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The role of governments in emission cuts: evidence from emerging and advanced economies[1]

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The Role of Governments in Emission Cuts: Evidence from Emerging and Advanced Economies

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Abstract

Government policies such as subsidies, environmentally-related research and development expenditures and technological incentives play crucial role in mitigating the implications of climate change. Our study investigates the role of governments in scaling up climate transition in advanced and emerging countries. We employ Panel Augmented Mean Group Estimator to find the long-term relationship between carbon intensity and various government policies. Covering 2010-2021 period, the data of 18 countries were included in the estimations. Carbon intensity, as a measure of climate change, is proxied by carbondioxide (CO_2) emissions per GDP while government policy is represented with 3 indicators: i. Total fossil fuel support as a % of tax revenue, ii. Environmentally-related government research and development (R&D) budget as a % of total government R&D budget and iii. Development of environment-related technologies as a % of all technologies. The results of the estimation covering all countries in the dataset indicate that development of environment-related technologies is positively interrelated with CO_2 emissions per GDP, contrary to our ex-ante expectations. It is inferred that the development of technologies does not necessarily reflect their level of usage. As for emerging countries, there is a mixed pattern in the interrelation between climate change and explanatory variables related to government policies. This is partly because the environmental policies and regulations in emerging countries are not sufficiently entrenched to achieve intended results and there appears to be a lack of effective data reporting. On the other hand, the results indicate that in advanced countries, fossil fuel subsidies are positively interrelated with CO_2 emissions per GDP in the long-term, compatible with our ex-ante expectations on the deteriorating impact of fossil fuel subsidies on climate change. Checking country-based estimation results, it is striking that in advanced countries with higher income levels, development of environment-related technologies does not contribute to limit climate change. This finding confirms difference between exporters and end-users of environmental technologies. We draw attention to the export factor where the exporter bears the environmental damages of production process while not thoroughly benefitting from the environmental advantages of the technology. US, UK, Canada, Japan and Germany, where environment-related technologies are not interrelated with carbon intensity, might be considered as predominant technology-exporters. Finally, we propose additional policy implications regarding the role of governments in emission cuts. Government support might range from grants, subsidies, feed-in-tariffs, tax exemptions, direct tax credits, credit guarantees and other kind of incentive schemes for decarbonization technology investments. Along with financial support, governments might also support decarbonization via creating an enabling regulatory landscape for the development of climate and environment-related technologies as well as removing information asymmetries pertaining to climate investments.

Keywords: Carbon Intensity, Government Policy, Environmentally-related R&D Budget, Fossil Fuel Subsidies, Environment-related technologies

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1. INTRODUCTION

Climate change has recently been more pronounced around the globe. On this ground, Paris Agreement serves as a significant landmark to mobilize a global response to the threat of climate change. Although the Agreement is not legally binding under international law, all stakeholders including governments are considered as part of global climate effort. It is hopeful that there has been some progress in cutting global emissions, since the Paris Agreement was signed in 2015. Still, the world is heading for a temperature rise far above the Paris Agreement goals, unless countries deliver more than they have promised. UN's 2023 Emissions Gap Report finds that fully implementing unconditional Nationally Determined Contributions (NDCs) made under the Paris Agreement would put the world on track for limiting temperature rise to 2.9°C above pre-industrial levels this century. (UN, 2023). Furthermore data shows that significant amount of renewable power additions are required to meet government targets with deadlines between 2020 and 2030. (FS-UNEP Centre, 2020) Thus, all sectors of the global economy will have to go a massive transformation to drive the emission reductions so as to live up to the Paris Agreement targets.

In an attempt to promote sustainable economic development, a supportive environment is needed to scale up domestic manufacturing capacities for the climate and environment-related technologies[3]. Technologies that are used to address climate change are known as climate technologies. Climate technologies that help reduce greenhouse gas emissions include renewable energies such as wind energy, solar power and hydropower. As for environment-related technologies, they include the means of production and services that contribute to the efficient use of available resources, as well as the protection and conservation of natural resources. Climate and environment-related technologies both have positive environmental impact and contribute to sustainability. The most common feature of all these technologies is that they all require high level of upfront investment, which pays itself back gradually.

Here comes the crucial role of government. Albeit being in varying levels, the role of governments in achieving climate targets and tackling climate change is undoubtful. Governments and related authorities might play a critical role in creating an enabling landscape for the development of both climate and environment-related technologies.

[3] In this study, climate technologies and environment-related technologies are used interchangeably, due to the lack of data on climate technologies.

Along these lines, it has recently been witnessed that some governments announced plans to green their industries and scale up climate transition in their respective jurisdictions. First and foremost is the European Union's (EU) Green Deal Industrial Plan. While the European Commission is looking to "secure the EU's industrial lead in the fast-growing net-zero technology sector", the plan is primarily to level the climate finance playing field following the passing of the Inflation Reduction Act (IRA) in the US and new subsidies to boost domestic clean-technology manufacturing in China (EU Commission, 2023). The current juncture has also witnessed the rise of green protectionism efforts by many jurisdictions, to secure the delivery of critical minerals. Furthermore, recent data indicates an upward trend in government measures to combat climate change; such as collecting environmental taxes and allocating government spending on environmental protection (IMF, 2023). All these recent actions and policies in the global or domestic landscapes reveal that governments are also in the game to address the implications of climate change.

Recently, government-provided fossil fuel subsidies that aim to support certain industries or households, have been loudly criticized due to their potential effect on increasing CO2 emissions, and subsequently elevating climate change. In this context, Black et al. (2023) puts forward the current use of fossil fuel subsidies by country and region and at the global level. According to data, global fossil fuel subsidies reached to $7 trillion by the end of 2022, representing 7.1% of global GDP. It defines total fossil fuel subsidy as a multiplication of consumption with the gap between efficient prices (total of supply, environmental and other costs) and retailed prices. This price gap is so pronounced that increased use of fossil fuels is leading to climate-related damages and exposure to air pollution, which is responsible for 4.5 million premature deaths worldwide. In addition, underpricing of fossil fuels reduces government revenues and disrupts the achievement of income distribution targets, as underpricing tends to benefit the wealthy rather than the low-income segment. The same study argues that fossil fuel price reform to remove subsidies could cushion global CO2 emissions by 43% below baseline levels by 2030, increase revenues by 3.6% of global GDP and restrain 1.6 million deaths a year from air pollution.

Another intriguing question is whether or not government policy is needed to redirect technical change from dirty to clean technologies. The response to the question has been widely discussed in the literature. Our study, as an attempt to comtemplate on the issue, builds its discussion on the stated earlier literature, while mainly targeting to capture the role of governments in scaling up climate transition in several jurisdictions.

We try to explore the interrelation between carbon intensity and government policy. Carbon intensity is proxied by CO2 emissions per GDP in each jurisdiction, on a yearly basis. Basically, carbon intensity is a measure of carbon dioxide per unit of activity, like generating a product. We believe that this indicator is a better proxy, depicting the level of dirtiness of the production. We proxy the government policy by 3 indicators; i. Environmentally-related government R&D budget as a % of total government R&D budget, ii. Total fossil fuel support as a % of tax revenue and iii. Development of environment-related technologies as a % of all technologies. The study is a cross-country analysis, aiming to differentiate between emerging and advanced economies. OECD Green Growth Indicators are utilized in annual frequency, with the most available time horizon. The study employs Panel Augmented Mean Group Estimator, based on cross-sectional dependence and slope homogeneity test results.

Our paper acknowledges the role of government in mitigating climate change, not only by the monetary support but also non-monetary support. Thus, we also focus on governments' and related public institutions' supporting role in increasing private climate investments, via closing climate-related data gaps and removing information asymmetries. Indeed, international institutions are also helping to remove such information barriers. IMF Climate Change Indicators Dashboard, World Bank Climate Change Knowledge Portal, OECD Climate Action Monitor, BIS Irving Fisher Committee on Central Bank Statistics and G20 Sustainable Finance Progress Tracking Dashboard are leading initiatives to effectively address climate-related data gaps.

The study, while including an analytical approach, also discusses the issues stated above. The remainder of the study is organized as follows: Section 2 reviews the literature. The data are presented in Section 3, while model and methodology are discussed in Section 4. Section 5 discusses panel estimation results. Finally, Section 6 concludes.

2. LITERATURE REVIEW

The interrelation of the climate change with various other indicators has been widely investigated in the earlier liteature. Examination of this line of literature reveals that most of the literature use CO2 emissions as a proxy for climate change.

Examining the empirical research, we find that Moosavian et al. (2022) try to constitute a government policy in respect to subsidy rate on research&development (R&D) investment and tax rates on fossil fuels in order to achieve the highest benefits in economic, welfare and environmental terms. They use a computable general equilibrium model to find the optimum subsidy rate for both R&D investment in GDP and the tax rate imposed on fossil fuels. In the context of the model, the optimal level of subsidy and tax rate is calculated based on two scenarios. Based on the results of the scenarios, they conclude that both of the fossil fuel tax policy and the environment-related R&D subsidy policy contribute to the reduction of energy consumption, air pollution and welfare, excluding the social benefits achieved by environmental government policies.

Petrovic and Lobanov (2019) examine the effect of R&D expenditure on CO2 emissions in 16 OECD countries. The results of the long-run regression indicate an expected average negative effect of R&D expenditure on CO2 emissions, while the country-specific analysis shows that R&D expenditure can have both negative and positive effects on emissions in the long-run. Thus, they emphasize that it is important for decision-makers to focus on reducing CO2 emissions when setting R&D policies, as R&D investments cannot be labeled beforehand as an emission-reducing factor.

Using a computable general equilibrium model, Yusoff and Bekhet (2016) examine the impact of removal of fuel subsidies in Malaysian economy. The study mentions that energy subsidies can lead to inefficient energy consumption and environmental pollution and have a negative impact on the government budget. The results of the general equilibrium model show that the removal of the subsidy policy significantly reduces fuel consumption and leads to an increase in the use of alternative energy. On the other hand, the removal of fuel tax subsidies also has a positive impact on macroeconomic variables, increasing real GDP, reducing government expenditure and increasing government revenue.

Garrone and Grilli (2010) explore the role of public energy R&D (PERD) spending on energy innovation process, by establishing a connection with carbon emissions per GDP. Their study examines two channels through which PERD influences greenhouse gas emissions: the carbon factor and the carbon intensity, where the carbon factor describes carbon emissions per unit of energy use. These two factors are important as their reduction leads to emission reductions without adverse effects on economic growth. In the analysis, 13 advanced economies are examined using a dynamic panel model, utilizing data for 1980-2004 period. The results show that, while PERD enhances energy efficiency, it does not have a significant contribution to explain the carbon factor and carbon intensity. They emphasise that government expenditures on R&D are necessary but not adequate to achieve the desired innovation in energy.

Halkos and Paizanos (2013) analyse the effect of government spending on the environmental pollution in 77 countries, using panel data spanning from 1980 to 2000. The study considers both direct and indirect effects of government spending on pollution, where its indirect effect comes from increasing per capita income. The study finds that government spending has a clear negative effect on CO2 emissions at all income levels, while it has a variable effect on sulphur dioxide emissions at different income levels.

In another interesting research, Acemoglu et al. (2012) argue that government policy is needed to steer technical change from dirty to clean technologies. They introduce an endogeneous growth model with endogenous and directed technical change and focus on the structure of the equilibrium with dynamic tax and subsidy policies that will ensure sustainable growth and maximize intergenerational welfare. Their endogenous growth model, which is in line with guided technological change, takes environmental constraints and limited resources into consideration. In their analysis, they divided inputs into clean and dirty (using non-renewable resources) to state that long-term sustainable growth can be possible with temporary policy measures when inputs are sufficiently substitutable. They also articulate that the optimal policies to prevent the intensive use of carbon taxes will consist of both carbon taxes and research subsidies. Additionally, they claim that the cost will increase in case of any delay in intervention and the economy will face environmental disaster when there is no intervention. As as a result, with timely interventions, environmental goals can be achieved without the need for continuous intervention and without compromising long-term growth. Otherwise, they stated that the laissez-faire paradigm would lead to environmental disasters.

Mongo et al. (2021) investigate the impact of environmental innovations, i.e. green technologies, on CO2 emissions. Their analysis employs an autoregressive distributed lag model (ARDL) model, utilizing data from 15 EU countries in the period between 1991 and 2014. In the model, they use environmental innovations, renewable energy consumption, GDP per capita and the degree of economic openness to explain CO2 emissions. According to the results, they interpret that environmental innovations would reduce CO2 emissions in the long run, while the effect of environmental innovations is reversed in the short run, indicating a possible rebound effect.

Du et al. (2019) examine the effect of green technology innovation on CO2 emissions with a panel data including 71 countries from 1996 to 2012, taking income level of the countries into account. The results show that green technology innovation does not contribute to mitigating CO2 emissions when the income level of the country is below a threshold which is close to USD 35,000. When the income level rises above this threshold, green technology innovation becomes a significant factor in reducing CO2 emissions.

Zhang (2021) investigates the impact of technological innovation and economic growth on carbon emissions employing Granger causality test and a regression model. The study utilizes panel data of five BRICS countries (Brazil, Russia, India, China and South Africa) from 1990 to 2019. According to causality test results, there is a one-way causality from both technology patents and economic growth to carbon emissions. On the other hand, regression results show that technology patents help reducing carbon emissions, as economic growth significantly uplifts carbon emissions.

To sum up, examination of the literature reveals varying results on the interrelation of environmental R&D expenditure as well as innovations with the level of CO2 emissions.

3. DATA

Our study utilizes data from various open international sources, mainly the data of international institutions. The data were used in annual frequency from 2010 to 2021, based on the availability of data span. The data of 18 countries have been included in the panel regressions, based on the availability of the country-based variables sourced from OECD Green Growth Indicators dataset. Thus; Chile, Colombia, Korea, Mexico, Türkiye, Czechia and Hungary were included in emerging countries, while Australia, Canada, France, Germany, Italy, Japan, Netherlands, Spain, Sweden, UK and US were included in advanced countries.

Table 1 summarizes the description of the data.

Table 1. Data Description

Abbreviation	**Indicator**	**Measurement Scale**	**Source**
CO2_Emission_per_GDP	CO2 Emission Per GDP (as a measure of carbon intensity)	t CO2/kUSD/yr	IEA-EDGAR CO2 Dataset (Crippa et al, 2022)
FFS_percentage_of_TR	Total Fossil Fuel Support	% of Tax Revenue	OECD Green Growth Indicators (OECD, 2024)
EnvR&D_percentage_of_GovR&D	Environmentally Related Government R&D Budget	% of Total Government R&D	OECD Green Growth Indicators (OECD, 2024)
EnvTech_percentage_of_AT	Development of Environment-related Technologies	% of All Technologies)	OECD Green Growth Indicators (OECD, 2024)

Descriptive statistics of the data are presented in Table 2. The descriptive statistics reveal that Environmentally Related Government R&D Budget, % of Total Government R&D variable has the highest standart deviation. It is also recognized that all series are positively skewed. The last but not least is that after checking residual variances, we transform all variables into logarithmic form to control heteroscedasticity, before employing our estimations.

Table 2. Descriptive Stats (Individual Samples)

Statistics	CO2 Emission Per GDP	Total Fossil Fuel Support, % of Tax Revenue	Environmentally Related Government R&D Budget, % of Total Government R&D	Development of Environment-related Technologies % of All Technologies)
Mean	0.20	1.27	3.04	12.28
Median	0.18	0.71	2.36	12.32
Maximum	0.41	12.19	21.56	26.42
Minimum	0.07	0.05	0.05	5.62
Std. Dev	0.07	1.69	3.53	2.72
Skewness	0.59	3.86	3.49	1.00
Kurtosis	2.41	21.57	15.21	7.52
Jarque-Bera	15.87	3544.55	1,692.29	183.69
Probability	0.00	0.00	0.00	0.00
Sum	44.38	266.74	624.67	2,210.79
Sum Sq. Dev.	1.36	599.38	2,550.87	1,324.58
Observations	216	210	205	180

4. MODEL AND METHODOLOGY

To explore the relationship between CO2 emissions per GDP and all other green growth indicators, we constructed the following model.

$$CO2\_Emission\_perGDP_{it} = \alpha + \beta_1\, FFS\_percentage\_of\_TR_{it} + \beta_2\, EnvR\&D\_percentage\_of\_GovR\&D_{it} + \beta_3 EnvTech\_percentage\_of\_AT_{it}$$

Based on our assumption checks, we find that there is cross-sectional dependence and slope heterogeneity in the dataset. Thus, we decided to use Augmented Mean Group (AMG) Estimator to estimate the model. AMG is one of the 2nd generation Panel ARDL estimators that deals with cross-sectional dependence and heterogeneity of slope parameters. The estimator was proposed by Eberhardt and Bond (2009) and developed by Eberhardt & Teal

(2010). It is possible to get long-run group-specific (emerging countries or advanced countries) coefficients. Due to the fact that AMG estimator is applicable even in the case of non-stationary data, it is not necessary to check unit-root and co-integration before employing AMG estimator.

Our assumption checks are employed at 3 stages. First, we inquired cross-sectional dependence in our data with 3 tests, Breusch-Pagan LM, Peseran Scaled LM and Peseran CD. Since the probability value shows 5% level of significance in all individual variables, confirmed by at least 2 tests, the null hypothesis is rejected. Thus, we report that there is cross-sectional dependence in each series. Furthermore, after estimating a simple ordinary panel regression, we checked the cross-sectional dependence of residuals as well and concluded that residuals are also cross-sectionally correlated.

Table 3. Cross-sectional Dependence Test

	Breusch-Pagan LM	**Peseran Scaled LM**	**Peseran CD**
Variable			
CO2_Emission_per_GDP	(1480.42) [0.00]*	(75.88) [0.00]*	(38.18) [0.00]*
FFS_percentage_of_TR	(472.66) [0.00]*	(18.27) [0.00]*	(-0.42) [0.67]
EnvR&D_percentage_of_GovR&D	(334.81) [0.00]*	(10.39) [0.00]*	(-0.025) [0.97]
EnvTech_percentage_of_AT	(360.78) [0.00]*	(11.87) [0.00]*	(11.70) [0.00]*
Residuals	(831.93) [0.00]*	(38.81) [0.00]*	(24.57) [0.00]*

Note: H_0: No cross-sectional dependence (correlation) (.) and [.] indicate test static and probability values respectively. * represents level of significance at 5%.

Second, we employed slope homogenity test of Pesaran, Yamagata (2008), named as Delta Test and its adjusted version. Based on the results of Delta test, we report that slope coefficients are heterogeneous except for the EnvR&D_percentage_of_GovR&D and the EnvTech_percentage_of_AT series, individually. However, since all 3 independent variables are jointly heterogeneous based on the Delta Test of the overall model, we infer that slope coefficients are heterogeneous.

Table 4. Slope Homogeneity Test

Delta	Overall Model	FFS_percentage_of_TR	EnvR&D_percentage_of_GovR&D	EnvTech_percentage_of_AT
$\hat{\Delta}$	(4.64) [0.00]*	(5.46) [0.00]*	(0.33) [0.74]	(-0.53) [0.60]
$\hat{\Delta}_{adj.}$	(6.64) [0.00]*	(6.97) [0.00]*	(0.43) [0.67]	(-0.76) [0.45]

Note: H_0: Slope coefficients are homogenous. (.) and [.] indicate test static and probability values respectively. * indicates level of significance at 5%.

At the last stage, we tested cointegration with Westerlund Cointegration Test. Based on the test results, we are able to reject the null hypothesis of no cointegration, confirming that variables are cointegrated in some panels as well as in all panels. Thus, we might infer that there is long-term relationship between investigated variables.

Table 5. Westerlund Cointegration Test

	H0: No cointegration Ha: Some panels are cointegrated	H0: No cointegration Ha: All panels are cointegrated
Variance Ratio	(4.90) [0.0000]*	(3.40) [0.0003]*

Note: (.) and [.] indicate test static and probability values respectively. * indicates level of significance at 5%.

5. ESTIMATION RESULTS

We use Panel Augmented Mean Group Estimator, the estimation results of which are summarised in Table 6, based on all countries, advanced and emerging country groups.

Table 6. Main Estimation Results

	All Countries	**Emerging Countries**	**Advanced Countries**
log_CO2_emission_perGDP			
log_FFS_percentage_of_TR	(0.029) [0.249]	(-0.023) [0.527]	(0.062) [0.021]*
log_EnvRD_percentage_of_Gov_RD	(0.014) [0.574]	(-0.003) [0.911]	(0.008) [0.749]
log_EnvTech_percentage_of_AT	(0.102) [0.018]*	(0.061) [0.186]	(0.086) [0.209]
__00000R_c	(0.954) [0.00]	(1.298) [0.00]	(0.852) [0.00]
_cons	(-1.758) [0.00]	(-1.658) [0.00]	(-1.710) [0.00]

Note: H0: Coefficient is equal to 0, (.) and [.] indicate coefficient and probability values respectively. * represents level of significance at 5%.

When **all countries** are included in the panel regressions, only variable that has significant contribution in explaining carbon intensity is the development of environmental technologies as a % of all technologies. However, the sign of the coefficient reflects a positive long-term relationship between the percentage share of environmental technology innovation and CO2 emissions per GDP, contrary to our ex-ante expectation. Based on this finding, we infer that development of technologies within a country does not necessarily reflect their level of use, as many countries export technologies. Thus, while countries may suffer from the side effects of technology development during production process, they may not be able to reap the long-term benefits of environment-related technologies in terms of reduction of CO2 emissions. Additionally, our dataset includes 13 years, which could be relatively short to see the long-term relation between environmental technologies and CO2 emissions. There is also some supporting evidence in the literature that the short-term implications of environmental technologies on climate change might be different from their long-term implications. On the other hand, there appears no significant relationship between CO_2 emissions per GDP and other two variables in the model: Environmentally-related government R&D budget as a % of government R&D budget (research and development budget) and Total fossil fuel support as a % of tax revenue (fossil fuel support) (Table 6).

As for **emerging economies**, none of three explanatory variables shows significance to indicate a relationship with CO_2 emissions per GDP in the long run. The results suggest a lack of efficient and sufficient data reporting on environmental policies in emerging economies. Furthermore, environmental policies in some emerging economies are not associated with a long history. Even if they are, the effective enforcement and results of these policies are somewhat questionable (Table 6).

Examining the estimation results for **advanced economies**, the significance level and the sign of the coefficient of fossil fuel support variable indicate that increased fossil fuel subsidies lead to deteriorating climate change problem, which is in line with the literature and with our ex-ante assumptions. The results draw attention to the negative implications of government policies in the form of subsidies on climate change. Such policies encourage the production and the consumption of fossil fuels. They directly guide consumer/producer behaviour to prefer fossil fuels and to make full use of government support, taking advantage of reduced production costs or reduced expenditure in energy. In addition, fossil fuel subsidies keep older technologies in place, leading to a more carbon-intensive production process. They therefore tend to inhibit the development of and the transition to clean technologies. Finally, aggregate results on advanced economies indicate that environmental technologies and environmental R&D budget do not contribute to limit climate change (Table 6).

Based on **country-level estimations of emerging countries**, the green technology variable is significant in 4 out of 7 emerging economies (Chile, Korea, Türkiye, Hungary). In Chile, Korea, Hungary, it has a positive long-term relationship with CO_2 emissions per GDP. This might be resulting from the fact that the industrial production processes are relatively dirtier in these countries due to insufficiency or lack of climate policies or regulations. Besides, Türkiye is the only emerging country, where environmental technologies are contributing to the expected ex-ante reduction in CO_2 emissions. This might indicate that Türkiye is domestically using its environment-related technologies, rather than exporting them. In addition, the industrial production processes might be relatively cleaner. Lastly, fossil fuel support variable is not significant in any of the emerging markets (Table 6.1).

Based on **country-level estimations for advanced economies**, in high-income countries such as Australia, Canada, France, Germany, Japan, the United States of America, the United Kingdom, green technologies are found to be unrelated with CO2 emissions per GDP, implying that development of environmental technologies does not contribute to limit climate change. This leads us to the argument that the development of technologies does not necessarily reflect their level of usage. These countries might be considered as predominant technology-exporters. However, in 3 out of 11 developed countries (the Netherlands, Spain, Sweden), the estimation results indicate a significant positive relationship between green technologies and CO2 emissions, implying adverse affects of technology development process on the environment. In the context of this study, the Netherlands stands out, as all explanatory variables are significant in the case of this country. Perhaps it is because the Netherlands has been an advanced practitioner of environmental policy for many years and it provides efficient data reporting for analysis (Table 6.2).

Table 6.1. Country-Based Estimation Results - Emerging Economies (EMEs)

	CHL	**COL**	**KOR**	**MEX**	**TUR**	**CZE**	**HUN**
log_FFS_percentage_of_TR	(0.056) [0.317]	(-0.074) [0.162]	(0.031) [0.397]	(0.008) [0.258]	(0.059) [0.165]	(-0.058) [0.059]	(-0.250) [0.12]
log_EnvRD_percentage_of_Gov_RD	(-0.166) [0.161]	(0.058) [0.487]	(0.151) [0.005]*	(0.005) [0.926]	(0.015) [0.784]	(-0.033) [0.339]	(0.028) [0.668]
log_EnvTech_percentage_of_AT	(0.180) [0.057]*	(0.041) [0.512]	(0.171) 0.001]*	(-0.006) [0.85]	(-0.162) [0.043]*	(0.040) [0.104]	(0.232) [0.019]*
__00000R_c	(1.084) [0.104]	(0.502) [0.001]	(0.749) [0.000]	(0.956) [0.000]	(1.080) [0.011]	(1.567) [0.000]	(1.280) [0.000]
_cons	(-1.921) [0.000]	(-2.251) [0.000]	(-1.595) [0.000]	(-1.429) [0.000]	(-1.209) [0.000]	(-1.208) [0.000]	(-2.200) [0.000]

Note: H_0: Coefficient is equal to 0, (.) and [.] indicate coefficient and probability values respectively. * represents level of significance at 5%.

Table 6.2. Country-Based Estimation Results - Advanced Countries

	AU	**CA**	**FR**	**DE**	**IT**	**JP**	**NL**	**ES**	**SE**	**UK**	**US**
log_FFS_percentage_of_TR	(0.048) [0.136]	(0.009) [0.721]	(0.097) [0.135]	(0.043) [0.860]	(-0.048) [0.213]	(0.131) [0.031]*	(-0.041) [0.000]*	(0.264) [0.107]	(0.130) [0.000]*	(0.049) [0.114]	(0.065) [0.438]
log_EnvRD_percentage_of_Gov_RD	(-0.012) [0.784]	(0.043) [0.595]	(0.016) [0.548]	(0.219) [0.498]	(0.075) [0.207]	(-0.029) [0.415]	(-0.022) [0.000]*	(-0.046) [0.698]	(-0.042) [0.14]	(-0.203) [0.279]	(0.197) [0.241]
log_EnvTech_percentage_of_AT	(0.106) [0.172]	(0.050) [0.674]	(-0.140) [0.366]	(-0.214) [0.474]	(0.030) [0.345]	(0.147) [0.455]	(0.438) [0.000]*	(0.436) [0.003]*	(0.187) [0.004]*	(0.308) [0.36]	(-0.010) [0.983]
__00000R_c	(0.944) [0.000]	(0.422) [0.003]	(1.494) [0.000]	(1.123) [0.069]	(0.884) [0.000]	(0.485) [0.082]	(0.473) [0.000]	(-0.559) [0.466]	(1.508) [0.000]	(2.555) [0.000]	(0.624) [0.477]
_cons	(-1.164) [0.000]	(-1.179) [0.000]	(-1.531) [0.001]	(-1.183) [0.236]	(-1.947) [0.000]	(-1.474) [0.01]	(-2.771) [0.000]	(-2.838) [0.000]	(-2.602) [0.000]	(-2.223) [0.019]	(-0.912) [0.408]

Note: H0: Coefficient is equal to 0, (.) and [.] indicate coefficient and probability values respectively. * represents level of significance at 5%.

6. CONCLUSION

It is undoubted that innovation and technology will play a critical role in green transition. Although energy transition holds the key to reach climate targets, development of other environment-related technologies or any kind of breakthrough in the form of environmental R&D and innovation will definitely affect the pace and scale of global transition. Not just the development of low-carbon technologies but also policies that establish free flow of these from advanced economies to EMEs would help achieving climate targets. Furthermore, the pace of transition, particularly in emerging countries, is heavily reliant on the level of climate finance, both for mitigation and adaptation efforts. Thus, fulfillment of developed countries' commitment to jointly mobilize $100 billion in climate finance per year through 2025 to developing countries is central to achieving the targets. In addition, there is an urgent need for coordinated action by international organizations, private investors and country authorities to mobilize climate finance to EMEs.

Since technology investments require high level of upfront investments, risks and uncertainties born by private capital providers are inevitably high. Thus, the role that governments might play in supporting these investments will be crucial. Government support might range from grants, subsidies, feed-in-tariffs, tax exemptions, direct tax credits, credit guarantees and other kind of incentive schemes for decarbonization technology investments.

Along with monetary support, governments might also support innovations via creating an enabling regulatory landscape for the development of both climate and environment-related technologies. Governments might also support the technology innovation, by removing information asymmetries pertaining to climate investments. This would be possible with comprehensive and globally comparable data sources, that could help monitor the effectiveness of policies, leading to remedial action when needed. Thereby, policymakers would use sophisticated and eloborative statistics in the complex process of reducing emissions to make the necessary interventions. In addition, filling the data gaps is essential to assess the impact of climate change and green transition on the overall economy and the financial system.

On the other hand, considering the fact that jurisdictions around the globe have just began to devise their climate policies, fiscal incentives to shift to clean energy sources are not adequate. In fact, fossil fuel subsidies are still prevalent both globally and regionally. This is mostly attributable to the fact that fossil fuels are the main source of energy for many countries and energy security is a major concern. However, policies to reduce fossil fuel subsidies would definitely complement other mitigation instruments.

The purpose of our study is to investigate the role of governments in scaling up climate transition in advanced and emerging countries. Carbon intensity is proxied by CO2 emissions per GDP while government policy is represented with 3 indicators: i. Total fossil fuel support as a % of tax revenue, ii. Environmentally-related government research and development (R&D) budget as a % of Government R&D budget and iii. Development of environment-related technologies as a % of all technologies.

In order to determine the long-run relationships, we employ Augmented Mean Group (AMG) estimator. Our estimation results are presented for emerging and advanced economies, along with a presentation of country-based results.

The results of the estimation indicate that the relationship between government policy indicators and CO2 emissions per GDP varies among different country groups. When all countries are included in estimations, a positive relationship between environment-related technologies and carbon intensity stands out, which is inconsistent with our ex-ante expectations. This means that an increase in the development of environment-related technologies may aggravate climate change, highlighting the environmental effects of technology production process. On this front, we draw attention to the export factor where the exporter bears the environmental damages of production process while not benefitting from the environmental advantages of the technology. Examining the country-based results, it is revealed that in advanced countries with higher incomes, development of environment-related technologies does not contribute to limit climate change in their respective jurisdictions. This finding confirms our inference on the difference between exporters and end-users of environmental technologies. In fact, US, UK, Canada, Japan and Germany, where environment-related technologies are not interrelated with carbon intensity, might be considered as predominant technology-exporters.

Another government policy indicator, fossil fuel subsidies are significantly and positively interrelated with carbon intensity in advanced countries, suggesting that an increase in fossil fuel subsidies worsens climate change in the long-run. This is consistent with our ex-ante expectation on deteriorating impact of fossil fuel subsidies on climate change.

As a last word, our study has some limitations. Due to the unavailability of technology-related OECD Green Growth Indicators for many countries as well as limited time span of the data, our sample size is small. Sample size problem is more pronounced for emerging countries. On the contrary, we are not subject to omitted variables bias, since our research tries to find the long-term relationships between the selected variables, rather than aiming to determine the drivers of climate change. Further research opportunities in this area might include use of other technology-related indicators such as patents. In addition, sample size might be expanded, via including more countries in the estimations.

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The Role of Governments in Emission Cuts: Evidence from Emerging and Advanced Economies

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Presentation Plan

- Research Question
- Literature
- Data
- Methodology
- Estimation Results
- Conclusion
- Further Research Areas
- Policy Recommendations

Research Question

Paris Agreement, although not binding, considers governments as being part of global climate effort.

- Recent actions and policies at the global or national level;
  - Reveals that governments are key players in addressing the impacts of climate change:
    - Via clean energy or technology subsidies, tax exemptions or climate-related regulations
- **Research Question:**
  - What is the role of governments in scaling up climate transition in advanced and emerging countries?
    - Is government policy needed to redirect technical change from dirty to clean technologies?
- We explore the interrelation between carbon intensity and government policy indicators.
  - Where;
    - Carbon intensity, a good measure of the level of dirtiness of the production, is proxied by CO_2 emissions per GDP
    - Government policy is represented with environmental R&D budget, fossil fuel subsidies and development of environmental technologies.

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Literature

The evidence is mixed on the interrelation of environmentally-related government R&D expenditure as well as innovative technologies with CO_2 emissions.

- Acemoglu at al. (2012) argue that government policy is needed to steer technical change from dirty to clean technologies. They state that with timely interventions, environmental goals can be achieved without the need for continuous intervention and without compromising long-term growth.
- Yusoff and Bekhet (2016) and Moosavian et al. (2022) find a relationship between fossil fuel subsidies/fossil fuel tax rates and the level of carbon emissions, showing the deteriorating effect of fossil fuels on the environment. Moosavian et al. (2022) also investigate the contribution of environment-related R&D subsidy policy to environmental protection.
- Petrovic and Lobanov (2019), Garrone and Grilli (2010) conclude that research&development expenditures are necessary but not sufficient to reduce carbon emissions.
- Halkos and Paizanos (2013) analyse the effect of government spending on environmental pollution, showing a clear negative effect of government spending on CO_2 emissions in all income levels. The same result is found by Mongo et al. (2021), however the effect of environmental technologies is reversed in the short run.
- According to Due et al. (2019), green technology innovation contributes to mitigating CO_2 emissions when the income level of the country is above a threshold (USD 35,000).
- Zhang (2021) investigates the impact of technological innovation and economic growth on CO_2 emissions. Results show that technology patents help reducing carbon emissions, as economic growth significantly uplifts carbon emissions.

Data

Our sample includes the data of **18** countries in annual frequency from **2010** to **2021**.

The variables are used in logarithmic form to control for heteroscedasticity.

Indicator	Measurement Scale	Source
CO_2 Emission Per GDP (as a measure of carbon intensity)	t CO_2/kUSD/yr	IEA-EDGAR CO_2 Dataset (Crippa et al, 2022)
Total Fossil Fuel Support	% of Tax Revenue	OECD Green Growth Indicators (OECD, 2024)
Environmentally Related Government R&D Budget	% of Total Government R&D	OECD Green Growth Indicators (OECD, 2024)
Development of Environment-related Technologies	% of All Technologies	OECD Green Growth Indicators (OECD, 2024)

- **Emerging countries**: Chile, Colombia, Korea, Mexico, Türkiye, Czechia and Hungary.
- **Advanced countries:** Australia, Canada, France, Germany, Italy, Japan, Netherlands, Spain, Sweden, UK and US.

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Descriptive Statistics

Environmentally-Related Government R&D Budget, % of Total Government R&D variable has the highest standart deviation.

All series are positively skewed

Statistics	CO2 Emission Per GDP	Total Fossil Fuel Support, % of Tax Revenue	Environmentally Related Government R&D Budget, % of Total Government R&D	Development of Environment-related Technologies % of All Technologies)
Mean	0.20	1.27	3.04	12.28
Median	0.18	0.71	2.36	12.32
Maximum	0.41	12.19	21.56	26.42
Minimum	0.07	0.05	0.05	5.62
Std. Dev	0.07	1.69	3.53	2.72
Skewness	0.59	3.86	3.49	1.00
Kurtosis	2.41	21.57	15.21	7.52
Jarque-Bera	15.87	3544.55	1,692.29	183.69
Probability	0.00	0.00	0.00	0.00
Sum	44.38	266.74	624.67	2,210.79
Sum Sq. Dev.	1.36	599.38	2,550.87	1,324.58
Observations	216	210	205	180

Methodology

Panel Augmented Mean Group (AMG) Estimator by Eberhardt and Bond (2009), Eberhardt and Teal (2010) is employed.

- **Model**

$$CO2\_Emission\_perGDP_{it} = \alpha + \beta_1\, FFS\_percentage\_of\_TR_{it} + \beta_2\, EnvR\&D\_percentage\_of\_GovR\&D_{it} + \beta_3 EnvTech\_percentage\_of\_AT_{it}$$

- **Assumption Checks to Use Augmented Mean Group (AMG) Estimator**

1) Breusch-Pagan LM, Peseran Scaled LM and Peseran CD tests revealed that the series are cross-sectionally dependent. *(Residuals are also cross-sectionally correlated)*

2) Slope homogeneity test of Pesaran, named as Delta Test and its adjusted version revealed that slope coefficients are heterogeneous.

3) Westerlund Cointegration Test revealed that there is long-term relationship between investigated variables. *(We reject the null hypothesis of no cointegration)*

Estimation Results

The estimation results differentiate between emerging and advanced economies.

	All Countries	Emerging Economies	Advanced Economies
CO2 Emission Per GDP			
Total Fossil Fuel Support % of Tax Revenue	(0.029) [0.249]	(-0.023) [0.527]	(0.062) [0.021]*
Environmentally Related Government R&D Budget % of Total Government R&D	(0.014) [0.574]	(-0.003) [0.911]	(0.008) [0.749]
Development of Environment-related Technologies % of All Technologies	(0.102) [0.018]*	(0.061) [0.186]	(0.086) [0.209]

Note: H0: Coefficient is equal to 0, (.) and [.] indicate coefficient and probability values respectively. * represents level of significance at 5%.

- In **all countries**, the development of environmental technologies as a % of all technologies is the only significant variable to explain carbon intensity.
  - Its sign reflects a positive long-term relationship between the percentage share of environmental technology innovation and CO2 emissions per GDP, contrary to our ex-ante expectation, due to high level of heterogeneity among countries.
- In **emerging economies**, none of three explanatory variables shows significance to indicate a relationship with CO2 emissions per GDP in the long run.
- For **advanced economies**, fossil fuel support variable is significant and it indicates that increased fossil fuel subsidies lead to deteriorating climate change problem, which is in line with the literature as well as our ex-ante expectations.

Conclusion

- A positive relationship between environment-related technologies and carbon intensity stands out, which means that an increase in the development of environment-related technologies may aggravate climate change, highlighting the environmental effects of technology production process.
    - We draw attention to the export factor where the exporter bears the environmental damages of production process while not benefitting from the environmental advantages of the technology.
    - This finding confirms our inference on the difference between exporters and end-users of environmental technologies.
    - US, UK, Canada, Japan and Germany, where environment-related technologies are not interrelated with carbon intensity, might be considered as predominant technology-exporters.
- Fossil fuel subsidies are significantly and positively interrelated with carbon intensity in advanced countries, suggesting that an increase in fossil fuel subsidies worsens climate change in the long-run.
- **To conclude**, governments might support decarbonization via creating an enabling regulatory landscape as well as financial support, for the development of climate and environment-related technologies.

Further Research Areas

- **Including other technology-related indicators** such as ***patents***

- **Extending *the time span*** of the sample, specifically for EMEs
  - Long-term patterns and interrelations could become more apparent.

- **Increasing cross-sections** in the sample, specifically related to EMEs
  - The analysis could give better results, that help differentiate among emerging and advanced countries.

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Policy Recommendations

- Although energy transition holds the key to reach climate targets, **development of other environment-related technologies** or any kind of breakthrough in the form of environmental R&D and innovation will definitely **affect the pace and scale of global transition.**
- Not just the development of low-carbon technologies but also policies **that establish free flow of these from advanced economies to EMEs** would help achieving climate targets.
- Furthermore, the pace of transition, particularly in emerging countries, is heavily reliant on **the level of climate finance**, both for mitigation and adaptation efforts.
- Climate finance is provided based on **proper and transparent reporting** on climate-related risks and opportunities.
- Here comes the role of reliable and **comprehensive data and availability of indicators** that helps standardization of reporting.
    - **National taxonomies and interoperability of those** is definitely needed for standardized data.
    - Central banks **with their soft power as well as their qualified work force** would help address climate-related data gaps via;
        - Publishing valuable **sustainable finance d**ata, to address the concerns of private investors.
        - Improving coordination with international institutions, that will serve for **exchange of knowledge and best practices** in the area.

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The Role of Governments in Emission Cuts: Evidence from Emerging and Advanced Economies

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Annexes

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Country-Based Estimation Results

Country-Based Estimation Results - Emerging Economies (EMEs)

	CHL	COL	KOR	MEX	TUR	CZE	HUN
log_FFS_percentage_of_TR	(0.056) [0.317]	(-0.074) [0.162]	(0.031) [0.397]	(0.008) [0.258]	(0.059) [0.165]	(-0.058) [0.059]	(-0.250) [0.12]
log_EnvRD_percentage_of_Gov_RD	(-0.166) [0.161]	(0.058) [0.487]	(0.151) [0.005]*	(0.005) [0.926]	(0.015) [0.784]	(-0.033) [0.339]	(0.028) [0.668]
log_EnvTech_percentage_of_AT	(0.180) [0.057]*	(0.041) [0.512]	(0.171) 0.001]*	(-0.006) [0.85]	(-0.162) [0.043]*	(0.040) [0.104]	(0.232) [0.019]*
__00000R_c	(1.084) [0.104]	(0.502) [0.001]	(0.749) [0.000]	(0.956) [0.000]	(1.080) [0.011]	(1.567) [0.000]	(1.280) [0.000]
_cons	(-1.921) [0.000]	(-2.251) [0.000]	(-1.595) [0.000]	(-1.429) [0.000]	(-1.209) [0.000]	(-1.208) [0.000]	(-2.200) [0.000]

Note: H_0: Coefficient is equal to 0, (.) and [.] indicate coefficient and probability values respectively. * represents level of significance at 5%.

Country-Based Estimation Results - Advanced Countries

	AU	CA	FR	DE	IT	JP	NL	ES	SE	UK	US
log_FFS_percentage_of_TR	(0.048) [0.136]	(0.009) [0.721]	(0.097) [0.135]	(0.043) [0.860]	(-0.048) [0.213]	(0.131) [0.031]*	(-0.041) [0.000]*	(0.264) [0.107]	(0.130) [0.000]*	(0.049) [0.114]	(0.065) [0.438]
log_EnvRD_percentage_of_Gov_RD	(-0.012) [0.784]	(0.043) [0.595]	(0.016) [0.548]	(0.219) [0.498]	(0.075) [0.207]	(-0.029) [0.415]	(-0.022) [0.000]*	(-0.046) [0.698]	(-0.042) [0.14]	(-0.203) [0.279]	(0.197) [0.241]
log_EnvTech_percentage_of_AT	(0.106) [0.172]	(0.050) [0.674]	(-0.140) [0.366]	(-0.214) [0.474]	(0.030) [0.345]	(0.147) [0.455]	(0.438) [0.000]*	(0.436) [0.003]*	(0.187) [0.004]*	(0.308) [0.36]	(-0.010) [0.983]
__00000R_c	(0.944) [0.000]	(0.422) [0.003]	(1.494) [0.000]	(1.123) [0.069]	(0.884) [0.000]	(0.485) [0.082]	(0.473) [0.000]	(-0.559) [0.466]	(1.508) [0.000]	(2.555) [0.000]	(0.624) [0.477]
_cons	(-1.164) [0.000]	(-1.179) [0.000]	(-1.531) [0.001]	(-1.183) [0.236]	(-1.947) [0.000]	(-1.474) [0.01]	(-2.771) [0.000]	(-2.838) [0.000]	(-2.602) [0.000]	(-2.223) [0.019]	(-0.912) [0.408]

Note: H0: Coefficient is equal to 0, (.) and [.] indicate coefficient and probability values respectively. * represents level of significance at 5%.

Cross-sectional Dependence Tests (Peseran, 2004)

	Breusch-Pagan LM	Peseran Scaled LM	Peseran CD
Variable			
CO2_Emission_per_GDP	(1480.42) [0.00]*	(75.88) [0.00]*	(38.18) [0.00]*
FFS_percentage_of_TR	(472.66) [0.00]*	(18.27) [0.00]*	(-0.42) [0.67]
EnvR&D_percentage_of_GovR&D	(334.81) [0.00]*	(10.39) [0.00]*	(-0.025) [0.97]
EnvTech_percentage_of_AT	(360.78) [0.00]*	(11.87) [0.00]*	(11.70) [0.00]*
Residuals	(831.93) [0.00]*	(38.81) [0.00]*	(24.57) [0.00]*

Note: H0: No cross-sectional dependence (correlation) (.) and [.] indicate test static and probability values respectively. * represents level of significance at 5%.

Slope Homogeneity Test (Peseran & Yamagata, 2008)

Delta	Overall Model	FFS_percentage_of_TR	EnvR&D_percentage_of_GovR&D	EnvTech_percentage_of_AT
Δˆ	(4.64) [0.00]*	(5.46) [0.00]*	(0.33) [0.74]	(-0.53) [0.60]
Δˆ adj.	(6.64) [0.00]*	(6.97) [0.00]*	(0.43) [0.67]	(-0.76) [0.45]

Note: H0: Slope coefficients are homogeneous. (.) and [.] indicate test static and probability values respectively.
* indicates level of significance at 5%.

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Cointegration Test of (Westerlund, 2007)

	H0: No cointegration Ha: Some panels are cointegrated	H0: No cointegration Ha: All panels are cointegrated
Variance Ratio	(4.90) [0.0000]*	(3.40) [0.0003]*

Note: (.) and [.] indicate test static and probability values respectively. * indicates level of significance at 5%.