR, KWT, LBN, LKA, LTU, LVA, MAR, MDA, MEX, MKD, MMR, MNG, MOZ, MUS, MYS, NAM, NER, NGA, NIC, NLD, NOR, NPL, NZL, OMN, PAK, PAN, PER, PHL, POL, PRT, PRY, QAT, ROU, RUS, SAU, SDN, SGP, SLV, SVK, SVN, SWE, TGO, THA, TJK, TKM, TUN, TUR, TZA, UKR, URY, USA, VEN, VNM, YEM, ZAF, ZMB and ZWE.