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Effects of Green Technology Support Policies on Carbon Dioxide Emissions

Abstract

This paper provides ex-post empirical evidence on the effects of green technology support policies, in comparison with other climate policies, on carbon dioxide emissions at the aggregate national level. The paper uses cross-country dynamic panel estimation for a sample of 38 countries over the period from 1990 to 2015, controlling for macroeconomic determinants such as economic development, GDP growth, urbanisation and the energy mix. It uses a new index which measures the strength of green technology support policies, including separate sub-indices for the public support of expenditure on research and development of low-carbon energy technologies, and for the support of the adoption of wind energy and of solar energy. We find that an increase by one index point of the green technology support policy index leads to a significant reduction of around 0.9% in CO2 emissions per capita in the short run, and of around 3.7% in the long run. An increase by one index point of the green R&D expenditure support policy index leads to a significant reduction of around 0.4% in CO2 emissions per capita in the short run, and of around 1.7% in the long run. An increase by one index point of the wind energy support policy index leads to a significant reduction of around 0.5% in CO2 emissions per capita in the short run, and of around 2.1% in the long run.

JEL-Codes: Q000, Q480, Q580, Q550, Q400, Q500.

Keywords: green technology support policies, solar energy, wind energy, climate policies, carbon tax, carbon dioxide, climate change, emissions.

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1. Introduction

Global emissions of carbon dioxide, which are a key driver of global warming and climate change, have continued to increase in recent years. Standard climate change scenarios predict an increase of around 3°C in global temperatures compared with pre-industrial levels by the end of the century under the assumption that current climate policies are unchanged (IPCC, 2014). Climate policies therefore need to be expanded in order to reduce the emission of carbon dioxide and the associated large risks from global warming (IPCC, 2022). Such policies include carbon taxes and emissions trading systems, but also other policies such as green technology support policies (Stern, 2008). The International Energy Agency argues that the US Inflation Reduction Act, via its subsidies and tax credits for clean energy technologies, has helped to increase investment in clean energy, especially solar energy (IEA, 2023).

This paper provides ex-post empirical evidence on the effects of green technology support policies, in comparison with other climate policies, on carbon dioxide emissions at the aggregate national level, using cross-country dynamic panel estimation. The results are relevant for the design of the best climate policies to achieve a more speedy transition to net zero carbon emissions, which is required to limit global warming and climate change.

The paper uses an updated and expanded dataset on the stringency of different kinds of climate policies, which includes new measures on the stringency of green technology support policies (Kruse et al., 2022). This dataset contains a new index that measures the strength of green technology support policies, including separate sub-indices for the support of expenditure on research and development (R&D) of low-carbon energy technologies, and support for the adoption of wind energy and for the adoption of solar energy. It also contains an index of overall climate policy stringency, as well as a range of other sub-indices for the stringency of different climate policies, such as market-based policies (including carbon taxes and carbon emissions trading) and non market-based policies. This dataset starts in 1990 and was recently updated for an expanded sample of countries.[1]

To estimate the ex-post effects of green technology support policies on carbon dioxide emissions, in comparison with those of other kinds of climate policies, we use a cross-country dynamic panel estimation approach developed in Kohlscheen et al. (2021a,b), which controls for macroeconomic determinants of carbon dioxide emissions, including economic development, GDP growth, urbanisation and the energy mix.

There has been surprisingly little ex-post cross-country empirical evidence on the effects of climate policies on carbon dioxide emissions at the aggregate national level (Green, 2021; Tol, 2023). Recent papers on this include Metcalf and Stock (2020), Kohlscheen et al. (2021b) and D'Arcangelo et al. (2022).[2] These three papers reach quantitatively similar conclusions for the effect of carbon taxes on carbon dioxide emissions, despite using different empirical approaches. De Silva and Tenreyro (2021) find that the introduction of carbon taxes and ETS leads to lower carbon dioxide emissions.

There has been particularly little ex-post cross-country empirical evidence on the effects of green technology support policies on carbon dioxide emissions at the aggregate national level, and this

[1] See Nachtigall et al. (2022) on data on climate change mitigation policies starting in 2000 within the climate actions and policies measurement framework (CAPMF).

[2] See also Rafaty et al. (2020), Sen and Vollebergh (2018), Best et al. (2020) and Schroeder and Stracca (2023).

paper helps to fill this gap in the literature. De Silva and Tenreyro (2021) find some evidence that green R&D subsidies led to a limited reduction in carbon dioxide emissions.

This paper uses the local projections estimation method (Jorda, 2005) applied to a cross-country dynamic panel, building on recent work on the effects of carbon pricing and other climate policies on carbon dioxide emissions (Kohlscheen et al., 2021b). Kohlscheen et al. (2021b) used as measures of climate policies carbon taxes, carbon ETS prices, and an earlier less comprehensive overall climate policy stringency index from the OECD without measures on the stringency of green technology support policies.

Theoretical models suggest that green technology policy is an important tool of climate policy to help achieve a transition to net zero carbon dioxide emissions. The following papers present theoretical models of the effects of green technology policy. Aghion et al. (2022) present a model in which public green R&D subsidies support the development of green technologies, complementing the tool of carbon taxes to reduce carbon emissions. Ploeg and Venables (2022) argue that in the presence of strategic complementarities due to technological spillovers, amplification mechanisms increase the effectiveness of green technology policies; but if there are multiple equilibria, more ambitious green technology policies are needed to move from an equilibrium of high carbon emissions to one of low emissions.[3] Acemoglu et al. (2012) present a model of directed technical change and find that optimal climate policy involves research subsidies for the development of green technologies in addition to carbon taxes. Zhou and Smulders (2022) also present a model of directed technical change and find that optimal climate policy requires a coordination device in addition to carbon taxes. Gerlagh et al. (2009) argue that research subsidies would allow lower carbon taxes, and Gerlagh et al. (2014) study optimal clean energy R&D policy.[4]

The effect of green technology policy and other climate policies on productivity at the firm- and country level is explored in Benatti et al. (2023), but they do not study the effect of green technology policy on carbon dioxide emissions. The effect of climate policy on innovation and productivity at the firm- and sectoral levels has been studied by Dechezleprêtre and Kruse (2022).

Rafaty et al. (2020) conclude that carbon pricing on its own, even if implemented globally, is likely to reduce carbon emissions insufficiently to meet the Paris climate agreement goals, since its effect is smaller than often assumed in theoretical models. It should therefore be complemented with other climate policies in order to be able to meet the goals of the Paris climate agreement. A policy report by the Coalition of Finance Ministers for Climate Action (2023) concludes that carbon pricing on its own is likely not to be sufficient for achieving the emission cuts needed for limiting global warming to 1.5°C above pre-industrial levels and achieve global net zero carbon emissions, due to market and non-market barriers, including innovation spillovers, infrastructure lock-in, network externalities, public goods, equity impacts, split incentives, information costs and gaps, financing constraints and coordination problems. The report suggests that policies to complement carbon pricing should include green technology policies such as subsidies and tax incentives for low-carbon R&D to drive innovation, and public investments in complementary enabling infrastructure, for example in clean mobility and grid infrastructure.

[3] See also Jaakkola et al. (2023).

[4] An overview of the results from 24 ex-ante models in the IPCC's AR6 Scenario Database (Byers et al., 2022) on the effects of carbon taxes on carbon dioxide emissions, in comparison with the results from ex-post empirical models, is provided in Tol (2023). See also Pisu et al. (2023) on assessing the effects of climate change mitigation policies on emissions using ex-ante analytical models versus ex-post empirical models.

The remainder of the paper proceeds as follows. Section 2 presents the data and Section 3 discusses the method and results. Finally, Section 4 concludes.

2. Data

Data on the stringency of different kinds of climate policies, as described by Kruse et al. (2022), are taken from the OECD. These include indices for the stringency of green technology support policies, which consists of three further sub-indices for the support by the government of expenditure on research and development on low-carbon energy technologies, and government support for the adoption of wind energy and for the adoption of solar energy. The index for public support of expenditure on research and development on low-carbon energy technologies is based on such expenditure relative to the size of a country's nominal GDP. The index of support for the adoption of wind and solar energy is based on the level of the price support for wind and solar energy technologies from feed-in tariffs and renewable energy auctions, relative to the global levelised cost of electricity (LCOE), each measured in US dollars/kWh (Kruse et al., 2022). The index ranges from zero (no policy in place) to six (most stringent policy in place). The index scores are assigned based on the distribution of observations which have the policy in place.

The index of overall climate policy stringency consists of the sub-indices for green technology support policies, market-based policies, and non-market based policies. The index for market-based policies includes carbon taxes, carbon emissions trading schemes, renewable energy trading schemes, as well as nitrogen and sulphur oxides taxes and diesel fuel taxes. The index for non market-based policies consists of policies which mandate emission limits and standards for nitrogen oxides, sulphur oxides, particulate matter, and the sulphur content for diesel.

Data on CO_2 emissions per capita (in metric tons per capita) are taken from the World Development Indicators (WDI) database. Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement, they include carbon dioxide produced during the consumption of solid, liquid, and gas fuels and gas flaring. Data on the shares of electricity production from coal, oil and gas sources are also taken from the WDI database (as a percentage of total electricity production), where they are only available up to 2015.

The following macroeconomic data are also taken from the WDI database. GDP growth (annual growth in percent) is defined as the annual percentage growth rate of GDP at market prices based on constant local currency. GDP per capita (in constant 2010 US dollars) is gross domestic product divided by mid-year population, in constant 2010 US dollars. Urbanisation is the urban population as a percentage of the total population, where the urban population refers to people living in urban areas as defined by national statistical offices; the data are collected and smoothed by the United Nations Population Division.

We consider the following 38 countries: Australia, Austria, Belgium, Brazil, Canada, Chile, China, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, South Korea, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Russian Federation, the Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The sample period is from 1990 to 2015.

3. Method and results

We quantify the effects of green technology support policies and other climate policies on carbon dioxide emissions using a dynamic panel model. The dynamic specification accounts for the high degree of persistence in CO_2 emissions. We control for macroeconomic factors affecting carbon emissions, such as economic development (GDP per capita), GDP growth, urbanisation and the energy mix used in electricity production. We determine the effects of climate policies (denoted by $cpol^{m}$) on the logarithm of carbon-dioxide emissions per capita (denoted by lnCO2) according to[5]

$$\begin{aligned} \mathrm{lnCO2}_{\mathrm{i,t}} = \alpha_i + \beta_t + \rho\, \mathrm{lnCO2}_{\mathrm{i,t-1}} + \sum_{m=1}^{M} \lambda_m\, cpol^{m}{}_{\mathrm{i,t-1}} + \gamma\, \mathrm{GDPpc}_{\mathrm{i,t}} \\ + \theta\, \mathrm{growth}_{\mathrm{i,t}} + \omega\, \mathrm{urbanisation}_{\mathrm{i,t}} + \mu_1 \mathrm{share}_{\mathrm{oil,i,t}} \\ + \mu_2\, \mathrm{share}_{\mathrm{coal,i,t}} + \mu_3\, \mathrm{share}_{\mathrm{renewables,i,t}} + \varepsilon_{i,t} \end{aligned} \quad (1)$$

Besides the lagged dependent variable, we include climate policies as key explanatory variables of interest, $cpol^{m}_{i,t}$, for m=1,…,M different kinds of policies in country *i* at time *t*. To address potential endogeneity concerns, we use lagged climate policy variables, which minimise the risk of reverse causality. As climate policies we consider green technology support policies (consisting of R&D expenditure on low-carbon energy technologies, adoption support for solar energy and adoption support for wind energy), market-based policies ($cpol^{market}_{i,t}$) and non-market based policies ($cpol^{non\text{-}market}_{i,t}$) at the national level, using the OECD's index and sub-indices for the stringency of climate policies described in Section 2. We consider green technology support policies both combined as one index, $cpol^{greentech}_{i,t}$, as well as in other specifications using separate variables for its three sub-components of green R&D expenditure ($cpol^{greenR\&D}_{i,t}$), adoption support for solar energy ($cpol^{solar}_{i,t}$) and adoption support for wind energy ($cpol^{wind}_{i,t}$).

We also include a number of macroeconomic variables as controls, economic development (GDP per capita) ($\mathrm{GDPpc}_{i,t}$), GDP growth ($\mathrm{growth}_{i,t}$) and the urbanisation rate ($\mathrm{urbanisation}_{i,t}$). We also include the energy mix used in electricity production, namely the share of electricity produced from oil ($\mathrm{share}_{oil,i,t}$), from coal ($\mathrm{share}_{coal,i,t}$), and from renewables ($\mathrm{share}_{renewables,i,t}$).

We include country fixed effects, α_i, to capture unobserved heterogeneities across countries that might affect the rate of carbon dioxide emissions. These include fixed institutional factors like enforcement of environmental laws, as well as natural factors such as average median temperatures, which tend to correlate with heating or cooling needs. We also include yearly time dummies, β_t, to control for the effects of global factors. These include for example technological advances which may reduce environmental effects, as well as other global trends or global shocks. As our baseline specification we use fixed effect panel estimations with robust standard errors clustered at the country level. The sample period is from 1990 to 2015.

For robustness we also perform dynamic panel estimation with instrumental variables using the method of Arellano and Bond (1991), in order to further address potential endogeneity problems. We implement it with the xtabond command in Stata, using its default settings of one lag of the dependent variable included in the model and the corresponding default settings for the maximum numbers of lags of the variables for use as instruments.[6]

[5] This dynamic specification is based on Kohlscheen et al. (2021b), but we drop the share of manufacturing in total output since it is not significant.

[6] The Sargan test of overidentifying restrictions does not reject the validity of the instruments at the 5% significance level in all our specifications.

As another robustness test, we also consider sub-indices for two of the important subcomponents of market-based policies separately, namely carbon taxes ($cpol^{carbon\ tax}{}_{i,t}$) and carbon trading schemes ($cpol^{carbon\ trading}{}_{i,t}$).

The results of equation (1) with the three climate policy variables green technology support policies, market-based policies and non-market based policies, using fixed effects dynamic panel estimation, are shown in Table 1. We find that green technology support policies have a significant effect (at the 1% significance level) in reducing CO_2 emissions per capita, when controlling for the significant effect of market-based policies (which include carbon taxes and carbon pricing schemes). An increase by one index point of the green technology support policy index leads to a reduction of 0.9% in CO_2 emissions per capita in the short run, and of 3.7% in the long run. The effect of market-based policies in reducing carbon dioxide emissions is also significant at the 1% level but larger, with an increase by one index point having a short-run effect of 2.1% on CO_2 emissions per capita, and a long-run effect of 8.9%. Non market-based policies have no significant effect on carbon dioxide emissions.

The results of equation (1) using as climate policy variables the three separate sub-indices of green R&D expenditure, adoption support for solar energy, and adoption support for wind energy, instead of the overall index for green technology support policies, in addition to market-based policies and non-market based policies, are shown in Table 2. Again, fixed effects dynamic panel estimation is used. We find that an increase by one index point of the green R&D expenditure support policy index leads to a significant reduction of 0.4% in CO_2 emissions per capita in the short run, and of 1.7% in the long run. An increase by one index point of the wind energy support policy index leads to a significant reduction of 0.5% in CO_2 emissions per capita in the short run, and of 2.1% in the long run. The effect of market-based policies in reducing carbon dioxide emissions is again significant at the 1% level and of similar magnitude as in the specification in Table 1.

As a robustness test, we next include two important subcomponents of market-based policies separately, namely carbon taxes and carbon trading schemes. The results of equation (1) using the climate policy variables green technology support policies and non-market based policies, but now using the sub-indices of carbon taxes and carbon trading schemes separately instead of the overall index for market-based policies, are shown in Table 3. The result for the effect of green technology support policies on carbon dioxide emissions is robust to using this specification. An increase by one index point of the green technology support policy index leads to a similar significant reduction of 0.8% in CO_2 emissions per capita in the short run, and of 3.5% in the long run. This effect on carbon dioxide emissions is similar in magnitude to the effect of one index point increase of the carbon tax index of 1.0% in the short run, and larger than the corresponding effect of the carbon trading scheme index of 0.5% in the short run. Our result that the carbon tax index and the carbon trading scheme index are significant individually is consistent with the findings of Kohlscheen et al. (2021b), who find significant effects for both carbon taxes and prices of permits in carbon emission trading schemes in reducing carbon dioxide emissions, using price information for these carbon pricing policy tools. It is also consistent with the significant effect of carbon taxes in reducing carbon dioxide emissions found in Metcalf and Stock (2020).

The results of equation (1) using as climate policy variables the three separate sub-indices of green R&D expenditure, adoption support for solar energy, and adoption support for wind energy, but now using the sub-indices of carbon taxes and carbon trading schemes separately instead of the overall index for market-based policies, in addition to non-market based policies, are shown in Table 4. The result for the effect of green R&D support policies on carbon dioxide emissions is robust to using this specification. An increase by one index point of the green R&D

expenditure support policy index leads to a slightly larger significant reduction of 0.5% in CO_2 emissions per capita in the short run, and of 2.2% in the long run. The effect of the wind energy support policy remains negative with a slightly smaller magnitude, but becomes insignificant. The effect of carbon taxes and of carbon trading schemes in reducing carbon dioxide emissions are again significant and of similar magnitudes as in the specification in Table 3.

The results of equation (1) using the three climate policy variables of green technology support policies, market-based policies and non-market based policies, but now employing dynamic panel estimation with instrumental variables using the method of Arellano and Bond (1991), are shown in Table 5. The result for the effect of green technology support policies on carbon dioxide emissions is robust to using this specification with instrumental variables. An increase by one index point of the green technology support policy index leads to a similar significant reduction of 0.9% in CO_2 emissions per capita in the short run, and of 3.2% in the long run. The effect of market-based policies in reducing carbon dioxide emissions is again significant at the 1% level and of slightly larger magnitude than in the specification in Table 1.

The results of equation (1) using as climate policy variables the three separate sub-indices of green R&D expenditure, adoption support for solar energy, and adoption support for wind energy, in addition to market-based policies and non-market based policies, employing dynamic panel estimation with instrumental variables using the method of Arellano and Bond (1991), are shown in Table 6. The result for the effect of wind energy support policy on carbon dioxide emissions is robust to using this specification. An increase by one index point of the wind energy support policy index leads to a slightly larger significant reduction of 0.6% in CO_2 emissions per capita in the short run, and of 2.1% in the long run. The effect of green R&D support policies remains negative with a somewhat smaller magnitude, but becomes insignificant. The effect of market-based policies in reducing carbon dioxide emissions is again significant and of slightly larger magnitude than in the specification in Table 2.

Our result of a significant effect of green technology support policies in reducing carbon dioxide emissions, when controlling for the effects of carbon pricing, supports the conclusion of Coalition of Finance Ministers for Climate Action (2023) that policies to complement carbon pricing should include green technology policies such as subsidies and tax incentives for low-carbon R&D. It also supports the conclusion of Rafaty et al. (2020) that carbon pricing should be complemented with other climate policies in order to meet the goals of the Paris climate agreement.

4. Conclusions

This paper provided ex-post empirical evidence on the effects of green technology support policies, in comparison with other climate policies, on carbon dioxide emissions at the aggregate national level. The paper used cross-country dynamic panel estimation for a sample of 38 countries over the period from 1990 to 2015, controlling for macroeconomic factors such as economic development, GDP growth, urbanisation and the energy mix. It used a new index which measures the strength of green technology support policies, including separate sub-indices for the support of expenditure on green research and development, and for the support of the adoption of wind energy and solar energy.

We find that an increase by one index point of the green technology support policy index leads to a significant reduction of around 0.9% in CO_2 emissions per capita in the short run, and of around 3.7% in the long run. An increase by one index point of the green R&D expenditure support policy index leads to a significant reduction of around 0.4% in CO_2 emissions per capita in the short run, and of around 1.7% in the long run. An increase by one index point of the wind energy support policy index leads to a significant reduction of around 0.5% in CO_2 emissions per capita in the short run, and of around 2.1% in the long run.

Our result of a significant effect of green technology support policies in reducing carbon dioxide emissions, over and above the effects of carbon pricing, supports the conclusion of Rafaty et al. (2020) and Coalition of Finance Ministers for Climate Action (2023) that carbon pricing should be complemented with other climate policies in order to meet the goals of the Paris climate agreement, including green technology policies such as subsidies and tax incentives for low-carbon R&D.

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Tables

Table 1
Effects of climate policies on CO2 emissions

Dependent variable: lnCO2 emissions per capita (in metric tons, log)	
previous year lnCO2 per capita	0.7629***
green tech support policy (lagged)	-0.0087***
market-based policy (lagged)	-0.0211***
non market-based policy (lagged)	-0.0001
GDP per capita (log)	0.1581***
GDP growth	0.5083***
urbanisation rate	0.2611**
share of electricity from oil	0.1152***
share of electricity from coal	0.2427***
share of electricity from renewables	-0.1267**
observations	937
number of countries	38
Time fixed effects	yes
R2 within	0.902
R2 between	0.972

Notes: Sample period: from 1990 to 2015, annual data. Cluster-robust standard errors reported in brackets are clustered at the country level. ***/**/* denote statistical significance at the 1%/5%/10% levels.

Table 2
Effects of climate policies on CO2 emissions: individual green tech policies separately

Dependent variable: lnCO2 emissions per capita (in metric tons, log)	
previous year lnCO2 per capita	0.7614***
green R&D expenditure support (lagged)	-0.0043*
wind energy adoption support (lagged)	-0.0049**
solar energy adoption support (lagged)	0.0006
market-based policy (lagged)	-0.0216***
non market-based policy (lagged)	-0.0003
GDP per capita (log)	0.1604***
GDP growth	0.5087***
urbanisation rate	0.2719**
share of electricity from oil	0.1172***
share of electricity from coal	0.2431***
share of electricity from renewables	-0.1254**
observations	937
number of countries	38
Time fixed effects	yes
R2 within	0.903
R2 between	0.971

Notes: Sample period: from 1990 to 2015, annual data. Cluster-robust standard errors reported in brackets are clustered at the country level. ***/**/* denote statistical significance at the 1%/5%/10% levels.

Table 3
Effects of climate policies on CO2 emissions: with carbon pricing separately

Dependent variable: lnCO2 emissions per capita (in metric tons, log)	
previous year lnCO2 per capita	0.7626***
green tech support policy (lagged)	-0.0084**
carbon tax (lagged)	-0.0096**
carbon trading scheme (lagged)	-0.0048*
non market-based policy (lagged)	-0.0010
GDP per capita (log)	0.1468***
GDP growth	0.5133***
urbanisation rate	0.2806**
share of electricity from oil	0.1152***
share of electricity from coal	0.2290***
share of electricity from renewables	-0.1407**
observations	937
number of countries	38
Time fixed effects	yes
R2 within	0.902
R2 between	0.973

Notes: Sample period: from 1990 to 2015, annual data. Cluster-robust standard errors reported in brackets are clustered at the country level. ***/**/* denote statistical significance at the 1%/5%/10% levels.

Table 4
Effects of climate policies on CO2 emissions: individual green tech policies and carbon pricing separately

Dependent variable: lnCO2 emissions per capita (in metric tons, log)	
previous year lnCO2 per capita	0.7614***
green R&D expenditure support (lagged)	-0.0053***
wind energy adoption support (lagged)	-0.0031
solar energy adoption support (lagged)	-0.0001
carbon tax (lagged)	-0.0090**
carbon trading scheme (lagged)	-0.0050*
non market-based policy (lagged)	-0.0011
GDP per capita (log)	0.1505***
GDP growth	0.5123***
urbanisation rate	0.2720**
share of electricity from oil	0.1169***
share of electricity from coal	0.2312***
share of electricity from renewables	-0.1373**
observations	937
number of countries	38
Time fixed effects	yes
R2 within	0.902
R2 between	0.973

Notes: Sample period: from 1990 to 2015, annual data. Cluster-robust standard errors reported in brackets are clustered at the country level. ***/**/* denote statistical significance at the 1%/5%/10% levels.

Table 5
Effects of climate policies on CO2 emissions: instrumental variable estimation

Dependent variable: lnCO2 emissions per capita (in metric tons, log)	
previous year lnCO2 per capita	0.7369***
green tech support policy (lagged)	-0.0085***
market-based policy (lagged)	-0.0262***
non market-based policy (lagged)	-0.0030
GDP per capita (log)	0.1562***
GDP growth	0.5210***
urbanisation rate	0.3143**
share of electricity from oil	0.1454***
share of electricity from coal	0.2532***
share of electricity from renewables	-0.2436***
observations	899
number of countries	38
Serial Correlation Test[a]	0.554

Notes: Sample period: from 1990 to 2015, annual data. Cluster-robust standard errors reported in brackets are clustered at the country level. ***/**/* denote statistical significance at the 1%/5%/10% levels. Arellano-Bond dynamic panel instrumental variable estimation. [a] Reports p-values for the null hypothesis that the errors in the first-difference regression exhibit no second-order serial correlation.

Table 6
Effects of climate policies on CO2 emissions: individual green tech policies separately with instrumental variable estimation

Dependent variable: lnCO2 emissions per capita (in metric tons, log)	
previous year lnCO2 per capita	0.7325***
green R&D expenditure support (lagged)	-0.0026
wind energy adoption support (lagged)	-0.0056**
solar energy adoption support (lagged)	-0.00005
market-based policy (lagged)	-0.0280***
non market-based policy (lagged)	-0.0034
GDP per capita (log)	0.1596***
GDP growth	0.5195***
urbanisation rate	0.3536***
share of electricity from oil	0.1452***
share of electricity from coal	0.2524***
share of electricity from renewables	-0.2418***
observations	899
number of countries	38
Serial Correlation Test[a]	0.537

Notes: Sample period: from 1990 to 2015, annual data. Cluster-robust standard errors reported in brackets are clustered at the country level. ***/**/* denote statistical significance at the 1%/5%/10% levels. Arellano-Bond dynamic panel instrumental variable estimation. [a] Reports p-values for the null hypothesis that the errors in the first-difference regression exhibit no second-order serial correlation.