DOES FISCAL DECENTRALIZATION CONTRIBUTE TO A REDUCTION IN NATIONAL CO_2 EMISSIONS?

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DOES FISCAL DECENTRALIZATION MATTER FOR CLIMATE MITIGATION?

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ABSTRACT

Is fiscal decentralization a fundamental policy pillar toward achieving the transition to a sustainable low-carbon economy? Despite recent evidence pointing to the importance of subnational government involvement in regulating transportation, buildings, and land use, little is known about whether decentralized governance systems perform better in curbing greenhouse gas emissions. Here I ask the question whether, since fiscal decentralization leads to greater responsiveness at the local level, more fiscally decentralized countries fare better at curbing CO_2 emissions. I hypothesize that more fiscally decentralized countries display lower levels of national CO_2 emissions. Based on a novel dataset covering 65 countries for the period 1991 to 2018, my findings support the notion that more fiscally autonomous subnational governments are a positive force on the path to decarbonization. Importantly, I show that this effect is a function of spending rather than revenue decentralization. From a policy perspective, my findings point to important positive spillover effects of fiscal decentralization for climate mitigation.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

In its Sixth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) highlighted that given the observed impacts of climate change and progress thus far, the need for climate-resilient development action is more urgent than previously assumed (IPCC, 2022, p.35). The report concluded that unless the Paris Agreement's goal of limiting the average global temperature increase to 1.5°C above pre-industrial levels is met, human and natural systems will face severe risks, some of which will be irreversible (p.20).

Subnational governments have increasingly been at the forefront of climate action. [1] With the shift to a more bottom-up international climate regime system sparked by the United Nations 21st Conference of the Parties (COP21), the role of subnational governments in climate mitigation has achieved new prominence on the world stage (Hale, 2016; Hsu et al., 2018). This is unsurprising given that subnational governments tend to exert regulatory and taxing powers over key emissions sectors, including building standards, transport, land use, waste, and in some cases, electricity – all major sources of greenhouse gas (GHG) emissions. Road transport, energy use in buildings, and waste alone makeup about 40% of global emissions (WRI, 2018). Moreover, with the drive towards more decentralized governance in recent decades, subnational governments control an increasing amount of spending. For example, in 2016, across 30 OECD countries, subnational governments accounted for 55% of public spending and 64% of public investment related to the environment and climate (OECD, 2020a, p.124). Cities and regional governments worldwide have been investing in electric bus fleets, promoting the switch to

[1] 'Subnational' includes all government tiers below the national level, thus encompassing local, provincial, regional, and state administrative units.

renewable energy, enforcing building codes to improve efficiency, and adopting measures to reduce fossil-fuel powered transport.

However, in many countries, subnational governments are limited in their climate mitigation potential. They face budgets shortfalls and limited control over resources and ‘unfunded mandates’ are common in developed, as in emergent economies (UCLG, 2019, p.385).

This paper, therefore, asks whether more fiscally decentralized countries – countries in which subnational governments are endowed with a large share of general government revenue and expenditure – are better at curbing CO2 emissions. I hypothesize that greater fiscal decentralization is indeed associated with lower CO2 emissions. The rationale for this hypothesis is rooted in subnational governments’ responsiveness to people’s preferences, as postulated in Oates’ (1972) “decentralization theorem” and as evidenced by the groundswell of subnational climate action worldwide (Hsu et al., 2017; Hale et al., 2021). However, I also hypothesize that, due to market failures in addressing climate change, and the amounts of private capital needed for climate mitigation measures, the share of subnational governments’ spending not financed through own revenues will be critical.

To test these predictions, I rely on a novel dataset comprising information from the International Monetary Fund (IMF) Fiscal Decentralization database, the World Bank, and other databases, covering 65 countries for the period 1991 to 2018. Following other studies, to test my first hypothesis, I use an index of revenue and expenditure decentralization, created using Principal Component Analysis (PCA), to measure fiscal decentralization. To test my second hypothesis, in contrast to earlier work, I analyze the differences between revenue and expenditure decentralization.

My regression results indicate that a one-unit increase in the PCA fiscal decentralization (FD) index is associated with a 1.5% decrease in metric tons of CO_2 per capita ($P>0.01$) at the national level. My findings also indicate that spending decentralization plays a more important role than revenue decentralization, highlighting the importance of supplementing subnational governments' own-source revenue for effective climate mitigation. These results withstand a battery of robustness checks, including using alternative specifications for the key independent and dependent variables, relaxing modeling assumptions, and excluding the possibility that the relationship between FD and CO_2 emissions is driven by economic factors.

This paper contributes to a growing literature on the relationship between fiscal decentralization and environmental degradation. Evidence on this relationship is ambiguous. Many recent studies focus on the relationship between FD and environmental quality in China, finding either a positive relationship (Cheng et al., 2021; Wang et al, 2021), a negative one (Chen & Liu, 2020; Yang. et al, 2019; Guo et al, 2020), a non-linear one (Liu et al., 2019; Liu & Li, 2019) or no relationship at all (He, 2015). Early studies in the United States analyzed the same relationship, also with divergent results (Millimet, 2003; Konisky, 2007; Potoski, 2001). Others explore FD and CO_2 emissions across a small number of highly decentralized countries (Khan et al., 2021; The Phan et al., 2021; Lingyan et al., 2021; Ji et al., 2020), finding a negative relationship between the two.[2] Finally, some studies find a positive relationship between FD and renewable energy deployment (Su et al., 2021; Elheddad et al., 2020; Albrecht, 2021).

Building on this research, a key innovation of my approach is that I rely on a larger sample of countries across more years. My findings align with the literature supporting the 'race

[2] Lingyan et al (2021) find an asymmetric impact of fiscal decentralization, with that fiscal decentralization significantly mitigating carbon emissions only at lower to medium emissions quantiles.

to the top' view, in which FD has positive spillovers for the environment. More broadly, this study contributes to the literature on how fiscal institutions affect a country's environmental performance. Building on studies that find a positive relationship between the level of democracy of a country and its climate mitigation efforts (Chou et al., 2019; Lv, 2017), my approach complements studies highlighting the quality of institutions as a mediating factor between GDP and CO_2 emissions (Wawrzyniak and Doryń, 2019). I also contribute to the literature on polycentric governance and its potential to address environmental challenges (Ostrom, 1990; Jordan et al., 2018).

Finally, this paper contributes to an important policy debate on the need to strengthen subnational climate finance and multi-level governance to unlock effective climate action (UN-Habitat, 2022; CCFLA, 2019). It underscores the importance of subnational governments as climate mitigation actors, and it draws attention to the conditions that enable them to decarbonize effectively.

THEORETICAL CONSIDERATIONS

The devolution of powers to subnational governments has been one of the most salient institutional transformations of the past few decades (Martinez-Vazquez, 2021). Fiscal decentralization (FD) – the devolution of taxing and spending responsibilities – is an important dimension of this trend.[3] Subnational governments in more fiscally decentralized countries not only have greater financial resources, but they also tend to have greater autonomy to decide how to use those resources (OECD, 2019, p.31). For example, subnational governments in OECD countries account for 57% of total public investment in their countries (OECD, 2020b, p.110). Similarly, the FD agenda has accelerated across emerging economies, driven by the 2030 focus on the "localization" of Sustainable Development Goals (SDGs) (UCLG, 2019).[4]

A substantial theoretical literature addresses the merits and limitations of decentralized governance when it comes to the provision of public goods, including environmental ones. Proponents of the "race to the top" highlight the greater efficiency of decentralized spending (Oates, 1972; Brennan and Buchanan, 1980) and the virtuous effect of competition as people "vote with their feet" (Tiebout, 1956). On the other hand, proponents of the "race to the bottom" highlight the free-rider problem and coordination failures (de Mello, 2000). The findings in the empirical literature are mixed, providing support for both views.

I hypothesize that greater FD will contribute positively to a country's climate mitigation efforts because of subnational governments' responsiveness to climate issues. The empirical literature already suggests a virtuous effect of FD on key public services, such as health and

[3] The other two key dimensions of decentralization are political and administrative.
[4] Localization is described as "the process of defining, implementing and monitoring strategies at the local level for achieving global, national, and subnational sustainable development goals and targets." (UCLG, 2019, p.21)

education (Faguet, 2004; Arze del Grenado et al., 2016; Faguet and Sanchez, 2014). The rationale for this finding is rooted in Oates (1972) seminal "decentralization theorem" of fiscal federalism, postulating that, by locating spending decisions closer to the needs and preferences of their constituencies, FD results in greater allocative efficiency. While the empirical literature on subnational governments' responsiveness to residents' environmental concerns is less developed, there is reason to believe that a similar pattern holds.[5]

Subnational governments are at the forefront of climate change impacts, particularly in urban centers (CDP, 2018; Bastin et al., 2019; IPCC, 2022, p.13). As a result, in the face of national inaction, cities and regions around the world have stepped up their climate mitigation commitments (Hsu et al., 2017; Hale, 2021). For example, 1,049 cities and 67 regions have joined the UNFCCC Race to Zero global campaign aiming to achieve net-zero carbon emissions by 2050 (UNFCCC, n.d). Under citizen pressure, cities such as London and Seoul, have led the way, in implementing zero-emission-zones. Regions like Spain's Catalonia, Mexico's Zacatecas and Tamaulipas states have implemented carbon taxes (World Bank, 2021). Closeness to residents, the tangibility of climate change impacts, and the ability to influence key emission sectors – together, these factors provide support for the view that subnational governments are particularly responsive to climate mitigation. Therefore, I would expect the greater financial resources and autonomy that come with FD to positively contribute to CO2 reductions, as summarized in *Hypothesis 1*:

Hypothesis 1: A greater degree of FD is associated with lower national CO2 emissions.

[5] Bedner (2009), for example, finds a positive effect of decentralization on responsiveness to complaints about water pollution in Indonesia.

However, FD is a two-dimensional concept. In countries worldwide, revenue and expenditure decentralization are highly correlated but never the same (Aldasoro and Seiferling, 2014). In fact, for most countries, spending decentralization is greater than revenue decentralization, creating what is often called a "vertical fiscal imbalance". Subnational governments have specific assignments and responsibilities enshrined in their countries' constitutions and legislation, but their own-source revenue is often not sufficient to fulfill them. This fiscal gap is filled by central government transfers (general or earmarked), through tax sharing arrangements, or by subnational government debt (OECD, 2019a, p.119).[6] These external sources of subnational public finance are therefore reflected in spending but not revenue decentralization.

I hypothesize that spending decentralization drives the relationship between FD and CO2 reductions, suggesting that, when it comes to climate mitigation, external public finance has a key role to play. I believe this to be the case for two reasons. First, subnational governments' own-source revenues are insufficient to fund the large capital expenditures required for mitigation projects (CCFLA, 2021, p.5). For example, electrifying public transport and promoting green buildings often require economies of scale and significant upfront investment, whether subnational governments participate in their financing directly or through tax incentives (Rojas et al., 2020; IFC, 2019). It is no surprise that there has been a rise in green bonds in cities and states (Climate Bonds Initiative, 2018), and that national governments, alongside the private sector, are the largest financial contributors to urban climate projects (CCFLA, 2021, p.17).

[6] Subnational government debt tends to be moderate, although it has increased in some OECD countries as a result of the COVID-19 pandemic (OECD, 2020b, p.118)

Second, the cross-jurisdictional nature of CO_2 emissions may require that national governments step in to create incentives to correct the negative externalities locally.[7] For instance, evidence suggests that water pollution is greater when rivers cross subnational borders (Sigman, 2005; Lipscomb and Mobarak, 2011). Climate mitigation interventions that have localized co-benefits, such as curbing air pollution from traffic, are more likely to find wide-spread local support. However, other interventions may be considered too burdensome if their benefits go beyond the jurisdiction. This is one of the reasons why the Netherlands national government provides funds to city governments to implement mitigation-related policies, such as transitioning to renewable energy, investing in green buildings, and investments to reduce traffic (Gupta, 2007). For these two reasons, I would expect the external finance reflected in spending decentralization to drive the relationship between FD and CO_2 emissions. I summarize these insights in *Hypothesis 2*:

Hypothesis 2: Spending decentralization but not revenue decentralization is associated with CO_2 emission reductions

Together, the two hypotheses surface a paradox. Greater FD can unlock effective climate action due to greater responsiveness at the subnational level to environmental concerns. Yet, due to the high costs of the transition to a green economy and the spill-over effects of CO_2 emissions, it is external public finance, and not own-source-revenue of subnational governments that makes the difference for climate mitigation.

[7] Oates' (1972) points out that the presence of substantial externalities justifies concentrating decision-making power at higher levels of government.

EMPIRICAL RESULTS

Research design

I explore the effects of FD using cross-national panel data. I structure my analysis as follows. First, I test a simple baseline model to examine the relationship between a country's FD index and CO_2 emissions. Second, I conduct a series of robustness checks including using alternative specifications for the key independent and dependent variables, relaxing modeling assumptions, and excluding the possibility that the relationship between FD and CO_2 emissions is driven by economic factors. Finally, in the 'Breaking down fiscal decentralization' section of this paper, I analyze the effect of the two components of the FD index (revenue and spending decentralization) separately.

Data

I construct a novel dataset covering 65 countries between 1991 and 2018, merging data from different sources. The countries are spread across different income levels and geographies, with a greater concentration in Europe and from the high-income bracket (see Appendix A for the full list of countries). The selection of countries and years is based on data availability from the *IMF Fiscal Decentralization Database*, the source of data for the key independent variables for this analysis.[8]

Data for my dependent variable, CO_2 per capita, comes from *Our World In Data 'CO2 and Greenhouse Gas Emissions' Database*. I use the per capita measure to account for

[8] Nine countries were removed from the original dataset due to missing values for the key independent variables of interest for this paper. The United Arab Emirates was also removed from the panel because of a large change in its FD index from one year to the next, which would bias results in a fixed effects regression

population differences (see Appendix B for data sources). I also test my models with total CO_2 as a robustness check.

As a key independent variable, I operationalize FD as an index of revenue and expenditure decentralization created using Principal Component Analysis (PCA) following the existing literature (Ji et al., 2020; Khan et al., 2020; Su et al, 2021). The IMF's database measures revenue and expenditure decentralization respectively as proportions of general government revenue collected and spending deployed at the subnational government level. Given the high degree of correlation between these two variables, PCA proves helpful for index creation.[9] This procedure generates two new linearly uncorrelated variables (called components) with mean zero that are not directly interpretable but capture all the variance in the data. I use the first of these components as an FD index as it explains over 92% of the variance in the two original variables. Below, the 'Breaking down fiscal decentralization' section, I use the spending and revenue decentralization measures separately to understand what drives the relationship between decentralization and CO_2 emissions.

The control variables come from the World Bank and the University of Gothenburg *Quality of Government 2021 Standard Dataset*. These include the log of GDP per capita, GDP growth, democracy score, and the log of renewable energy consumption – all measuring possible confounders of the relationship between FD and CO_2 emissions.[10] GDP per capita is controlled for to account for both individual and economy-wide wealth effects (Dong et al., 2019). I control for the level of democracy in a country to account for findings in the literature that more democratic countries are better at curbing national emissions (Chou 2020; Lv, 2017) and finally,

[9] The two variables have a correlation of .844 in the panel.
[10] GDP per capita and renewable energy consumption are logged due to the variables' wide dispersion.

following the literature (Ji et al., 2020; Adams and Nsiah, 2019; Dong et al., 2019), the level of renewable energy consumption as a proxy for how green an economy already is. Some countries in my panel, such as Norway, Paraguay, and Uganda, are largely dependent on renewable energy (especially hydroelectric power), which significantly limits their CO2 emissions. Table 1 presents summary statistics for the variables used in the analysis.

Table 1. Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
CO2 emissions, metric tons per capita	1.67	0.83	0.04	3.73	2885
FD index	0	1.36	-2.14	3.69	845
Revenue decentralization	0.18	0.14	0	0.63	1358
Spending decentralization	0.3	0.16	0	0.69	869
GDP per capita, constant 2015 US$	8.99	1.4	4.94	11.57	2720
GDP growth	3.4	4.73	-44.9	45.3	2689
Democracy score	5.11	6.67	-9	10	2706
Renewables consumption	2.73	1.05	0.37	4.58	1885

Model and estimation strategy

To estimate the relationship between fiscal decentralization and CO2 emissions, I estimate a multivariate regression model. To remove country-specific heterogeneity, such as countries' historic environmental preferences and industrial make-up, I include country fixed effects (indexed by t). I also include year-fixed effects (indexed by i) to control for cross-sectional events, such as the Conference of the Parties (COPs) or global oil shocks that might have led to a decrease in CO2 emissions. Both fixed effects are meant to lessen omitted variable bias in my estimates. My baseline regression model is:

$$CO2_{it} = \beta FDIndex_{it} + X_{it} + \alpha_i + \delta_t + u_{it}$$

where the log of CO2 per capita is the outcome variable, FD Index is my key variable of interest and X represents the controls described in the 'Data' section: log of GDP per capita, GDP growth, democracy score, share of renewables in total energy consumption. To account for CO2 persistence in the atmosphere, I include lagged CO2 levels as an additional control variable. α and δ represent country and year fixed effects respectively, and u represents a random shock. I adopt robust standard errors in all regressions.

Baseline results

Table 2 reports my regression results. Across all models, the coefficient on the FD index is negative and significant at less than 1%, decreasing in magnitude as fixed effects and controls are added. Model 1 estimates the correlation between the FD index and CO2 using country fixed effects only. Model 2 and Model 3 add year fixed effects and the controls discussed in the 'Model and estimation strategy' section, respectively. Finally, Model 4 adds the lag of CO2 emissions per capita. Here, in Model 4, the coefficient of the FD index is negative and smaller in magnitude than the previous models, indicating the importance of controls and fixed effects in limiting omitted variable bias. In substantive terms, a one-unit increase in a country's FD index is associated with a 1.5% decrease in metric tons of CO2 per capita. This broadly confirms *Hypothesis 1*, which anticipates a negative relationship between a country's level of fiscal decentralization and CO2 emissions. The signs and significance of the coefficients of my control variables closely map onto the findings in the literature.[11] The one-year lag of CO_2 is highly significant, indicating the persistence of emission levels in the atmosphere.

Table 2. Baseline results

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
FD index	-0.101***	-0.100**	-0.024	-0.015***
	(0.037)	(0.037)	(0.026)	(0.005)
GDP per capita			0.771***	0.196***
			(0.200)	(0.038)
GDP growth			0.003	0.006***
			(0.003)	(0.002)
Democracy score			-0.000	0.000
			(0.003)	(0.001)
Renewables consumption			-0.126***	-0.027***
			(0.031)	(0.010)
Lag of CO2 emissions,				0.800***
				(0.036)
Constant	1.859	1.963***	-4.795**	-1.328***
	(.)	(0.079)	(1.849)	(0.359)
R-squared	0.050	0.068	0.618	0.861
Number of countries	52	52	49	49
Country FE	YES	YES	YES	YES
Year FE		YES	YES	YES
Controls			YES	YES
Lagged dependent				YES

Notes: Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

To probe the robustness of these results, I implement several additional empirical analyses found in Appendix C. First, the results are robust to relaxing modeling assumptions through a Vector Error Correction Model (VECM), in which the differenced outcome variable is regressed on differenced covariates and lagged covariates (Table 8) (De Boef and Keele, 2008).

[11] The democracy score coefficient is positive but not significant, providing support for some recent studies finding no effect of democratic qualities on nation's climate mitigation potential (Selseng et al., 2022)

The results of these models suggest that the relationship between FD and CO_2 emissions takes time to materialize and is most pronounced when considering a lagged effect. In the long run, a one-unit increase in the FD index is associated with a decrease in CO_2 emissions of about 6%.

Second, to mitigate concerns that my results are driven by measurement error, I perform a series of robustness checks focusing on alternative measures of key variables. Instead of the FD index that is based on a PCA, I follow Lingyan et al (2021) and Martinez-Vazquez and Timofeev (2010) and use an alternative fiscal decentralization index as an independent variable.[12] The results of the baseline model remain qualitatively similar, but only in the long run VECM model specification (Table 9). The results also hold when specifying total, rather than per capita CO_2 as a dependent variable when adding population as a control (Table 10).

Finally, the results are robust to three alternative specifications of the dependent variable using the VECM model specification (Table 11). First, I use consumption-based CO_2 emissions per capita as opposed to standard production-based measures that do not take into account emissions embedded in trade. This is an important test because one reason why the emissions of high-income countries have plateaued since the 1990s is that these countries started importing carbon-intensive goods from emerging economies (Peters et al., 2011). Second, my results also hold using mean annual exposure to PM2.5 pollution as a dependent variable, a pollutant that generated in large part from the combustion of car-engines prevalent in cities. This is a particularly relevant test as one of the key climate mitigation areas that subnational governments have broad authority over is transportation. Finally, I test the model using CO_2 emissions over

[12] This alternative index is constructed using the IMF measures as follows: Revenue decentralization / (1- Spending decentralization)

nation’s GDP as a dependent variable, a common measure of an economy’s carbon intensity.[13] Again, I find that these results provide support for the idea that FD may have a positive impact not only on CO2 emissions, but on environmental quality more broadly.

To further disentangle these results, I perform two additional tests that provide support for the general validity of the theory of change outlined in my ‘Theoretical considerations’ section grounded on subnational governments’ responsiveness. First, I show that the effect of FD on CO2 emissions is most pronounced in democracies (see Table 12). I expect this to be the case because responsiveness depends on a feedback mechanism between government and people, which is stronger in democracies. Second, I verify that the effect between my variables of interest is most pronounced in federal states (see Table 13). Subnational governments’ ability to adopt climate mitigation measures depends, in part, on their expenditure assignments (i.e., whether they have a mandate to regulate and fund certain policy areas). For this reason, I would expect the effect of FD on CO2 emissions to be more pronounced in countries with higher degrees of subnational autonomy. I use federalism as a proxy for this, as federal countries have been found to be statistically more autonomous than unitary countries (Kantorowicz and Grieken, 2019, p.43). These robustness tests strengthen my original findings, suggesting that democracy and subnational autonomy are important conditions for FD’s climate mitigation effect.

A key final concern about these findings is that fiscal decentralization and CO2 emissions are the result of lower economic activity and not necessarily of decreased carbon-intensity. FD is

[13] Data on consumption-based CO2 and carbon intensity were retrieved from Our World in Data, while data on PM2.5 pollution comes from the World Bank. All of my alternative measures were logged to account for their skewed distribution.

often assigned by the IMF as a structural adjustment measure (Reinsberg et al., 2021), and as such it could be an indication of worse economic performance. To mitigate this concern, I construct a new variable, which I call “green growth”, based on deviations from predicted CO2 levels, given a country’s GDP. This is a technique that has been employed in other studies (Kern et. al., 2020; Rodrik, 2008). To construct this variable, I run a two-way fixed effects regression in which I predict a country’s CO2 emissions per capita based on its GDP per capita. Next, from this regression, I generate the predicted CO2 levels. And finally, I take the difference between realized CO2 levels and predicted levels to create the green growth variable. This variable is roughly normally distributed around zero (Figure 1 in Appendix C), and positive values can be interpreted as growth that is less carbon intensive. Running the green growth variable on the regressors of my baseline regression, I find that one standard deviation increase in the FD index is associated with a lowering carbon footprint of economic growth (Table 14). This supports the robustness of my results, suggesting that the relationship between FD and climate mitigation is likely not driven by economic fundamentals, but instead it contributes to decreased carbon intensity as economies grow – the so called “green growth”.

Breaking down fiscal decentralization

To better understand what drives the negative relationship between FD and climate mitigation, I test the two dimensions of FD separately. Below, Table 3 shows that the coefficient of revenue decentralization is positive and not significant. On the other hand, the coefficient of spending decentralization is negative and significant at less than 1%. These results support *Hypothesis 2*, that spending decentralization, rather than revenue decentralization, is associated with CO2 emission reductions.

Table 3. Revenue and spending decentralization

VARIABLES	(1) Revenue Decentralization	(2) Spending Decentralization
Decentralization type	0.019	-0.169***
	(0.042)	(0.046)
Constant	-1.189***	-1.330***
	(0.382)	(0.322)
R-squared	0.860	0.866
Number of countries	60	50
Country FE	YES	YES
Year FE	YES	YES
Controls	YES	YES
Lagged dependent	YES	YES

Notes: Robust standard errors in parentheses.*** $p<0.01$, ** $p<0.05$, * $p<0.1$

These findings suggests that the external public finance that makes up the difference between spending and revenue decentralization – whether subnational debt or central government transfers – is the key driver behind FD's virtuous effect on climate mitigation. The reason is that subnational governments' own-source revenue may be insufficient to fund capital intensive investments in climate mitigation that benefit from economies of scale. Moreover, national transfers may play a key role in funding climate mitigation projects that may not find local support due to the cross-boundary nature of CO2 emissions.

DISCUSSION AND CONCLUSION

In the face of an accelerating global climate crisis and slow sovereign country progress, subnational climate action is poised to play an important role in meeting the Paris Agreement goals. To advance the understanding of the environmental performance of decentralized governance systems, I study the effect of their fiscal setup. Specifically, I ask the question: do fiscally more decentralized countries fare better at curbing CO2 emissions?

Building on Oates' theory of the allocative efficiency of decentralization (1972) and on the groundswell of subnational climate action worldwide, I argue that subnational governments are likely to be responsive to the necessity of climate action due to their closeness to residents, the tangibility of climate change impacts locally, and their ability to influence key sectors such as building, transport, and waste. Relying on a novel dataset covering 65 countries for the period 1991-2018, my findings support two notions. First, fiscally more autonomous subnational governments are a positive force on the path to decarbonization. Second, this is an effect of spending decentralization and not revenue decentralization, suggesting that it is the share of subnational governments' own spending not financed through own revenues that drive emission reductions. The latter notion, I argue, can be explained by the large upfront costs and economies of scale required by climate mitigation investments, as well as by the cross-boundary nature of emissions. My study adds to an emerging literature that finds a positive relationship between fiscal decentralization and environmental quality (e.g., Cheng et al, 2021; Khan et al., 2021; Su et al., 2021). My contribution lies in using a larger sample of countries across more years and in analyzing the effect of revenue and spending decentralization separately.

There remains considerable scope for future empirical research exploring the specific mechanisms that drive the mitigating effect of spending decentralization on emissions. For example, to what extent does subnational governments' ability to borrow, for example through green bonds, influence their climate mitigation potential? Similarly, it would be interesting to explore what types of central government transfers (i.e. general or earmarked) are most valuable, although cross-country data on this is limited. Also, while this study has focused on public finance, private finance has a key role to play in funding climate mitigation projects (Battison et al., 2021). Future research could focus on whether fiscal decentralization leads to a crowding-in of potential private investment. Furthermore, while this study has focused on climate mitigation, future studies could explore questions about the effect of fiscal decentralization on other "wicked problems" such as homelessness or the coronavirus crisis, which polycentric governance has the potential to address effectively (Ostrom, 1990, McGinnis, 2000).

From a policy perspective, my findings point to important positive spillover effects of fiscal decentralization for climate mitigation. While no substitute for national climate action, strengthening national FD can be part of countries' strategies to meet the Paris Agreement goals. Critically, however, FD needs to come with additional finance to supplement subnational governments' own-source revenue. The bottom-up international climate regime system sparked by COP21 has increased appreciation of the contribution subnational actors (Hale, 2016; Hsu et al., 2018). Now it is time to go further to capitalize on institutional configurations and reforms that allow for the unlocking of critical economic and climate dividends.

APPENDIX A: PANEL INFORMATION

Table 4. Panel income distribution

	Income Level	
	Frequency	Percentage
High income	33	50.8
Low income	2	3.1
Lower-middle-income	11	16.9
Upper-middle-income	19	29.2
Total	65	100.0

Table 5. Panel regional distribution

	Region Name	
	Frequency	Percentage
East Asia and Pacific	10	15.4
Europe and Central Asia	38	58.5
Latin America and Caribbean	8	12.3
Middle East and North Africa	2	3.1
North America	2	3.1
South Asia	1	1.5
Sub-Saharan Africa	4	6.2
Total	65	100.0

Table 6. Country list

Afghanistan	El Salvador	Korea	Russia
Albania	Estonia	Kyrgyz Republic	Serbia
Armenia	Finland	Latvia	South Africa
Australia	France	Lithuania	Spain
Austria	Georgia	Luxembourg	Sweden
Azerbaijan	Germany	Mauritius	Switzerland
Belarus	Honduras	Moldova	Thailand
Belgium	Hungary	Mongolia	Tunisia
Brazil	Iceland	Myanmar	Turkey
Bulgaria	Indonesia	Netherlands	Uganda
Canada	Ireland	New Zealand	Ukraine
Chile	Israel	Norway	United Kingdom
China	Italy	Paraguay	United States
Colombia	Japan	Peru	Uzbekistan
Costa Rica	Kazakhstan	Poland	
Czech Republic	Kenya	Portugal	
Denmark	Kiribati	Romania	

APPENDIX B: DATA SOURCES

Table 7. Data sources

Variable Name	**Description**	**Source**
CO_2 emissions	Per capita emissions in metric tons	Our World in Data CO_2 and Greenhouse Gas Emissions database
Revenue decentralization	Share of revenue at the subnational level as a proportion of general government revenue	IMF Fiscal Decentralization database
Spending decentralization	Share of spending at the subnational level as a proportion of general government revenue	IMF Fiscal Decentralization database
GDP per capita	Gross domestic product divided by midyear population in constant 2015 U.S. dollars	World Bank
GDP growth	Annual percentage growth rate of GDP based on constant 2015 prices, expressed in U.S. dollars	World Bank
Democracy score	Revised combined polity score ranging from +10 (strongly democratic) to -10 (strongly autocratic)	University of Gothenburg Quality of Government Indicators
Renewable energy consumption	The share of renewable energy in total final energy consumption	World Bank

APPENDIX C: ROBUSTNESS CHECKS RESULTS

Table 8. Vector Error Correction Model (VECM)

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
ΔFD index	0.008	0.052	0.063	0.027
	(0.010)	(0.053)	(0.059)	(0.019)
L.FD index,	-0.012	-0.190**	-0.202**	-0.055**
	(0.010)	(0.079)	(0.083)	(0.025)
ΔGDP per capita				-0.004
				(0.642)
GDP per capita (lag),				0.219
				(0.657)
ΔGDP growth				0.008
				(0.007)
GDP growth (lag),				-0.002**
				(0.001)
ΔDemocracy score				0.001
				(0.001)
Democracy score (lag),				-0.001
				(0.002)
ΔRenewables consumption				-0.132***
				(0.035)
Renewables consumption (lag),				0.114***
				(0.036)
CO2 emissions (lag),				0.790***
				(0.032)
Constant	0.001	1.881***	1.918***	-1.569***
	(0.002)	(0.001)	(0.085)	(0.342)
R-squared	0.013	0.111	0.132	0.872
Number of countries	52	52	52	49
Country FE		YES	YES	YES
Year FE			YES	YES
Controls				YES
Lagged dependent				YES

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 9. Alternative fiscal decentralization index

VARIABLES	(1) Index 1 - Static	(2) Index 2 - Static	(3) Index 1 - Dynamic	(4) Index 2 - Dynamic
FD	-0.015***	-0.057	0.027	0.102
	(0.005)	(0.041)	(0.019)	(0.084)
FD (lag),			-0.055**	-0.236**
			(0.025)	(0.097)
GDP per capita	0.196***	0.198***	-0.004	-0.157
	(0.038)	(0.043)	(0.642)	(0.758)
GDP per capita (lag),			0.219	0.373
			(0.657)	(0.778)
GDP growth	0.006***	0.006***	0.008	0.009
	(0.002)	(0.002)	(0.007)	(0.009)
GDP growth (lag),			-0.002**	-0.002**
			(0.001)	(0.001)
Democracy score	0.000	0.000	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Democracy score (lag),			-0.001	-0.001
			(0.002)	(0.002)
Renewables consumption	-0.027***	-0.027***	-0.132***	-0.133***
	(0.010)	(0.010)	(0.035)	(0.037)
Renewables consumption (lag),			0.114***	0.116***
			(0.036)	(0.037)
CO2 emissions (lag),	0.800***	0.800***	-0.210***	-0.206***
	(0.036)	(0.035)	(0.032)	(0.033)
Constant	-1.328***	-1.335***	-1.569***	-1.542***
	(0.359)	(0.405)	(0.342)	(0.379)
R-squared	0.861	0.861	0.364	0.350
Number of countries	49	49	49	49
Country FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Controls	YES	YES	YES	YES
Lagged dependent	YES	YES	YES	YES

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 10. Total CO2 emissions

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
FD index	0.840***	-0.125*	-0.101*	-0.012*
	(0.042)	(0.063)	(0.059)	(0.007)
GDP per capita				0.274***
				(0.065)
GDP growth				0.007***
				(0.002)
Democracy score				0.002
				(0.001)
Renewables consumption				-0.031**
				(0.013)
Population				0.309***
				(0.114)
Total C02 (lag),				0.767***
				(0.039)
Constant	4.290***	4.290	4.270***	-6.488***
	(0.051)	(.)	(0.112)	(2.293)
R-squared	0.371	0.038	0.127	0.880
Number of countries	52	52	52	49
Country FE		YES	YES	YES
Year FE			YES	YES
Controls				YES
Lagged dependent				YES

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 11. Alternative specifications of the dependent variable

VARIABLES	(1) Production-based CO2	(2) Consumption-based CO2	(3) PM2.5 air pollution	(4) Carbon Intensity
FD index	0.027	0.027*	0.031	0.019*
	(0.019)	(0.014)	(0.020)	(0.011)
FD index (lag),	-0.055**	-0.053**	-0.039***	-0.019*
	(0.025)	(0.024)	(0.014)	(0.010)
GDP per capita	-0.004	-1.050	-0.064	0.012
	(0.642)	(0.697)	(0.299)	(0.164)
GDP per capita (lag),	0.219	1.273*	0.166	0.005
	(0.657)	(0.707)	(0.297)	(0.166)
GDP growth	0.008	0.018**	0.001	0.000
	(0.007)	(0.008)	(0.003)	(0.002)
GDP growth (lag),	-0.002**	-0.001	-0.002**	-0.000
	(0.001)	(0.001)	(0.001)	(0.000)
Democracy score	0.001	0.002*	-0.007*	
	(0.001)	(0.001)	(0.004)	
Democracy score (lag),	-0.001	-0.003*	0.004***	
	(0.002)	(0.002)	(0.001)	
Renewables consumption	-0.132***	-0.142***	0.012	
	(0.035)	(0.035)	(0.017)	
Renewables consumption (lag),	0.114***	0.118***	-0.008	
	(0.036)	(0.031)	(0.016)	
Lagged Dependent	-0.210***	-0.260***	-0.598***	-0.257***
	(0.032)	(0.029)	(0.081)	(0.026)
Constant	-1.569***	-1.600***	0.880	-0.086
	(0.342)	(0.405)	(0.642)	(0.070)
R-squared	0.364	0.419	0.625	0.341
Number of countries	49	45	48	51
Country FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Controls	YES	YES	YES	YES
Lagged dependent	YES	YES	YES	YES

Notes: Robust standard errors in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table 12. Democratic vs. non-democratic countries

VARIABLES	(1) Democracies	(2) Non-democracies	(3) Democracies	(4) Non-democracies	(5) Democracies	(6) Non-democracies
FD index	-0.0837**	-0.212***	-0.0875**	-0.00174	-0.0169***	0.0301
	(0.0381)	(0.0587)	(0.0362)	(0.0435)	(0.00531)	(0.0176)
GDP per capita					0.209***	0.0879
					(0.0480)	(0.155)
GDP growth					0.00629***	0.00541***
					(0.00200)	(0.00156)
Democracy score					0.00282	0.000898
					(0.00448)	(0.00290)
Renewables consumption					-0.0242**	-0.0750*
					(0.00981)	(0.0353)
CO2 emissions (lag),					0.808***	0.596***
					(0.0341)	(0.128)
Constant	1.904***	1.512***	2.010***	1.181***	-1.522***	-0.0265
	(0.00256)	(0.0253)	(0.0773)	(0.0439)	(0.428)	(1.058)
R-squared	0.031	0.465	0.053	0.765	0.861	0.897
Number of countries	46	15	46	15	42	15
Country FE	YES	YES	YES	YES	YES	YES
Year FE			YES	YES	YES	YES
Controls					YES	YES
Lagged dependent variable					YES	YES

Notes: A score of 6 was used as the cut-off between more and less democratic countries in the Polity score (ranging from -10 to 10). Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 13. Federal vs. unitary countries

VARIABLES	(1) Federal	(2) Non-federal	(3) Federal	(4) Non-federal	(5) Federal	(6) Non-federal
FD index	-0.237**	-0.0870**	-0.0963	-0.0584	-0.0231**	-0.0132**
	(0.0753)	(0.0421)	(0.0862)	(0.0410)	(0.00992)	(0.00594)
GDP per capita					0.329***	0.187***
					(0.0632)	(0.0386)
GDP growth					0.000712	0.00610***
					(0.000942)	(0.00180)
Democracy score					0.00824***	0.000145
					(0.00212)	(0.000808)
Renewables consumption					0.00408	-0.0351***
					(0.00647)	(0.0123)
CO2 emissions ,					0.761***	0.797***
					(0.0354)	(0.0399)
Constant	2.820***	1.630***	2.653***	1.757***	-2.791***	-1.285***
	(0.120)	(0.0212)	(0.164)	(0.0588)	(0.705)	(0.340)
R-squared	0.211	0.038	0.626	0.099	0.949	0.855
Number of countries	9	43	9	43	9	40
Country FE	YES	YES	YES	YES	YES	YES
Year FE			YES	YES	YES	YES
Controls					YES	YES
Lagged dependent variable					YES	YES

Notes: The federal countries in the panel are Brazil, Germany, United States, Australia, Russia, Switzerland, Austria, Belgium, and Canada.
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

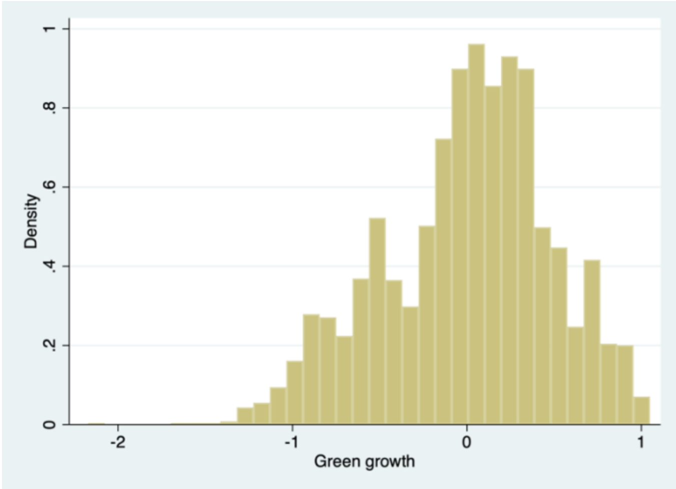

Figure 1. Distribution of the green growth variable

Table 14. Green growth

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3
FD index	0.065***	0.064**	0.015***
	(0.024)	(0.025)	(0.005)
GDP per capita			-0.102**
			(0.042)
GDP growth			-0.002
			(0.002)
Democracy score			-0.000
			(0.001)
Renewables consumption			0.028***
			(0.010)
Green growth (lag),			0.801***
			(0.036)
Constant	-0.071***	-0.159***	0.874**
	(0.001)	(0.046)	(0.392)
R-squared	0.035	0.058	0.761
Number of countries	52	52	49
Country FE	YES	YES	YES
Year FE		YES	YES
Controls			YES
Lagged dependent			YES

Notes: Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.

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