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Maximilian W. Dirks

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Ruhr-Universität Bochum (RUB), Department of Economics
Universitätsstr. 150, 44801 Bochum, Germany

Technische Universität Dortmund, Department of Economic and Social Sciences
Vogelpothsweg 87, 44227 Dortmund, Germany

Universität Duisburg-Essen, Department of Economics
Universitätsstr. 12, 45117 Essen, Germany

Editors

Prof. Dr. Thomas K. Bauer
RUB, Department of Economics, Empirical Economics
Phone: +49 (0) 234/3 22 83 41, e-mail: thomas.bauer@rub.de

Prof. Dr. Wolfgang Leininger
Technische Universität Dortmund, Department of Economic and Social Sciences
Economics – Microeconomics
Phone: +49 (0) 231/7 55-3297, e-mail: W.Leininger@tu-dortmund.de

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RWI, Phone: +49 (0) 201/81 49-213, e-mail: presse@rwi-essen.de

Editorial Office

Sabine Weiler
RWI, Phone: +49 (0) 201/81 49-213, e-mail: sabine.weiler@rwi-essen.de

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Paola D'Orazio and Maximilian W. Dirks[1]

The Impact of Climate-Related Fiscal and Financial Policies on Carbon Emissions in G20 countries – A Panel Quantile Regression Approach

Abstract

This paper investigates the impact of climate-related fiscal and financial policies on CO2 emissions implemented by G20 countries in the period 2000-2017. The analysis show that the impact of various policy instruments is heterogeneous across the carbon emissions distribution. In particular, the effect of a green investment bank is significant across all percentiles and contributes to improving environmental quality. Moreover, our findings suggest that what matters is not the financial sector size per se or the amount of credit devoted to the private sector, but rather the type of finance. This suggests that policymakers and researchers should devote more effort to calibrate their policy instruments and develop an efficient policy mix to achieve climate change mitigation, especially in countries with high carbon emissions.

JEL-Code: E58, E62

Keywords: Mitigation strategies; financial regulation; green investment banks; carbon dioxide emissions; climate risks; green financey

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1 Both RUB. – All correspondence to: Paola D'Orazio, Ruhr-Universität Bochum, Universitätsstr. 150, 44801 Bochum, Germany, e-mail: paola.dorazio@rub.de

1. Introduction

Global warming has become one of the most severe and pressing world issues because of the devastating consequences of environmental degradation on humanity and economic systems. The human effect on climate change is also widely reported, and carbon emissions are now considered to be the highest in history (Nagelkerken and Connell 2015). Carbon dioxide is the most important greenhouse gas implicated in global warming, and its accumulation in the atmosphere beyond certain limits can lead to irreversible impacts, which will be challenging to tackle at later stages (IPCC 2014, 2018). At the international level, several efforts are put forward to mitigate the adverse effects of climate change by reducing carbon emissions. The success of these efforts depends on the commitment of the major CO2 producers, all of which are G20 countries, of meeting the global emissions target as well as on their commitment to keeping the rise in global temperature well below 2°C, as agreed in the COP16 (den Elzen et al. 2019).

In the past decade, the literature has focused in particular on the role of economic growth in affecting climate change and adaptation (Bowen et al. 2012) and on the effects of growth on CO2 emissions. When including also the financial sector development in the analysis of the determinants of CO2 emissions, investigators find negatively correlation. The rationale for this is that financial development can facilitate more financial resources at a lower cost, thus increasing financing also for environmental projects (see Tamazian et al. 2009, among others). Moreover, some argue that financial development may provide enough incentives for firms to lower their CO2 emissions (Lanoie and Roy 1997; Dasgupta et al. 2001).

In our paper, however, we argue that a closer look at the dynamics of financial markets and the implementation of mitigation efforts in the past decades suggests the existence of a more complex financial picture that needs to be investigated. Overall, the evidence collected in the recent literature suggests that, when studying the dynamics of carbon dioxide emissions in the past decades, it is essential to account for novel variables that may have been playing a role in tackling physical and transition risks (Carney 2015), besides traditional indices of GDP growth and financial development. Within the context of climate change mitigation, the effect of climate-related fiscal and financial policies on CO2 emissions stands out as a complex issue due to different new regulations that have been taken into account by G20 countries in the past decades. Nevertheless, on the one hand, the link between finance (and in particular green finance) and emissions is still under-investigated (De Haas and Popov 2019). On the other hand, to the best of our knowledge, fiscal, and financial policies related to climate change have not been considered in any empirical analysis of the determinants of CO2 emissions.

The remainder of the paper is organized as follows. Section 2 reviews the recent literature. Section 3 discusses the method and data used in the analysis. Section 4 present the empirical results and, finally, Section 5 concludes.

2. Literature review

Considering CO2 emissions per capita, G20 countries are very heterogeneous. We report this evidence in Figure 1, that displays the distribution of CO2 emissions (tons per capita) by country in the period 2000-2017. On the one hand, we observe that advanced economies, such as Australia, Canada, and the US, are associated with higher

total CO2 emissions per capita. On the other hand, emerging economies like Brazil, India, Indonesia, Mexico, and Turkey tend to emit less CO2 per capita.

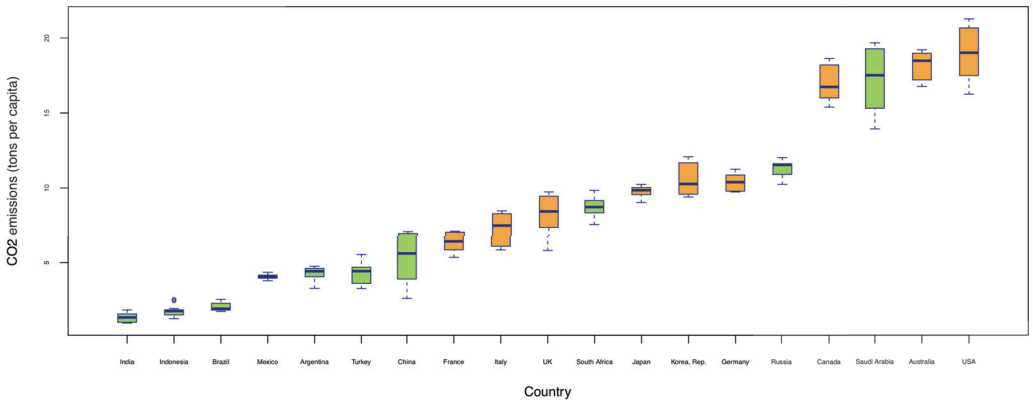

Figure 1.: Distribution of CO2 emissions per capita by country (2000-2017).

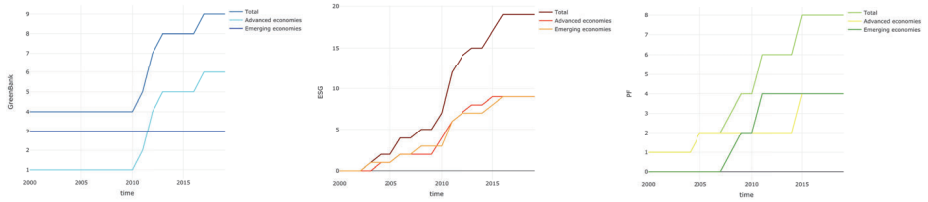

Figure 2.: Green investment and development banks (2000-2017) (left panel) and adoption of ESG criteria (middle panel) and climate-related disclosure for pension funds (right panel).

In this paper, we focus in particular on the role of green investment and development banks (GBank), because of their growing importance in both empirical and theoretical literature. Existing literature emphasises that green banks are important actors in supporting green and low-carbon energy projects, as the cases of Germany, Australia, and the UK suggest (Geddes et al. 2018). In particular, empirical studies have found that the lending attitude of green banks is less pro-cyclical than that of standard commercial banks (Bertay et al. 2015); this activity is particularly relevant because "guarantees" financial capital and contributes to the de-risking of long-term investments, thus contributing to reducing the financing costs of low-carbon investments (Egli et al. 2018; Mazzucato 2013; Mazzucato and Semieniuk 2018). Data collected on G20 countries show that the creation of these institutions has increased among advanced economies in our sample, especially starting from 2010, while, as shown in Figure 2, the number of green banks existing in emerging economies has remained stable in the past two decades.

Regarding "green" financial policies, all G20 countries - although to different degrees - have acknowledged the need to adjust national financial architectures and are discussing, or have already implemented, green financial principles, such as national green finance strategies, climate-related financial risks, and taxonomy of green and brown investments (see D'Orazio and Popoyan 2019, for a comprehensive discussion).

Regarding the adoption of financial regulation explicitly aimed at increasing green finance and addressing climate change mitigation, our review conducted on G20 countries shows a heterogenous picture, as reported in Figure 2, with interesting differences between advanced and emerging economies.

3. Empirical analysis

3.1. *Variables, data sources and description*

This paper focuses on the effects of climate-related fiscal and financial policies on CO2 emissions for G20 countries, excluding the European Union. Based on data availability, we select the yearly sample observations from 2000 to 2017. In particular, through the panel quantile regression approach described in Section 3.2, we propose an analysis aimed at studying the empirical relationship between CO2 emissions per capita, GDP per capita, financial sector size, bank credit to the private sector, the presence of green investment banks, the implementation of ESG disclosure regulations for financial and non-financial firms, and pension funds and green banking regulations. In this way, we investigate to what extent the climate-related fiscal and financial policies affected CO2 emissions in G20 countries in the period 2000-2017.

As the dependent variable, we use the per capita CO2 emissions deriving from the use of fossil fuels (coal, natural gas, and oil) and cement. Because CO2 is reported to be the primary greenhouse gas responsible for the problem of global warming, we use it as an environmental degradation measure. We collected data on CO2 emissions per capita from the database "CO2 and Greenhouse Gas Emissions", which uses data from Le Quéré et al. (2018) and are published online at OurWorldInData.org. The choice to rely on this source is that it provides the latest available data (2017) regarding CO2 emissions at the G20 level.

The independent variables included in the analysis are defined according to four main categories, i.e., (i) financial policy aimed at tackling climate change, (ii) "green" fiscal policy (iii) features of the financial sector, and (iv) control variables. The adoption of ESG criteria and Corporate Responsibility, and the green prudential regulations belong to the first category. Green investment banks fall under the second category, while financial sector size, measured by the total assets held by commercial banks as a % of the GDP, and domestic credit to the private sector are features of the financial sector, whose data are retrieved from the International Financial Statics of the IMF. In the empirical analysis, dummy variables are used to incorporate the adoption of ESG criteria and Corporate Responsibility, green prudential regulations, pension funds, and the presence of a green bank. Finally, GDP per capita is a control variable, which is retrieved from the World Bank database.

Regarding the novel fiscal and financial variables included in the analysis, information is retrieved from the Green Finance Measures Database and used to build our own dataset[1].

Variable	Definition	Source
emissions	CO2 emissions. Annual territorial emissions of carbon dioxide (CO2) from fossil fuels and cement. Data has been converted by Our World in Data from tonnes of carbon to tonnes of carbon dioxide (CO2) using a conversion factor of 3.664.	Hannah Ritchie and Max Roser (2020)
GDP	Gross domestic product. GDP per capita (current US$). GDP per capita is gross domestic product divided by midyear population.	World Bank
FSS	Financial sector size. Total assets held by deposit money banks as a share of GDP.	International Financial Statistics (IFS) International Monetary Fund (IMF)
GBank	Green investment and development banks.	Green Finance Measures Database
PF	Climate-related reporting regulations on pension funds.	Green Finance Measures Database
ESG	Environmental, social and governance (ESG) criteria and social corporate responsibility.	Green Finance Measures Database
GPR	Green prudential regulation.	Green Finance Measures Database
CredPS	Private credit by deposit money banks to GDP (%). The financial resources provided to the private sector by domestic money banks as a share of GDP.	International Financial Statistics (IFS) International Monetary Fund (IMF)

Table 1.: Variables definitions and data sources. All data are annual over the period 2000-2017.

[1]The Green Finance Measures Database includes policy and regulatory measures issued by public authorities, including governments, central banks, financial regulators, and public financial institutions. It builds on data and analysis compiled by the UNEP Inquiry into the Design of a Sustainable Financial System, including country analysis, global reports and the Green Finance Progress Report series delivered to G20 finance ministers.

3.2. *The econometric methodology*

Two empirical approaches are used to carry out the investigation; namely the *Method of Moments Quantile Regression*(MMQR).

The econometric model specification involves the use of the Method of Moments Quantile Regression (MMQR) developed by Machado and Silva (2019). This choice is motivated by the fact that this method allows us to identify the conditional heterogeneous covariance effects of the determinants of CO2 emissions by allowing the individual effects to affect the entire distribution, rather than being just locations (means) shifters, as in the case of Koenker (2004). The MMQR estimation technique is particularly relevant in scenarios where the panel data model is embedded with individual effects, as in the case of our analysis. As discussed in Section 2, G20 countries are indeed very heterogenous in several respects; therefore, we consider it useful to deal with individual effects in the estimation process.

The estimation of the conditional quantiles $Q_Y(\tau|X)$ for a model of the location/scale variant of quantile regression takes the following form:

$$Y_{it} = \alpha_i + X_{it}^{'}\beta + (\delta_i + Z_{it}^{'}\gamma)U_{it} \tag{1}$$

where the probability $P\{\delta_i + Z_{it}^{'}\gamma > 0\} = 1.(\alpha, \beta^{'}, \delta, \gamma^{'})^{'}$ are parameters to be estimated. In particular, $(\alpha_i, \delta_i), i = 1, \ldots, n$ designates the individual i fixed effects and Z is a k-vector of identified components of X which are differentiable transformations with elements l given by

$$Z_l = Z_l(X), l = a, \ldots, k \tag{2}$$

X_{it} is independently and identically distributed for any fixed i and is independent across time (t). U_{it} is independently and identically distributed across individuals i and through time (t) and are orthogonal to X_{it} and normalised to satisfy the moment conditions in Machado and Silva (2019). Equation 1 implies

$$Q_Y(\tau|X) = (\alpha_i + \delta_i q(\tau)) + X_{it}^{'}\beta + Z_{it}^{'}\gamma q(\tau) \tag{3}$$

In Equation 3, $X_{it}^{'}$ is a vector of independent variables. $Q_Y(\tau|X)$ indicates the quantile distribution of the dependent variable Y_{it}, that in our case is the logarithm of CO2 emissions per capita and is conditional on the location of independent variable X_{it}. $\alpha_i + \delta_i q(\tau)$ is the scalar coefficient which is indicative of the quantile-*tau* fixed effect for individual i. It is important to note that the individual effect in this context does not denote an intercept shift, but they are time-invariant parameters whose heterogeneous impact are allowed to differ across the quantiles of the conditional distribution of the endogenous variable Y. $q(\tau)$ denotes the τ-th sample quantile which is estimated by solving the following optimization problem

$$\min_q \sum_i \sum_t \rho_\tau(R_{it} - (\delta_i + Z_{it}^{'}\gamma)q) \tag{4}$$

where $\rho_\tau(A)$ denotes the check function.

4. Results

In this section, we discuss the estimation results of the model specification involving the MMQR[2]. Results are reported in Table 2 for the 10th, 20th, 30th, 40th, 50th, 60th, 70th, 80th, and 90th percentiles of the conditional CO2 emissions distribution. Figure 3 shows the quantile regression coefficients across all percentiles and the corresponding 95% confidence interval for all independent variables. To allow for a comparison, we report the results of the OLS-FE in Figure 3 (see blue dotted lines). Overall, the signs and significance of the coefficients found in the OLS-FE correspond to those observed in the MMQR (see also Table 3). However, the OLS-FE describes only a partial picture of the empirical relationship existing between the variables, as it focuses on the mean effects.

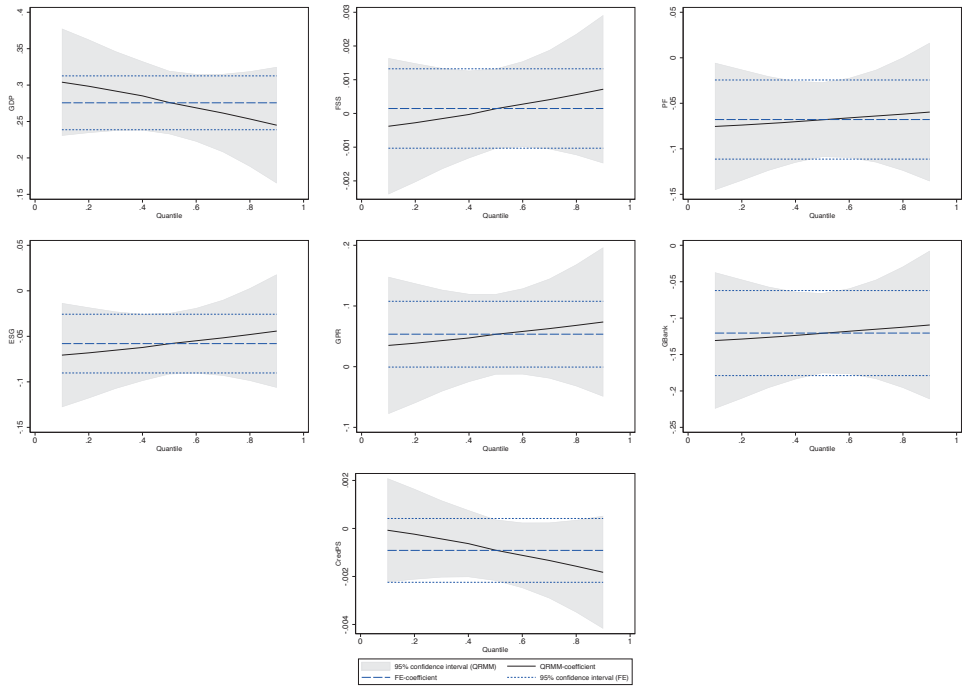

Figure 3.: Method of Moments Panel Quantile Regression results.

In the following, we focus on the description of the results obtained with the MMQR. We start from the effects of the presence of a green bank, for which we find a significant effect across all percentiles, suggesting a positive effect of the presence of a green bank on the limitation of carbon emissions. This result confirms our expectation - described in the introduction - about the existence of a negative correlation between green banks and CO2 emissions.

When looking at the effect of the financial policies, a more complex picture arises. Regarding PF and ESG disclosure, the MMQR estimation suggests that both have an impact on limiting environmental degradation on the whole CO2 distribution. This effect is, however, not detected for the 90th percentile, which is found to be not significant, highlighting that these policies are ineffective for high-emission countries. Re-

[2]Before estimating the panel quantile regression; we conducted the ADF and PP unit root tests, which confirmed that the variables used are stationary (the p-values are all significant at the 1% level). Therefore, we conduct our panel quantile regression by working with variables in levels.

garding PF, its impact is stable at different percentiles, with the highest significance detected at the 30th, 40th, 50th, and 60th percentiles. Regarding the ESG disclosure requirements, the highest significance is detected for the 20th, 30th, 40th, 50th, and 60th percentiles. Surprisingly, the coefficients for the green banking regulations are positive; in particular, they are higher as we move from low- to high-emission countries. However, a significance at the 10% level is observed only for countries that belong to the median of the CO2 emission distribution, i.e., the 60th percentile. Notably, the positive coefficients suggest that having such regulations in the financial architecture causes an increase in CO2 emissions across the whole distribution; this is in contrast to the aim of those tools which have been put in place to limit transition risks and promote mitigation measures.
These results concerning banking regulations imply three possible explanations. One is related to the un-effectiveness of these policies because in the majority of G20 countries, especially the advanced ones, they have been implemented only very recently. The other is related to the type of regulation adopted at the country level. According to the data collected for the past two decades, in the majority of G20 countries, the regulations are related to the adoption of so-called green prudential principles, rather than green lending limits, or green capital and liquidity requirements for banks. Therefore, these measures, for the moment, fall short to meet the ambitious objectives of scaling up green finance for climate mitigation. A third possible interpretation of this result is that the commercial loans that are created under these regulations, although aimed at complying with green lending criteria, are still favoring investments in (brown) polluting sectors, rather than (green) ecological and pollution reduction technologies. This issue could, in turn, be related to the lack of a standardised green-brown-neutral taxonomy for screening the type of technology and climate-related risks of a specific investment (TCFD 2017, 2018; NGFS 2019).

Coefficients for GDP per capita are found to be higher in lower percentiles, which implies that economic growth in low-emitting countries is associated with a high degree of environmental pollution. As most low-emitting countries are also emerging economies, this result suggests that their economic growth is more carbon-intensive than in advanced economies.

Finally, in contrast to existing literature, no significance is detected for the financial sector size and credit to the private sector. According to us, our result suggests that what matters is not the financial sector size per se or the amount of credit devoted to the private sector, but rather the type of finance.

	Dependent variable:								
	emissions								
Quantiles	10th	20th	30th	40th	50th	60th	70th	80th	90th
GDP	0.304***	0.298***	0.292***	0.285***	0.276***	0.269***	0.262***	0.253***	0.245***
	(8.10)	(9.13)	(10.49)	(11.80)	(12.48)	(11.37)	(9.56)	(7.60)	(6.01)
FSS	-0.000380	-0.000276	-0.000153	-0.0000304	0.000140	0.000276	0.000409	0.000560	0.000718
	(-0.37)	(-0.31)	(-0.20)	(-0.05)	(0.23)	(0.43)	(0.55)	(0.61)	(0.64)
PF	-0.0754**	-0.0739**	-0.0722***	-0.0704***	-0.0679***	-0.0660***	-0.0641**	-0.0619*	-0.0596
	(-2.12)	(-2.38)	(-2.73)	(-3.08)	(-3.25)	(-2.96)	(-2.47)	(-1.95)	(-1.54)
ESG	-0.0707**	-0.0681***	-0.0652***	-0.0622***	-0.0581***	-0.0549***	-0.0517**	-0.0480*	-0.0442
	(-2.42)	(-2.68)	(-3.02)	(-3.32)	(-3.40)	(-3.00)	(-2.43)	(-1.85)	(-1.39)
GPR	0.0350	0.0387	0.0430	0.0473	0.0533	0.0581*	0.0628	0.0681	0.0736
	(0.61)	(0.77)	(1.01)	(1.28)	(1.58)	(1.61)	(1.50)	(1.33)	(1.17)
CredPS	-0.0000736	-0.000240	-0.000436	-0.000632	-0.000904	-0.00112	-0.00133	-0.00157	-0.00183
	(-0.07)	(-0.25)	(-0.53)	(-0.89)	(-1.39)	(-1.61)	(-1.66)	(-1.60)	(-1.52)
GBank	-0.131***	-0.129***	-0.126***	-0.124***	-0.121***	-0.118***	-0.115***	-0.112***	-0.109**
	(-2.74)	(-3.09)	(-3.57)	(-4.05)	(-4.31)	(-3.95)	(-3.32)	(-2.65)	(-2.10)

Table 2.: Method of Moments Panel Quantile Regression results. Figures in parentheses are z-scores. *Note:* *p<0.1; **p<0.05; ***p<0.01

	Dependent variable:		
	emissions		
	OLS pooled	OLS one-way FE	OLS two-way FE
	(1)	(2)	(3)
	emissions	emissions	emissions
GDP	0.471***	0.276***	0.367***
	(5.27)	(4.19)	(4.27)
FSS	-0.00648**	0.000147	0.000433
	(-2.37)	(0.12)	(0.44)
PF	-0.142	-0.0678*	-0.0516
	(-1.25)	(-1.84)	(-1.64)
ESG	-0.251**	-0.0580	-0.0490
	(-2.19)	(-1.47)	(-1.42)
GPR	-0.252*	0.0535	0.0200
	(-1.85)	(1.18)	(0.45)
CredPS	0.00625**	-0.000914	-0.00103
	(2.43)	(-0.71)	(-0.86)
GBank	0.0365	-0.121*	-0.119*
	(0.22)	(-2.01)	(-1.94)
Intercept	-2.426***	-0.580	-1.430*
	(-3.47)	(-1.01)	(-1.89)
N	329	329	329
R^2	0.741	0.533	0.580
adj. R^2	0.735	0.522	0.547

Table 3.: Panel estimation results. *Note:* *p<0.1; **p<0.05; ***p<0.01

5. Conclusions

In the past two decades G20 countries have implemented - although to different degrees - a wide range of policy instruments, including climate-related fiscal and financial policies, to affect climate change and achieve effective mitigation results. By considering the new fiscal and financial policies landscape, through the panel quantile regression approach, we investigated the determinants of carbon emissions per capita in G20 countries throughout its conditional distribution. This methodological choice has allowed us to perform a more in-depth "screening" of the effects of a so-called *green financial development* on environmental quality in G20 countries in the period 2000-2017, with a particular focus on the countries with the lowest and highest emissions. The investigation is carried out by using the panel quantile regression approach. The main results can be summarised as follows.

First, the econometric analysis confirms, in line with existing literature, the hypoth-

esis that GDP per capita is positively correlated with CO2 emissions, and the effect is found to be higher for countries with the lowest emissions.

Second, regarding the role of fiscal and financial policies related to climate change, interesting insights can be drawn from our analysis. Our estimation suggests that fiscal policies, proxied by the existence of a green investment bank or a development bank, play a role in limiting environmental degradation in G20 countries. The rationale for this is that green investment banks are usually characterised by very ambitious lending programs that are explicitly targeted at fostering green investments, such as environmental-friendly technologies and renewable energy (see, e.g., the case of the German KfW or the Green Investment Bank set up in 2011 in the UK).

Third, regarding the *green financial development*, intended as the financial policies and regulations explicitly aimed at climate change mitigation, we observed that it has been playing a role in controlling the environment from degradation. Empirical results emphasise the role of regulations on climate-risk disclosure for pension funds and the introduction of ESG criteria particularly. The estimated coefficients for these two variables show a stable impact across the whole distribution, but they are not significant for the 90th percentile, suggesting that high-emission countries should implement more audacious policies in this sense.
Related to the green financial policies, green prudential regulations explicitly aimed at the banking sector, are found to be positively correlated with carbon emissions across all percentiles. However, the estimated coefficients are significant only for the 60th percentile. According to us, these findings suggest that more countries, both those at the bottom and the top of the distribution, should implement such regulations, possibly aimed at setting a green bank capital or green liquidity requirements. Moreover, to be effective, these policies should be better calibrated and based on standardised taxonomies of green/brown investments. The proposed criteria for 67 economic activities by the Technical Expert Group on Sustainable Finance represents an excellent tool for this purpose (EP 2019); however, they were released in mid-2019, and more time is needed to verify their efficacy.

Fourth, considering the features of the financial sector, its size and the bank credit to the private sector are found to be not significant. In our view, the results of our analysis should be read in light of the additional variables that are incorporated in the analysis to reflect the changing landscape related to green finance in G20 countries. Indeed, our findings suggest that what matters is not the financial sector size *per se* or the amount of credit devoted to the private sector, but rather the *type* of finance, i.e., financial resources explicitly aimed at a green transition, as well as regulations aimed at scaling up green finance or - symmetrically - limiting "brown" finance.

Fifth, our findings draw attention to the need to implement policy mixes for climate change mitigation. We believe that our analysis highlights that no policy alone would be able to improve environmental quality; determining which is the most effective policy mix depends on countries' peculiarities and requires, however, further research. In particular, the empirical evidence suggests that countries characterised by the highest carbon emissions should implement bolder policies and mitigation strategies to meet the decarbonisation objectives recognised in international agreements.

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