Exploring the Effects of Climate-related Financial Policies on Carbon Emissions in G20 Countries: A Panel Quantile Regression Approach

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ARTICLE

Exploring the effects of climate-related financial policies on carbon emissions in G20 countries: a panel quantile regression approach

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ABSTRACT

This paper studies the effects of financial development, economic growth, and climate-related financial policies on carbon (CO₂) emissions for G20 countries. The focus is on policies implemented to different degrees by G20 countries to scale up green finance and address climate-related financial risks in 2000-2017 and represents this paper’s value-added. The empirical results obtained by relying on the panel quantile regression approach indicate that the impacts of the different explanatory variables on carbon emission are heterogeneous. Specifically, the effect of the stock of short-term financial policies on carbon emissions is negative, and its effect becomes smaller at higher quantiles. No significance is reported for the 10th quantile. The stock of long-term policies also show significant negative coefficients, but their impact is stronger for higher quantiles. Financial development contributes to improving environmental quality, and its impact is larger in higher emission countries. Energy consumption increases carbon emissions, with the strongest effects occurring at higher quantiles. Our results also support the validity of the EKC relationship and positive effects of GDP and population on high emissions levels. The study highlights that climate-related financial policies have a negative direct effect on CO₂ emissions but a positive indirect effect in some percentiles. This evidence can imply a worsening of environmental quality in high-emission countries when considering the stock of short-term policies and low-emission countries when analyzing the stock of long-term policies. The total effect appears nevertheless negative, which indicates that these policies may improve environmental quality overall in G20 countries.

KEYWORDS

Financial development, Climate-related financial policies, Carbon Dioxide Emissions, Climate risks, Green finance

1. Introduction

Global warming has become one of the most severe and pressing issues because of the devastating consequences of environmental degradation on humanity and economic systems globally. The human effect on climate change is also widely reported, and carbon emissions are now considered the highest in history (Nagelkerken and Connell 2015). Carbon dioxide (CO₂) is the most important greenhouse gas implicated in global warming (Scheffer et al. 2006; Solomon et al. 2009). 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 climate change's adverse effects by reducing carbon emissions. The UN Paris Agreement of 2015 set the goal of keeping global warming well below 2°C and as close as possible to 1.5°C above pre-industrial levels. To comply with this objective, countries should reduce emissions to almost zero by 2050. Nevertheless, the special report of the IPCC (2018) on the global temperature goals shows that the gap between current trends and emissions reduction targets set by countries through their nationally determined contributions (NDCs) is widening and leading to somewhere between 3°C and 4 °C of warming (den Elzen et al. 2019). This scenario is consistent with what has been defined as a "Hothouse Earth" pathway (Steffen et al. 2018). Indeed, the most recent evidence suggests that global carbon emissions have been increasing despite the efforts to reduce them (Peters et al. 2020). In 2020, the International Energy Agency (IEA) reported that global energy-related CO₂ emissions flattened in 2019, following two years of increases. According to the analysis, this resulted mainly from a sharp decline in CO₂ emissions from the power sector in advanced economies, thanks to the expanding role of renewable sources (primarily wind and solar PV), fuel switching from coal to natural gas, and higher nuclear power output (IEA 2020). However, according to Le Quéré et al. (2019), to limit global warming to below 2°C by the year 2100, greenhouse gas emissions would have to decrease by one to two billion tons every year.

Because of the natural, social and economic disruption it risks generating, the research community from different disciplines has agreed on the compelling need to tackle climate change (Stern et al. 2006; Heller and Zavaleta 2009; Dasgupta 2021). As CO₂ is the primary responsible for global warming, the determinants of CO₂ emissions have been largely studied in the literature. Among the main drivers, economic growth is usually considered because it promotes economic development and progress. Still, it is detrimental to the environment. Therefore, the literature has investigated the nexus between economic growth and the environment, popularly known as the Environment Kuznets Curve (EKC). Besides the EKC relationship, some researchers focused on the role of democracy and renewable energy in reducing carbon emissions (Adams and Acheampong 2019), others looked at the impact of democracy, globalization and urbanization (Wang et al. 2018), the role played by financial stability and energy consumption (Nasreen et al. 2017). Finally, a broad stream of literature studied the effects of financial development (see Gök 2020, for a recent review). The latter is particularly relevant because both capital markets and the financial sector play a crucial role in delivering the necessary investments in low-carbon technologies to achieve green structural change.

In our view, a closer look at the effects of climate change, the dynamics of CO₂ emissions, and the development of financial policies in the past decades suggests the existence of a more complex picture that needs to be investigated. First, the implementation of adaptation and mitigation strategies is related to developing green technologies whose diffusion is constrained by several "barriers", such as costs, lack of competencies and knowledge, market structure, and lack of financial resources (D'Este et al. 2012). The latter is particularly relevant and is motivated by the fact that eco-innovation requires long-term financial capital, which is, by definition, riskier and, therefore, more expensive than standard "non-green" innovation. Second, although positive trends of green finance development have been detected in the past years, the flow of financial resources is insufficient to close the "green finance gap" (Buchner et al. 2017; IEA 2018; Geddes et al. 2018; D'Orazio and Löwenstein 2020). As a

result, the existing green finance volumes fall short to meet the 2°C scenario called for by IPCC (2018), and a green structural change is difficult to achieve. Overall, this evidence suggests that, when studying the dynamics of carbon dioxide emissions in the past decades, it is essential to account for novel variables. In particular, we claim that it is necessary to include climate-related financial policies (CRFP), which are characterized by two main aims, i.e., to scale up green finance and tackle physical and transition risks for the financial sector (D’Orazio and Popoyan 2019). They are promoted mainly by central banks and financial regulators, whose role in addressing climate-related issues has been at the core of academic and policy discussion in the past years (see Batten et al. 2016; Campiglio et al. 2018, for a review on these topics). Within the context of climate change mitigation, the effect of these policies on CO₂ emissions stands out as a complex issue due to different new financial regulations that G20 countries have adopted in the past decades (see Section 4 for a review). However, despite their importance in shaping the climate-related financial landscape, the link between CRFPs and CO₂ emissions is still under-investigated (De Haas and Popov 2019).

Against this backdrop, the contribution of this paper to the literature is threefold. First, to the best of our knowledge, CRFPs have not been considered in any empirical analysis of the determinants of CO₂ emissions. Our study investigates this issue for the first time and thus provides a primary contribution to understanding their role in affecting environmental quality (proxied by CO₂ emissions). Second, this study applies a panel quantile regression (PQR) approach to explore the effect of CRFPs, financial development, and economic growth on the CO₂ emissions. Applying the PQR approach will allow us to provide more detailed results than the standard ordinary least squares (OLS) approach and discuss the heterogeneity characterizing countries’ experiences. Third, the study’s focus on G20 countries is important because they represent the leading global economies and offer a broad sample of developed and developing countries. Furthermore, they are the most significant contributors to global carbon emissions. Hence, we deem it relevant to study the role of CRFP from the G20 perspective.

The remainder of the paper is organized as follows. Section 2 offers a review of the literature and puts our study in context. The methodology is presented in section 3 and data are described in section 4. Section 5 provides the empirical results and discussions, and, finally, section 6 offers concluding remarks and discusses policy implications of the investigation.

2. Literature review

2.1. *Economic growth, financial development and environmental quality*

After the seminal contribution by Grossman and Krueger (1995), academic research has focused on the effects of growth on CO₂ emissions. The relationship between the measure of environmental degradation, i.e., CO₂ emissions, and per capita income is defined as the Environmental Kuznets Curve (EKC). The EKC hypothesis states that an inverted U-shaped relationship between environmental degradation and economic growth exists. It is maintained that environmental degradation increases at the initial stage of economic growth; as the economy grows, environmental degradation falls, and environmental quality improves. The evidence on the EKC is, however, still mixed. According to some researchers, the EKC relationship is not valid because it is observed

that environmental degradation is monotonically increasing with economic growth (see Stern 2004; Alkhathlan and Javid 2013; Farhani and Ozturk 2015, among others). Others find instead support for the EKC hypothesis (see He and Richard 2010; Apergis and Payne 2010; Apergis and Ozturk 2015; Jebli et al. 2016, among others). Therefore, it is essential to test the ECK hypothesis's validity when designing appropriate policy tools to fight against global warming and protect the environment.

Moreover, when discussing the relationship between economic growth and CO₂ emissions, it is important to consider financial development. The rationale for this is that financial development enhances economic growth, which requires, among others, more energy consumption, resulting in pollution and environmental degradation. While financial development is claimed to have significant implications for the environment, its impact on carbon emissions remains contentious.

Two main opposing views about the impact of financial development on the environment can be distinguished. Some scholars believe that financial development improves the environment's quality by reducing carbon emissions. They argue that financial development can facilitate more financial resources at a lower cost, thus increasing financing for environmental projects (see Tamazian et al. 2009; Acheampong 2019, among others), and that financial development may provide enough incentives for firms to lower their CO₂ emissions (Lanoie and Roy 1997; Dasgupta et al. 2001). Some researchers also maintain that financial development provides developing countries with more opportunities for advanced technologies, which implies increased energy efficiency and sustainable and environmentally-friendly production, thus reducing CO₂ emissions (Claessens and Feijen 2007). According to others, financial development contributes instead to environmental degradation. It increases households' consumption and firms' production and accelerates economic growth, resulting in polluting activities and thereby causes an increase in emissions. Zhang (2011) found that financial development is one of the factors responsible for increasing the level of CO₂ emissions. Financial development also contributes to a rise in energy consumption and CO₂ emissions in Sub-Saharan African countries, as discussed in Al-Mulali et al. (2012). As noted by Gök (2020), the difference in the estimated effect depends on the financial development indicator used (see Acheampong 2019, on this point), the econometric technique employed, selected countries, country group, region, or provinces involved, and time span considered in the investigation.

Overall, by considering the literature published so far on the role of financial development on CO₂ emissions, it seems that different impacts are observed for different countries or groups of countries (Gök 2020). On the one hand, studies considering African countries or focusing on individual countries such as Brazil, Greece, India, Indonesia, Nigeria, Pakistan, Portugal, Saudi Arabia, Sri Lanka, Tunisia, Turkey, USA, and Vietnam tend to report a significant positive impact on the effect of financial development on CO₂ emission. On the other hand, studies analyzing emerging markets, Asia, Commonwealth of Independent States (CIS), European Union (Park et al. 2018), Gulf Cooperation Council (GCC), Next 11, APEC (Zaidi et al. 2019) and OECD countries (Lee et al. 2015) or focusing on individual countries such as Bangladesh (Khan et al. 2018), China, Iran, Malaysia and Russia tend to report a significant negative impact on the effect of financial development on CO₂ emission.

2.2. *Green financial development: climate-related financial policies and environmental quality*

Although central banks and financial regulators cannot substitute for an adequate climate policy (Lane 2019; Weidmann 2020), it is now widely acknowledged that they have to take action to scale-up green finance and adopt regulations to address climate-related financial risks. The rationale for this is that (i) climate change affects monetary policy and financial regulation (Batten et al. 2016; Campiglio 2016; D’Orazio and Popoyan 2019; Chenet et al. 2021) and (ii) financial actors play an essential role in the global economy (Rogoff 1999; Wang 2017; Geddes et al. 2018; Mazzucato and Semieniuk 2018).

Central banks and financial regulators have been particularly engaged in climate-related financial policymaking in the past decades. Regarding their green finance action, they can redirect financial flows towards activities that protect natural capital and positively affect the environment (Galaz et al. 2015). This policy action is also aligned to the Paris Agreement goal (Article 2.1c) of “making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development” (COP 2015). Compared with traditional finance, green finance emphasizes environmental interests; it regards environmental protection and the effective use of resources as important criteria for measuring the effectiveness and ultimately realizes sustainable development and promotes economic growth (Yadav and Pathak 2013; Steckel et al. 2017; Sachs et al. 2019). Therefore, like financial development, the development of green finance can also promote economic growth. Regarding action taken against climate risks, their effort is crucial as climate change poses threats to the conduct of monetary policy because of its effects on supply price shocks, market volatility, and economic growth, which are related to inflation through credit spreads, saving rates, and real interest rates (Coeuré 2018; Monnin 2018; Schnabel 2020). Moreover, climate-related financial risks (CRFRs), namely, physical, transition, and liability risks, represent a threat to financial stability (Carney 2015). CRFRs can cause credit risks, market risks, liquidity risks, and insurance risks because of financial losses, destruction of production capital, decline in profitability of exposed firms, and stranding of assets related to climate-relevant sectors (e.g., fossil fuels and mining) (Batten et al. 2016; Elderson 2018). Central banks and regulators are thus required to assess financial institutions’ performance and report how they account for environmental and social issues and provide guidance and requirements regarding how financial institutions impact ecosystems (Carney 2015; Scholtens 2017; HLEG 2018; ECB 2020).

Several policies are suitable for scaling up green finance and address climate risks, thus contributing to the decarbonization and low-carbon transition (D’Orazio and Popoyan 2019). We define them as climate-related financial policies (CRFPs) throughout the paper, and we distinguish among four categories; namely (i) climate-related prudential regulations; i.e., measures such as governance and risk management measures, climate-related stress tests and climate-related risk disclosure aimed at the banking sector (ii) promotional credit measures; (iii) green financial principles; i.e., policies aimed at “creating green financial markets”, such as green finance principles and green taxonomy and (iv) other climate-related disclosure requirements aimed at non-financial institutions, insurance companies and pension funds.

In the first category, several prudential measures existing under the Basel III framework can be used to meet the Paris Agreement goals (see D’Orazio and Popoyan 2019, for a review). Among others, leverage ratios, countercyclical capital buffers, and risk weights applied to banks’ assets, such as the Green Supporting Factor (GSF) or the

Brown Penalising Factor (Schoenmaker and Van Tilburg 2016), could be implemented. Following the proposal of a GSF by the European Commission (Dombrovskis 2017), green capital regulations have been discussed in the past years, with many analyses pointing to significant risks deriving from its potential implementation. Among others, threats to financial stability are emphasized, considering that green assets are not risk-free. Sectoral leverage ratios could also be implemented to limit the financial sector’s exposure to brown assets, thus addressing potential threats from a low-carbon transition. Other measures relate to climate-related stress tests¹ that provide useful information to policymakers regarding the financial system exposure to climate-related risks (see, e.g., Vermeulen et al. 2019) and their results could be used to calibrate and evaluate green macroprudential tools. Other (banking) prudential measures, such as disclosure requirements of the physical, liability and transition risks associated with climate change, are also relevant to develop a credible green financial system and avoid the so-called ‘green washing’ (TCFD 2018).

Central banks can also directly promote green-sustainable investments through promotional credit measures, such as green lending quotas and concessional loans to priority and environmentally friendly sectors.

Sustainability reporting and compliance practices are increasingly considered complementary to risk management practices in dealing with concerns about the adverse consequences of climate change (Ng 2018). Accordingly, the fourth category concerns reporting regulations and environmental, social, and governance (ESG) criteria aimed at pension funds, insurance companies, and other non-financial institutions. Reporting regulations on pension funds have become prominent in the debate on the importance of climate risks for institutional investors (Della Croce et al. 2011) and on how to tackle climate change from the financial sector perspective (see Ameli et al. 2019, among others). In particular, after the Paris Agreement, a better understanding of whether institutional investors’ portfolios are exposed to asset stranding and, consequently, financial risks has become increasingly important for investors, regulators, and the economy at large (Boermans and Galema 2019; Krueger et al. 2020). Regarding ESG criteria, they have been gathering much consideration, both in the economics profession and among policymakers (Wang and Sarkis 2017; Lokuwaduge and Heenetigala 2017; Li et al. 2018; Widyawati 2020). Indeed, ESG metrics and their implementation have become a critical part of business strategy. Although there are risks of greenwashing (Yu et al. 2020), ESG disclosure is becoming relevant because it is found to have positive effects on firms’ performance, besides reducing uncertainty, business risk, and the cost of capital (El Ghoul et al. 2011; Amel-Zadeh and Serafeim 2018; Bhaskaran et al. 2020).

3. Method

3.1. *Panel quantile regression*

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. More precisely, the method

¹They aim at assessing the resilience of the financial system to adverse climate shocks by considering the possible impact of hypothetical climate-related shock scenarios on the stability of individual financial institutions and the financial system in its complexity (NGFS 2019).

developed by Machado and Silva (2019) allows the individual effects to affect the entire distribution, rather than being just locations (means) shifters, as in the case of Koenker (2004). Moreover, 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.

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:

$$Y_{it} = \alpha_i + X'_{it}\beta + (\delta_i + Z'_{it}\gamma)U_{it} \quad (1)$$

where the probability $P\{\delta_i + Z'_{it}\gamma > 0\} = 1$. $(\alpha, \beta', \delta, \gamma)'$ are parameters to be estimated. In particular, $(\alpha_i, \delta_i), i = 1, \dots, n$ 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

$$Z_l = Z_l(X), l = a, \dots, k \quad (2)$$

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

$$Q_Y(\tau|X) = (\alpha_i + \delta_i q(\tau)) + X'_{it}\beta + Z'_{it}\gamma q(\tau) \quad (3)$$

$Q_Y(\tau|X)$ 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- τ 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

$$\min_q \sum_i \sum_t \rho_\tau(R_{it} - (\delta_i + Z'_{it}\gamma)q) \quad (4)$$

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

In Equation 3, X'_{it} is a vector of independent variables as specified in Equation 5.

$$\begin{aligned} Q_{CO2_{it}}(\tau_k|\alpha_i x_{it}) = & (\alpha_i + \delta_i q(\tau)) + \beta_{1\tau}GDP_{it} + \beta_{2\tau}GDP_{it}^2 + \beta_{3\tau}Pop_{it} \\ & + \beta_{4\tau}LTFP_{it} + \beta_{5\tau}STFP_{it} + \beta_{6\tau}Domcredit_{it} + \beta_{7\tau}ChinnIto_{it} \\ & + \beta_{8\tau}ROA_{it} + \beta_{9\tau}FFC_{it} + Z'_{it}\gamma q(\tau) \end{aligned} \quad (5)$$

where GDP denotes Gross Domestic Product in country i in period t and Pop is the population size. $LTFP$ represents long-term financial policies, whereas short-term financial policies are labelled as $STFP$. Domestic credit, Chinn-Ito Index for financial openness, return on assets and fossil fuel consumption are denoted with $Domcredit$,

ChinnIto, *ROA* and *FFC*, respectively. Details about the description and source of variables are reported in Section 4.

3.2. The effect of climate-related financial policies on CO₂ emissions

To estimate the direct and indirect effect of CRFPs on CO₂ emissions in G20 countries, we develop the following two equations. Equation 6 defines pollution as a function of income, population, short-term and long-term green policies, and other factors. Equation 7 defines income as a function of lagged income, short-term and long-term green policies, and other explanatory variables, such as total consumption, public spending and investment and net exports.

$$CO2_{it} = \alpha_i + \beta_{1\tau}GDP_{it} + \beta_{2\tau}GDP_{it}^2 + \beta_{3\tau}Pop_{it} + \beta_{4\tau}LTFP_{it} + \beta_{5\tau}STFP_{it} + \beta_{6\tau}Domcredit_{it} + \beta_{7\tau}ChinnIto_{it} + \beta_{8\tau}ROA_{it} + \beta_{9\tau}FFC_{it} + \epsilon_{it} \quad (6)$$

$$\widehat{GDP}_{it} = \alpha_i + GDP_{it-1} + K_{it} + \pi_{it} + Pop_{it} + LTFT_{it} + STFT_{it} + \mu_{it} \quad (7)$$

where $\widehat{GDP}$ represents the estimated GDP in billion US-Dollar, K denotes the gross capital formation in percent of GDP, and π is the inflation rate. The population size is denoted with Pop . The subscript i represent the country, while t denotes the year; ϵ_{it} and μ_{it} represent the error terms.

We then apply the Two-Stage Least Squares method (Kelejian 1971) to estimate direct, indirect and total effect by considering the whole CO₂ distribution. The direct effects are calculated by estimating equation 6. More precisely, the coefficient size of $\beta_{4\tau}$ and $\beta_{5\tau}$ corresponds to the direct effect of the LTFPs and STFPs on CO₂ emissions. In a second step, the estimated $\widehat{GDP}_{it}$ is used to reestimate equation 6. The coefficients obtained with $\widehat{GDP}_{it}$ instead of GDP_{it} correspond to the total effect of LTFPs and STFPs. The indirect effects are equal to the difference between total effects and direct effects.

4. Data

The following section presents the variables used in the empirical analysis. Their description and sources are summarized in Table 1 and summary statistics are provided in Table 2. Among others, we note that all variables are skewed; this represents another motivation for employing the quantile regression approach to detect the effect of climate-related financial policies on CO₂ emissions in this paper.

The sample considered in our investigation includes G20 countries, except the European Union, which was excluded because of the unavailability of data for several variables considered in the analysis. The choice to focus on G20 countries is motivated by the fact that they represent the leading global economies and offer a broad sample of developed and developing countries. Furthermore, they are the most significant contributors to global carbon emissions.

The correlation matrix of the data presented in Table 3 shows a positive relationship between GDP and CO₂ emissions, population and GDP, fossil fuels consumption and

Variable	Abbreviation	Source
CO ₂ Emissions in metric tons in million	CO ₂	Hannah Ritchie and Max Roser (2020)
GDP (in billion current US-Dollar)	GDP	World Bank, World Development Indicators
Squared GDP (in billion current US-Dollar)	GDP ²	World Bank, World Development Indicators
Population, in million	Pop	World Bank, World Development Indicators
Regulatory quality	RQ	World Bank, World Governance Indicators
Long-term financial policies	LTFP	Individual Assessment, public available information from official sources
Short-term financial policies	STFP	Individual Assessment, public available information from official sources
Domestic credit to private sector (share of GDP)	Domcredit	World Bank, Global Financial Development Database
Chinn-Ito index	ChinnIto	Chinn and Ito (2010)
Bank Return On Assets (Percentages, After Tax)	ROA	World Bank, Global Financial Development Database
Fossil fuel consumption in TWH per capita	FFC	World Bank based on IEA Statistics

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

Variable	Mean	Std. Dev.	Min.	Max.	Skewness	Kurtosis	N
CO ₂ Emissions in metric tons in million	1244.389	1915.701	124.381	9599.007	2.81326	10.33977	342
GDP (in billion current US-Dollar)	2425.476	3426.546	97.724	19519.354	2.973936	11.94385	342
Squared GDP (in billion current US-Dollar)	1.76e+07	5.42e+07	9549	3.81e+08	4.339691	22.61093	342
Population, in million	221.536	367.277	19.153	1386.395	2.419018	7.239013	342
Long-term financial policies weighted by regulatory quality	0.698	1.727	-2.605	10.732	2.604342	11.9387	342
Short-term financial policies weighted by regulatory quality	0.068	0.408	-0.475	3.521	6.463013	48.43763	342
Domestic credit to private sector (share of GDP)	90.174	53.284	9.683	212.269	2269743	1.882335	312
Chinn-Ito index	0.835	1.43	-1.917	2.347	-3234056	1.607863	342
Bank Return On Assets (Percentages, After Tax)	0.984	1.07	-6.697	6.843	-860239	14.81627	342
Fossil fuel consumption in TWH per capita	35.463	23.907	3.221	94.873	.6237114	2.342099	342

Table 2.: Summary statistics of variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CO ₂ Emissions in metric tons in million	1.000									
GDP (in billion current US-Dollar)	0.764	1.000								
Squared GDP (in billion current US-Dollar)	0.677	0.950	1.000							
Population, in million	0.667	0.249	0.181	1.000						
Stock of long-term financial policies weighted by regulatory quality	-0.152	0.086	0.048	-0.253	1.000					
Stock of short-term financial policies weighted by regulatory quality	-0.081	-0.004	-0.039	-0.090	-0.067	1.000				
Domestic credit to private sector (share of GDP)	0.403	0.588	0.484	0.009	0.289	0.080	1.000			
Chinn-Ito index	-0.116	0.307	0.211	-0.472	0.410	0.183	0.396	1.000		
Bank Return On Assets (Percentages, After Tax)	-0.017	-0.131	-0.039	-0.014	-0.201	-0.078	-0.371	-0.298	1.000	
Fossil fuel consumption in TWH per capita	0.111	0.290	0.303	-0.365	0.230	0.022	0.378	0.513	0.016	1.000

Table 3.: Cross-correlation table of variables

CO₂ emissions. The outcomes also reveal positive co-movement of GDP and fossil fuels consumption and domestic credit to the private sector and GDP. A negative correlation is observed for both the long-term and short-term stock of policies and CO₂ emissions.

4.1. *Dependent variable*

As the dependent variable, we consider total CO₂ emissions (in million metric tons) deriving from fossil fuels' consumption, i.e., coal, natural gas, and oil and cement. Because CO₂ is reported to be the primary greenhouse gas responsible for global warming, we use it as an environmental degradation measure. We collected data from the "CO₂ and Greenhouse Gas Emissions" database, which uses data from Le Quéré et al. (2018) and provides the latest available data (2017) regarding CO₂ emissions at the G20 level.

The heterogeneity concerning the CO₂ distribution in our sample is shown in Figure 1, which allows us to visualize the countries that belong to the lowest and highest quantiles. Summary statistics reported in Table 2 show that the distribution of CO₂ emissions is positively skewed.

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

4.2. *Climate-related financial policies in the G20*

Using the taxonomy presented in Section 2.2, we surveyed official documents by central banks, financial supervisory authorities, governments, and banking associations and found 93 policies adopted by G20 countries, as described in Anonymized (2021). Consequently, our CRFP data constitutes a panel of 342 country-year observations (as we consider 19 countries over 18 years).

As shown in Figure 2 and Table 4, 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. In particular, our data show that a steady increase over time characterizes the adoption of CRFPs. The rationale for this is that, on the one hand, countries increasingly recognize that climate-related risks such as transition, liability, and physical risks may harm the financial system and financial stability in general; hence, central banks and financial regulators are considering how to integrate them into existing regulatory frameworks (Carney 2015; Thoma and Chenet 2016; Volz 2017; NGFS 2019; D’Orazio and Popoyan 2019). On the other hand, the financial sector’s role in enhancing a low carbon transition by providing adequate financial resources to scale up green finance has got increasing attention in the past decades (Wang and Zhi 2016; Sachs et al. 2019; Hafner et al. 2020).

According to our data, some G20 countries such as UK and France, have been engaged in green finance policymaking since the early 2000s, with the adoption of green finance principles and climate-related disclosure requirements for non-financial institutions, pension funds, and insurance companies². Indonesia stands as the earliest adopter of CRFPs; already in 1998, it started to require banks to conduct environmental impact assessments for large or high-risk loans (GoI 1998), while China and Brazil rise as the most engaged G20 countries in climate-related financial policymaking; at the end of 2017, they have both 11 policies. China adopted measures explicitly aimed at

²European Central Bank (ECB) is also showing a progressively increasing commitment to “greening the financial system” by announcing the goal to make climate change a “mission-critical” priority (FT 2020). Moreover, it emphasizes that banks lag on their climate-related and environmental risk disclosures, despite some improvement since 2019 (ECB 2020).

governance and risk management, such as the Green Credit Policy approved in 2007³. Moreover, it encourages climate-related stress testing (CRST) at the portfolio level since 2012 with the Green Credit Guidelines⁴. Brazil, instead, promotes sustainable development through lines of credit and programs since 2008. These policies aim to foster the population’s standards of living and environmental protection (Berchin et al. 2018). Other policies implemented in Brazil are Resolution 4.327/2014, which legally mandates that financial institutions develop and implement a social and environmental policy, and sustainability risk management and ESG disclosures. Moreover, the Brazilian central bank (BaCen) requires that financial institutions demonstrate how they are assessing the risk of exposure to socio-environmental damages in their assessment processes and in their calculation of the capital needed for dealing with risks⁵. Climate-related disclosure requirements for banks have been promoted by the Chinese macroprudential authority, the Indonesian central bank, Turkey’s and Mexico’s banking associations. Instead, climate-related disclosure requirements for non-financial institutions, pension funds, insurance companies, and ‘green’ finance principles and guidelines have been widely adopted in the past 20 years in most G20 countries. These measures aim not to be macroprudential but to create a financial market aligned with climate change concerns. Notably, China, which represents a very engaged country in green finance and financial regulation, is the only jurisdiction among the G20s that has adopted differentiated reserve requirements. Finally, we note that all countries except Saudi Arabia have developed green market-shaping policies and adopted disclosure requirements for non-financial firms, insurance companies or institutional investors.

Regarding credit allocation to priority and environmentally friendly sectors, such as green lending quotas and concessional loans, we found that they are adopted mainly by emerging economies, namely, Brazil, China, India, and Indonesia. Among developed countries, two exceptions are represented by Japan⁶ and South Korea⁷.

To account for lags between the date of adoption and the effects created by the policies, we aggregate the annual impact of climate-related financial policies in two different variables, i.e., the stock of short-term policies (STFP) and the stock of long-term policies (LTFP)⁸. The first refers to policies adopted between 2016 and 2017, while the latter refers to policies adopted between 2000 and 2015. Both variables are then multiplied by the time-varying World Governance Indicator for Regulatory Quality from the World Bank database (Kaufmann et al. 2011) to account for the role played by institutional governance. This allows us to model the evidence that financial policies that are implemented in countries with a higher ability to formulate and implement sound policies and regulation are more effective.

³It recommends banks to include environmental compliance and environmental risk assessment in the loan origination process (Wang et al. 2019; Xing et al. 2020).

⁴The Network for Greening the Financial Sector (NGFS) gave an additional impulse to this trend in 2019, leading several of its members to incorporate socially responsible investing in their portfolio management and reviewing their operations (NGFS 2017, 2019). The UK government and regulators, the Central Bank of the Netherlands, and the Banque de France, among others, have lately shown strong leadership in this area (Carney 2015; DNB 2017; Batten et al. 2016; Campiglio et al. 2018) and planned to conduct CRST in upcoming years.

⁵See Brazilian Circular on Internal Process of Capital Adequacy Assessment, No. 3,547/2011.

⁶In 2010, the Bank of Japan launched the Loan Supporting program consisting of concessional loans for priority sectors (i.e., environment and energy business).

⁷In 2017, the Shinhan Bank launched its ‘Green Management Firm Loan Program’ with the South Korean Ministry of Environment and KEITI, a UNEP FI Supporting Institution. The program aims at promoting Eco-friendly Small and Medium Enterprises, and loans are created with a lower interest rate.

⁸A similar approach has been developed in Eskander and Fankhauser (2020) to study the impact of national climate legislation on the reduction of GHG emissions.

Figure 2.: Stock of climate-related financial policies adopted by country at the end of 2017 (top graph). Number of climate-related financial policies adopted per year during 2000-2017 in G20 (bottom graph). Source: authors' elaboration on data retrieved from Anonymized (2021).

Country	Macroprudential regulations	Other disclosure requirements	Promotional credit measures	Green Financial Principles
Argentina				✓
Australia	GRM	✓		✓
Brazil	ICAAP	✓	✓	✓
Canada		✓		✓
China	GRM, CRST, DR, RR	✓	✓	✓
France	GRM	✓		✓
Germany		✓		✓
India		✓	✓	✓
Indonesia	GRM, DR	✓	✓	✓
Italy		✓		✓
Japan		✓	✓	✓
Mexico	GRM, DR			✓
Russian Federation		✓		✓
Saudi Arabia	GRM			
South Africa		✓		✓
South Korea		✓	✓	✓
Turkey				✓
United Kingdom	GRM, DR	✓		✓
United States of America		✓		✓

Table 4.: Type of policies adopted by country at the end of 2017. Legend: GRM: Governance and risk management, CRST: Climate-related stress test, DR: Disclosure requirements, RR: Reserve requirements. Source: authors' elaboration on data retrieved from Anonymized (2021).

4.3. Other variables

The statistical model is completed by a set of control variables on economic factors, financial development and financial stability. Regarding the former, GDP controls for the possibility of an environmental Kuznets curve (Stern 2004) and population controls for changes in the countries' structure that may affect the emissions profile (Meyerson 1998). Both variables are retrieved from the World Bank's World Development Indicators database. Summary statistics show that the sample is very heterogeneous concerning these variables. Differences in GDP are relatively high and similar to CO₂ emissions distribution; it shows a positive skewness and high kurtosis. Fossil fuel consumption (TWH per capita) data are retrieved from the World Bank database. This variable serves as an indicator of the economy's climate footprint since fossil energy consumption is a major source of environmental degradation as it contributes to polluting emissions (Meyerson 1998; Zhou and Feng 2017; Peters et al. 2020). The highest fossil fuel consumption can be observed in the US, Saudi-Arabia and Canada. In contrast, less advanced economies like Indonesia and India tend to consume fewer fossil fuels per capita. However, since energy consumption and economic growth alone may not explain CO₂ emissions, we need to consider other variables associated with carbon emissions. Therefore, we also include variables related to financial development, openness and efficiency.

Domestic credit to the private sector (as a share of GDP) is employed to account for the development of the financial industry; the higher the value of this indicator, the more mature the financial system. The choice to include domestic credit to the private sector is related to the evidence that economic development is a complex process that causes a structural change in the economy. In turn, a significant structural change that accompanies economic development is the financial sector's size and structure.

Return on assets (ROA) is considered to account for the banking system's profitability and efficiency, as ROA is a good proxy for the financial system's soundness. A high value indicates profitability and efficiency, as the banks' profits should reduce the extent of risk in the financial market; a low value indicates the banking sector's

fragility. Overall, a better-developed financial system is believed to increase economic efficiency (Fase and Abma 2003; Sahay et al. 2015) which in turn could be associated with environmental degradation.

Finally, to control the effects of financial openness, the Chinn-Ito Index (or Kaopen index) is used (Chinn and Ito 2010)⁹. It is one of the most commonly used indices in the literature (Ozturk and Acaravci 2013; You et al. 2015; Rasoulinezhad and Saboori 2018) and is constructed based on the data from the IMF Annual Report on Exchange Arrangements and Exchange Restrictions. It ranges between -2.66 (full capital controls) and 2.66 (complete liberalization).

5. Empirical results and discussions

5.1. *Diagnostics*

Before estimating the model, some standard preliminary tests are performed to ensure the time-series properties of the selected variables.

First, we check the stationary properties for all variables in this paper and the detailed results of the ADF test are reported in Table 5. The null hypothesis following an AR(1) or AR(3) process cannot be rejected in almost all cases in levels. Hence, regression results may be biased due to a spurious relationship. The use of first differences would solve this problem, but we note that the long-term relationship between the variables would be lost.

Second, to control if a spurious relationship biases the regression results, cointegration tests are applied. The Pedroni (2004), Kao (1999) and Westerlund (2007) cointegration test results are displayed in Table 6. In general, the test results provide robust support for cointegration. Therefore, the analysis considers data in levels.

Third, we check the existence of cross-sectional dependence (CD) within the panel, as it can distort the true parameter values of coefficient estimates. CD may arise due to unobserved common factors; if ignored, it can diminish panel data efficiency gains (Phillips and Sul 2003). To produce robust estimation, the Pesaran (2004) CD test is thus applied; results are reported in Table 7. The null hypothesis of strict cross-sectional independence is rejected for all variables, except for the financial openness index.

5.2. *Panel quantile regression results*

In this section, we discuss the estimation results of the model specification involving the MMQR. To facilitate comparison, we first estimate the model by OLS regression. Results (taking into account robust standard errors) are shown in Table 8 considering pooled (columns 3 and 6), fixed (columns 1 and 4) and random effect (columns 2 and 5)¹⁰. OLS results are also displayed in Figure 3 (see blue dotted lines). Overall, the signs and significance of the OLS-FE coefficients correspond to those observed in the MMQR. However, the OLS-FE describes only a partial picture of the empirical relationship between the variables, focusing on the mean effects.

⁹In line with existing literature, we note that the omission of financial openness from the carbon emissions model could result in possible biased and misleading empirical results. However, we also note that the research on financial openness and its effects on CO₂ emissions is more recent and still in its infancy.

¹⁰Columns 4, 5 and 6 refer to specifications involving regulatory quality directly in the regression. This specification is used as a robustness check, as discussed in Section 5.4.

Variable	time-lag	Levels			number of observations	1st Differences		
		inverse	normal Z statistic	p-value for Z statistic		inverse	normal Z statistic	p-value for Z statistic
CO ₂	lags(1)	2.629		0.996	342	-8.497		0
	lags(3)	0.918		0.821	342	-2.378		0.00871
Domcred	lags(1)	-1.383		0.0833	312	-6.103		5.20e-10
	lags(3)	-0.541		0.294	312	-1.871		0.0307
FFC	lags(1)	2.158		0.985	342	-7.335		0
	lags(3)	0.955		0.830	342	-1.777		0.0378
ChinnIto	lags(1)	-0.154		0.439	342	-4.379		5.96e-06
	lags(3)	1.476		0.930	342	-0.506		0.306
GDP	lags(1)	0.835		0.798	342	-7.619		0
	lags(3)	-0.154		0.439	342	-2.483		0.00652
Pop	lags(1)	1.528		0.937	342	-4.665		1.54e-06
	lags(3)	0.713		0.762	342	0.246		0.597
ROA	lags(1)	-5.075		1.94e-07	342	-11.61		0
	lags(3)	-3.523		0.000213	342	-6.206		2.71e-10
STFP	lags(1)	2.942		0.998	342	-8.370		0
	lags(3)	2.979		0.999	342	-7.505		0
LTFP	lags(1)	-1.050		0.147	342	-2.967		0.00151
	lags(3)	-1.607		0.0541	342	-2.896		0.00189
TFP	lags(1)	3.896		1.000	342	-5.434		2.76e-08
	lags(3)	4.635		1.000	342	-3.099		0.000969

Table 5.: Dickey-Fuller test results

Test		Test Statistic	p-value
Pedroni	Modified Phillips-Perron	2.8730	0.0020
	Phillips-Perron	-7.6372	0.0000
	Augmented Dickey-Fuller	-7.5883	0.0000
Kao	Modified Dickey-Fuller	-0.2299	0.4091
	Dickey-Fuller	-2.4571	0.0070
	Augmented Dickey-Fuller	-2.2044	0.0137
	Unadjusted modified Dickey-Fuller	1.2270	0.1099
	Unadjusted Dickey-Fuller	-1.5580	0.0596
Westerlund	Variance ratio	-1.3727	0.0849

Table 6.: Co-integration test results

Variable	CD-test	p-value	average joint T	mean ρ	mean abs(ρ)
CO ₂ Emissions in metric tons in million	4.439	0.000	18.00	0.08	0.74
GDP (in billion current US-Dollar)	46.162	0.000	18.00	0.83	0.83
Squared GDP (in billion current US-Dollar)	43.251	0.000	18.00	0.78	0.78
Population, in million	32.83	0.000	18.00	0.59	0.81
Stock of long-term financial policies weighted by regulatory quality	6.075	0.000	18.00	0.11	0.53
Stock of short-term financial policies weighted by regulatory quality	2.718	0.007	18.00	0.05	0.43
Domestic credit to private sector (share of GDP)	13.079	0.000	15.14	0.26	0.60
Chinn-Ito index	0.081	0.936	18.00	0.00	0.07
Bank Return On Assets (Percentages, After Tax)	7.368	0.000	18.00	0.13	0.29
Fossil fuel consumption in TWH per capita	1.825	0.068	18.00	0.03	0.69

Table 7.: Cross-sectional dependence

By adopting the MMQR approach, the results provide a detailed description throughout the conditional distribution, especially in the countries with the most and least emissions. Moreover, we distinguish between the effects of the stock of recent (short-term) and older (long-term) climate-related financial policies. The MMQR estimation results are reported for the 10th, 20th, 30th, 40th, 50th, 60th, 70th, 80th, and 90th percentiles of the conditional CO₂ emissions distribution. The lower quantiles include Argentina, Turkey, Australia, Brazil, France, Indonesia, Italy, South Africa. The higher quantiles refer to countries with higher CO₂ emissions, such as Germany, Japan, the Russian Federation, India, the United States and China (See Figure 1 for more insights on the CO₂ distribution).

The quantile regression results based on Equation 5 are shown in Table 9. Figure 3 shows the coefficients across all quantiles and the corresponding 95% confidence interval for all independent variables. Overall, the empirical results illustrate that the impact of the different variables included in the analysis is heterogeneous and indicate several important findings. First, they suggest that adopting a CRFP has an overall statistically significant negative effect on CO₂ emissions, over both the short and the long term (see Table 9), thus implying that implementing climate-related financial policies improves the environmental quality in these countries. This result is a relevant contribution to the existing literature as it emphasizes the existence of a significant relationship between CO₂ emissions and climate-related financial policies for the first time. The impact of long-term financial policies on CO₂ emissions is significantly negative (at 1% level) in all quantiles, while different effects are observed for short-term policies. For example, at the 10th quantile, the coefficient of STFP is negative but insignificant, indicating that these policies do not affect the environmental quality in countries with lower emissions. The rationale for this is that the majority of the countries which are located at the bottom of the CO₂ distribution adopted the bulk of the CRFPs before 2015. Indeed, as discussed in Section 4.2, in countries like Australia, Brazil, France, and Indonesia, the adoption of CRFPs dates back to the early 2000s (see also the evidence reported in Figures 2 and A2). Additionally, we observe that for STFPs, their impact decreases in magnitude as we move from lower to higher quantiles of the distribution. The rationale for this is to be found in the type of policies adopted. In the short term (i.e., the period 2016-2017 in our analysis), the majority of the countries located at the top of the distribution have adopted only “soft” measures, such as “green finance principles” that are usually not binding for financial institutions, or disclosure requirements aimed at companies or non-financial institutions. Interestingly, when considering LTFPs, we note instead that their impact increases when moving from lower to higher emission countries. Also in this case the effect can be explained by combining the information on the total stock of policies and type. Specifically (1) the countries located at the top of the distribution adopted the bulk of the policies before 2015, and (2) they adopted mandatory prudential requirements and/or promotional credit measures, which contributed to improving environmental quality in these countries characterized by higher emissions.

Second, the effect of our indicator for financial development, i.e., domestic credit to the private sector, on CO₂ emissions is negative across all quantiles at a 1% significance level. This result confirms that an increase in private credit contributes to improving environmental quality and is in line with a stream of the literature that points to a positive role played by financial development in decreasing environmental degradation. Indeed, as extensively discussed in Section 2, existing literature explains that financial development amplifies investments in modern technology that may reduce carbon emissions (see Shahbaz et al. 2016; Zaidi et al. 2019; Zafar et al. 2019, among oth-

ers). Moreover, we argue that our findings on financial development are related to the overall climate-related financial landscape, i.e., green finance and policy developments characterizing G20s. As discussed in previous sections, our investigation of CRFPs reveals a major commitment to promoting sustainability and ecological investments in the past decades, which in turn “feeds-in” the overall financial development. Finally, we note the impact of financial development increases as we move towards the top of the distribution. This result is consistent with the evidence that more mature financial systems characterize these countries; this encourages green technology progress and hence alleviates CO₂ emissions.

Third, regarding financial openness, negative signs characterize all quantiles, thus confirming the hypothesis that an improvement in financial infrastructure (based on the openness of capital account) may contribute to the efficient technological use and, therefore, affect the environmental degradation as well (Tamazian et al. 2009; Tamazian and Rao 2010; Jalil and Feridun 2011; You et al. 2015). However, heterogeneous effects are observed with respect to the coefficients for the 10th, 20th and 90th quantiles that are not significant. On the one hand this implies that the degree of financial openness of a country is associated with environmental degradation. On the other hand, this is not observed in countries with the highest and lowest emissions. Moreover, we note that significant coefficients are found in quantiles mainly referring to high- and upper-middle-income countries.

Fourth, regarding the indicator for financial soundness, i.e., bank return on assets, statistically significant results cannot be reported for all quantiles. Therefore, our analysis cannot support the hypothesis that a financially sound banking system is associated with environmental degradation (Kim et al. 2020).

Fifth, the estimated coefficients on GDP are positive and significant for all quantiles and all specifications. Moreover, the squared term - that is introduced to capture the non-linear effects of economic growth on carbon emissions - is negative, proving the EKC’s existence, as discussed in Section 2. Regarding population, the estimated coefficients are positive and statistically significant for all quantiles - except the 10th quantile. The levels of significance vary across quantiles and are higher in the middle of the distribution. This result suggests that a larger population size could harm the environment’s quality and aligns with existing empirical evidence provided by Sadorsky (2014); Yeh and Liao (2017); Dong et al. (2018).

Finally, regarding the effects of fossil fuel consumption, the estimated coefficients show a positive effect (at 5% and 1% level) on CO₂ emissions. This confirms the evidence that CO₂ emissions increase due to primary energy consumption (Acaravci and Ozturk 2010; Pao and Tsai 2011; Sheraz et al. 2021). Moreover, the observed impact is larger for lower quantiles and progressively decreases as we move towards higher quantiles.

Figure 3.: Method of Moments Panel Quantile Regression results

5.3. Direct, indirect and total effect

Studying the direct and indirect influence mechanisms discussed in Section 5.3 allows us to prevent over- or under-estimating the real effects of climate-related financial policies on CO₂ emissions. The regression results of the Equations 6 and 7 are reported in Table 10. They show statistically significant coefficients of GDP and GDP², thus confirming the existence of EKC.

The results of this analysis are reported in Figure 4 and Tables 11 and 12, which demonstrate that both short-term and long-term financial policies *directly* affect emissions negatively at different levels of the distribution, implying an improvement of the environmental quality as discussed in Section 5.2. The magnitude of the LTFPs effect increases by moving from lower to higher quantiles, confirming the effects presented above. Regarding STFPs, results reported in Table 11 show that they have a larger *direct* impact on lower quantiles.

Considering the *indirect* effect, heterogeneity is observed among quantiles, as shown in Figure 4 (green lines). For LTFPs, negative coefficients are observed for higher quantiles, confirming their role in improving environmental quality in higher emission countries. Positive coefficients characterize instead lower quantiles, implying that these policies could worsen environmental quality in countries located at the bottom of the distribution. This evidence calls for increased attention to the type and the amount of climate-related financial policies implemented in these countries. For STFPs, the *indirect* effect is negative only in the 10th percentile and positive for all higher quantiles, implying an undesired worsening of these countries' environmental quality.

Overall, the total effect of policies is negative across all quantiles, for both short-

	(1) FE	(2) RE	(3) OLS	(4) FE	(5) RE	(6) OLS
GDP (in billion current US-Dollar)	0.747*** (0.197)	0.738*** (0.181)	0.775*** (0.0672)	0.771*** (0.213)	0.770*** (0.198)	0.781*** (0.0648)
Squared GDP (in billion current US-Dollar)	-0.0000248*** (0.00000708)	-0.0000245*** (0.00000677)	-0.0000248*** (0.00000351)	-0.0000255*** (0.00000760)	-0.0000256*** (0.00000729)	-0.0000252*** (0.00000342)
Population, in million	2.050 (1.886)	2.462** (1.182)	2.014*** (0.239)	2.446 (1.948)	2.695** (1.136)	1.996*** (0.237)
Long-term financial policies weighted by regulatory quality	-75.83*** (23.96)	-75.33*** (22.73)	-53.95*** (16.22)			
Short-term financial policies weighted by regulatory quality	-122.8** (49.94)	-121.0*** (45.11)	-70.63 (47.55)			
Domestic credit to private sector (share of GDP)	-7.322* (4.088)	-6.801* (3.809)	-0.849 (0.787)	-6.621 (3.937)	-6.346* (3.762)	-0.155 (1.139)
Chinn-Ito index	-90.90 (69.93)	-104.5 (71.19)	-411.7*** (47.52)	-121.4 (72.62)	-136.7* (72.65)	-391.9*** (53.37)
Bank Return On Assets (Percentages, After Tax)	-5.628 (34.59)	-4.187 (34.74)	46.31 (36.80)	-16.60 (32.63)	-13.39 (32.46)	47.88 (34.32)
Fossil fuel consumption in TWH per capita	21.64 (13.79)	21.32* (11.27)	20.65*** (1.598)	27.04 (15.89)	24.99** (12.18)	21.19*** (1.746)
Long-term financial policies				-50.29*** (13.77)	-50.09*** (12.81)	-17.77 (24.95)
Short-term financial policies				-74.01 (56.48)	-75.67 (54.78)	72.42 (73.23)
Regulatory Quality (Estimate)				72.14 (186.1)	38.22 (164.0)	-157.5* (82.90)
Constant	-578.1 (639.3)	-682.5 (471.6)	-991.0*** (117.7)	-985.5 (700.8)	-945.7* (491.6)	-1029.9*** (122.4)
Number of observations	312	312	312	312	312	312
R-squared	0.790	0.790	0.894	0.781	0.780	0.894
P-value of F-statistics	0.00627	0.0000142	1.62e-149	0.0000254	2.06e-22	1.67e-149

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8.: Climate-related financial policies and their effects on CO₂ emissions: OLS estimation results

	(1) 1	(2) 2	(3) 3	(4) 4	(5) 5	(6) 6	(7) 7	(8) 8	(9) 9
GDP (in billion current US-Dollar)	0.858*** (0.152)	0.817*** (0.112)	0.795*** (0.0940)	0.774*** (0.0786)	0.749*** (0.0655)	0.729*** (0.0621)	0.709*** (0.0663)	0.688*** (0.0768)	0.669*** (0.0898)
Squared GDP (in billion current US-Dollar)	-0.0000274*** (0.00000537)	-0.0000264*** (0.00000397)	-0.0000260*** (0.00000332)	-0.0000255*** (0.00000276)	-0.0000249*** (0.00000230)	-0.0000244*** (0.00000218)	-0.0000239*** (0.00000233)	-0.0000234*** (0.00000271)	-0.0000230*** (0.00000318)
Population, in million	2.342 (1.579)	2.232* (1.164)	2.176** (0.972)	2.121*** (0.807)	2.053*** (0.668)	2.001*** (0.635)	1.948*** (0.680)	1.893** (0.796)	1.844** (0.937)
Long-term financial policies weighted by regulatory quality	-94.76*** (30.94)	-87.66*** (22.88)	-84.02*** (19.11)	-80.42*** (15.92)	-76.03*** (13.23)	-72.69*** (12.56)	-69.22*** (13.43)	-65.66*** (15.62)	-62.49*** (18.35)
Short-term financial policies weighted by regulatory quality	-77.81 (71.49)	-94.67* (52.73)	-103.3** (44.00)	-111.8*** (36.57)	-122.3*** (30.31)	-130.2*** (28.80)	-138.4*** (30.83)	-146.9*** (36.01)	-154.4*** (42.41)
Domestic credit to private sector (share of GDP)	-9.542*** (3.652)	-8.709*** (2.701)	-8.283*** (2.256)	-7.861*** (1.879)	-7.346*** (1.562)	-6.954*** (1.483)	-6.548*** (1.585)	-6.130*** (1.844)	-5.759*** (2.165)
Chinn-Ito index	-102.3 (89.33)	-98.02 (65.91)	-95.83* (55.02)	-93.67** (45.71)	-91.02** (37.87)	-89.01** (36.02)	-86.92** (38.54)	-84.77* (45.03)	-82.86 (52.99)
Bank Return On Assets (Percentages, After Tax)	1.713 (43.85)	-1.041 (32.34)	-2.451 (27.00)	-3.845 (22.43)	-5.549 (18.58)	-6.845 (17.67)	-8.189 (18.91)	-9.569 (22.10)	-10.80 (26.01)
Fossil fuel consumption in TWH per capita	27.04** (10.72)	25.01*** (7.919)	23.97*** (6.612)	22.95*** (5.500)	21.70*** (4.563)	20.74*** (4.336)	19.75*** (4.638)	18.74*** (5.408)	17.84*** (6.360)
N	312	312	312	312	312	312	312	312	312

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9.: Climate-related financial policies and their effects on CO₂ emissions: panel quantile regression results.

and long-term policies, as shown in Figure 4 (blue lines), confirming that these policies have an impact on environmental quality.

Dependent variable:	(1) CO ₂ emissions	(2) GDP
GDP (in billion current US-Dollar)	0.747*** (0.0356)	
Squared GDP (in billion current US-Dollar)	-0.0000248*** (0.00000169)	
Domestic credit to private sector (share of GDP)	-7.322*** (1.390)	
Chinn-Ito index	-90.90** (40.37)	
Bank Return On Assets (Percentages, After Tax)	-5.628 (20.92)	
Fossil fuel consumption in TWH per capita	21.64*** (4.872)	
Population, in million	2.050** (0.822)	0.597 (0.608)
Long-term financial policies weighted by regulatory quality	-75.83*** (14.09)	-18.73* (9.758)
Short-term financial policies weighted by regulatory quality	-122.8*** (44.64)	-30.94 (30.47)
Inflation		1.505 (2.794)
Gross capital formation (percent of GDP)		15.31*** (4.659)
GDP (in billion current US-Dollar)(t-1)		1.009*** (0.0119)
Constant	-578.1** (242.7)	-418.1*** (151.5)
N	312	324
R-squared	0.790	0.971

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10.: The regression results of the CO₂ and GDP equations (Eqs. 6 and 7, respectively)

Figure 4.: The direct, indirect and total effect of short term (left plot) and long term (right plot) CRFPs on the CO₂ distribution

Quantile	Total effect	Direct effect	Indirect effect
1	-80.92704	-77.81095	-3.116089
2	-84.41449	-94.67371	10.25922
3	-96.91357	-103.3075	6.393929
4	-103.0959	-111.8441	8.748146
5	-109.9328	-122.2746	12.34183
6	-116.9494	-130.2092	13.25974
7	-122.218	-138.4381	16.22008
8	-133.3991	-146.8899	13.4908
9	-142.285	-154.4163	12.13132

Table 11.: Direct, indirect and total effect of short-term policies

Quantile	Total effect	Direct effect	Indirect effect
1	-66.21326	-94.76025	28.54699
2	-68.00264	-87.6566	19.65396
3	-69.73299	-84.01952	14.28652
4	-70.8371	-80.42339	9.586281
5	-71.92606	-76.02938	4.103325
6	-72.93642	-72.68686	-.2495651
7	-73.72478	-69.22034	-4.504448
8	-74.95133	-65.65988	-9.291451
9	-75.99686	-62.48929	-13.50758

Table 12.: Direct, indirect and total effect of long-term policies

5.4. *Alternative model specifications*

To gain further insights into our research question, we run three additional specifications of the model. Specification I does not consider regulatory quality in implementing long-run and short-run policies; rather, regulatory quality enters the regression directly as an explanatory variable. These results are shown in Table 13. Specifications II and III exclude the recent and older stock of policies and consider the cumulated stock instead, i.e., the total stock of policies over 2000-2017, without any distinction between the long- and short-term. Moreover, the specifications distinguish the consideration (Specification II) or exclusion (Specification III) of the implementation's regulatory quality. Results are reported in Tables 15 and 14 respectively.

Overall, the results from these various alternative specifications largely support the findings discussed in Section 5.2. The effect of LTFP, STFP and cumulated policies are negative and heterogeneous across different quantiles in the conditional distribution of CO₂ emissions. However, in Specifications I and III (excluding the implementation's regulatory quality in the interaction term), significant effects are observed only for higher quantiles, namely the 60th, 70th and 80th for LTFP and 60th, 70th, 80th, 90th for STFP. Regarding the effects of the cumulated policies, they are also found to improve environmental quality across all quantiles. In Specification II, the coefficients are not significant for countries located at the bottom of the distribution, i.e., those with lower emissions. This is consistent with the result discussed in Section 5.2. Our finding shows that domestic credit to the private sector is statistically significant at almost all quantiles across all specifications and has a negative impact on CO₂ emissions. Coefficients for other control variables are similar to the results reported above and do not seem to be sensitive to a particular estimation procedure or alternative measures

of climate-related policies. Thus, we conclude that the results reported in this paper are robust.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	1	2	3	4	5	6	7	8	9
GDP (in billion current US-Dollar)	0.854*** (0.302)	0.827*** (0.238)	0.806*** (0.190)	0.788*** (0.149)	0.774*** (0.121)	0.755*** (0.0910)	0.741*** (0.0809)	0.724*** (0.0877)	0.710*** (0.107)
Squared GDP (in billion current US-Dollar)	-0.0000270** (0.0000107)	-0.0000265*** (0.00000845)	-0.0000261*** (0.00000675)	-0.0000258*** (0.00000528)	-0.0000255*** (0.00000430)	-0.0000252*** (0.00000323)	-0.0000249*** (0.00000287)	-0.0000246*** (0.00000311)	-0.0000243*** (0.00000381)
Population, in million	2.879 (2.947)	2.738 (2.320)	2.630 (1.853)	2.532* (1.449)	2.460** (1.178)	2.359*** (0.883)	2.286*** (0.784)	2.198*** (0.852)	2.123** (1.044)
Long-term financial policies	-61.45 (62.74)	-57.83 (49.39)	-55.05 (39.45)	-52.52* (30.86)	-50.65** (25.10)	-48.06** (18.84)	-46.18*** (16.74)	-43.92** (18.17)	-41.98* (22.25)
Short-term financial policies	-27.82 (143.0)	-42.80 (112.6)	-54.31 (89.90)	-64.79 (70.33)	-72.51 (57.19)	-83.21* (42.92)	-91.00** (38.12)	-100.4** (41.38)	-108.4** (50.70)
Regulatory Quality (Estimate)	296.7 (524.9)	223.9 (413.3)	167.9 (330.1)	117.0 (258.4)	79.46 (210.2)	27.44 (158.1)	-10.42 (140.4)	-55.91 (152.2)	-94.96 (186.3)
Domestic credit to private sector (share of GDP)	-7.128 (6.871)	-6.964 (5.409)	-6.837 (4.319)	-6.723** (3.379)	-6.638** (2.747)	-6.521*** (2.062)	-6.435*** (1.832)	-6.333*** (1.989)	-6.244** (2.436)
Chinn-Ito index	-155.8 (173.9)	-144.7 (137.0)	-136.1 (109.4)	-128.3 (85.56)	-122.6* (69.59)	-114.6** (52.25)	-108.8** (46.43)	-101.8** (50.40)	-95.84 (61.70)
Bank Return On Assets (Percentages, After Tax)	-11.66 (85.94)	-13.26 (67.66)	-14.49 (54.02)	-15.61 (42.25)	-16.44 (34.35)	-17.59 (25.77)	-18.42 (22.89)	-19.42 (24.87)	-20.28 (30.46)
Fossil fuel consumption in TWH per capita	30.57 (22.19)	29.43* (17.47)	28.55** (13.95)	27.75** (10.91)	27.16*** (8.876)	26.34*** (6.662)	25.74*** (5.919)	25.03*** (6.426)	24.41*** (7.869)
N	312	312	312	312	312	312	312	312	312

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 13.: Robustness analysis: long-term stock & short-term stock of policies

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	1	2	3	4	5	6	7	8	9
GDP (in billion current US-Dollar)	0.833*** (0.211)	0.815*** (0.163)	0.803*** (0.132)	0.793*** (0.107)	0.780*** (0.0829)	0.770*** (0.0719)	0.760*** (0.0718)	0.752*** (0.0796)	0.742*** (0.0974)
Squared GDP (in billion current US-Dollar)	-0.0000259*** (0.00000745)	-0.0000257*** (0.00000574)	-0.0000256*** (0.00000466)	-0.0000255*** (0.00000378)	-0.0000254*** (0.00000292)	-0.0000254*** (0.00000253)	-0.0000253*** (0.00000253)	-0.0000252*** (0.00000281)	-0.0000251*** (0.00000344)
Population, in million	3.828* (2.243)	3.457** (1.730)	3.208** (1.403)	2.989*** (1.140)	2.724*** (0.880)	2.521*** (0.763)	2.301*** (0.761)	2.140** (0.847)	1.928* (1.037)
Cumulated total financial policies	-50.04 (38.62)	-49.58* (29.79)	-49.26** (24.17)	-48.99** (19.61)	-48.66*** (15.13)	-48.41*** (13.11)	-48.13*** (13.11)	-47.93*** (14.58)	-47.66*** (17.85)
Regulatory Quality (Estimate)	341.2 (362.4)	260.5 (279.9)	206.3 (227.0)	158.6 (184.8)	101.0 (143.3)	56.75 (124.2)	9.055 (123.7)	-26.13 (137.0)	-72.27 (167.9)
Domestic credit to private sector (share of GDP)	-6.429 (4.656)	-6.183* (3.592)	-6.018** (2.914)	-5.872** (2.366)	-5.697*** (1.826)	-5.562*** (1.583)	-5.416*** (1.582)	-5.309*** (1.759)	-5.168** (2.152)
Chinn-Ito index	-199.5* (118.3)	-176.5* (91.38)	-161.1** (74.12)	-147.5** (60.33)	-131.2*** (46.77)	-118.6*** (40.56)	-105.0*** (40.40)	-94.97** (44.75)	-81.84 (54.80)
Bank Return On Assets (Percentages, After Tax)	-16.16 (57.18)	-16.67 (44.10)	-17.01 (35.78)	-17.31 (29.03)	-17.68 (22.39)	-17.96 (19.41)	-18.26 (19.41)	-18.48 (21.59)	-18.77 (26.42)
Fossil fuel consumption in TWH per capita	31.14** (15.26)	29.17** (11.78)	27.84*** (9.553)	26.68*** (7.763)	25.27*** (6.003)	24.19*** (5.205)	23.03*** (5.195)	22.17*** (5.766)	21.05*** (7.058)
N	312	312	312	312	312	312	312	312	312

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 14.: Robustness analysis: cumulated stock of policies

6. Conclusions and policy implications

This paper aims to study the effects of financial and economic development, energy consumption, and climate-related financial policies on CO₂ emissions in G20 countries. This analysis is relevant because the devastating consequences of environmental degradation on humanity and economic systems represent a pressing issue for governments and societies. Indeed, according to the latest IPCC (2018) report, G20 countries need to cut their current emissions by at least 45% in 2030 (below 2010 levels) to be in line with global benchmarks set on 1.5°C. Against this backdrop, in the past two decades, G20 countries have implemented a wide range of policy instruments, including different climate-related financial policies, to affect climate change and achieve effective mitigation results.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	1	2	3	4	5	6	7	8	9
GDP (in billion current US-Dollar)	0.825*** (0.151)	0.794*** (0.118)	0.769*** (0.0935)	0.753*** (0.0799)	0.731*** (0.0669)	0.713*** (0.0629)	0.692*** (0.0672)	0.674*** (0.0773)	0.659*** (0.0896)
Squared GDP (in billion current US-Dollar)	-0.0000259*** (0.00000548)	-0.0000252*** (0.00000426)	-0.0000247*** (0.00000337)	-0.0000244*** (0.00000288)	-0.0000239*** (0.00000239)	-0.0000236*** (0.00000225)	-0.0000232*** (0.00000241)	-0.0000228*** (0.00000279)	-0.0000225*** (0.00000324)
Population, in million	2.625* (1.590)	2.496** (1.232)	2.394** (0.977)	2.327*** (0.831)	2.236*** (0.689)	2.164*** (0.647)	2.078*** (0.696)	2.005** (0.809)	1.942** (0.940)
Cumulated total financial policies weighted by regulatory quality	-59.69** (25.88)	-54.79*** (20.11)	-50.94*** (15.94)	-48.39*** (13.60)	-44.92*** (11.33)	-42.22*** (10.65)	-38.95*** (11.41)	-36.16*** (13.20)	-33.78** (15.31)
Domestic credit to private sector (share of GDP)	-8.931** (3.718)	-8.318*** (2.888)	-7.835*** (2.290)	-7.515*** (1.953)	-7.082*** (1.625)	-6.743*** (1.528)	-6.333*** (1.638)	-5.985*** (1.895)	-5.686*** (2.199)
Chinn-Ito index	-69.07 (94.17)	-68.98 (73.02)	-68.92 (57.89)	-68.88 (49.28)	-68.82* (40.87)	-68.78* (38.40)	-68.72* (41.27)	-68.68 (47.94)	-68.64 (55.69)
Bank Return On Assets (Percentages, After Tax)	13.40 (46.59)	8.809 (36.14)	5.190 (28.65)	2.798 (24.39)	-0.454 (20.25)	-2.987 (19.02)	-6.063 (20.43)	-8.674 (23.72)	-10.91 (27.55)
Fossil fuel consumption in TWH per capita	26.70** (11.26)	25.08*** (8.741)	23.81*** (6.929)	22.97*** (5.904)	21.82*** (4.907)	20.93*** (4.611)	19.84*** (4.948)	18.92*** (5.736)	18.14*** (6.661)
N	312	312	312	312	312	312	312	312	312

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 15.: Robustness analysis: cumulated stock of policies, accounting for regulatory quality

By focusing on the climate-related financial policies landscape developed between 2000 and 2017, we investigated the determinants of carbon emissions in G20 countries throughout its conditional distribution through the panel quantile regression approach. This method takes the unobserved individual heterogeneity and distributional heterogeneity into consideration. Furthermore, compared with OLS mean regression, the MMQR approach used in the paper allows us to obtain a complete understanding of the factors that affect our sample's carbon emissions distribution.

The empirical results indicate that the impacts of various factors on carbon emission are heterogeneous. First, we find that the implementation of CRFPs reduces CO₂ emissions. This result represents a relevant contribution to the existing literature as it emphasizes the existence of a significant relationship between CO₂ emissions and climate-related financial policies for the first time. Evidence is provided for recently implemented measures (i.e., those adopted in 2016 and 2017) and policies adopted before 2016. The analysis shows that the older stock of policies has a larger impact on emissions in high emission countries, i.e., those located at the top of the distribution. Regarding more recent policies, they have larger effects on the reduction of CO₂ emission in countries in the lower rather than upper quantiles. However, they do not affect the environmental quality in countries located at the 10th quantile, as the coefficient is not significant. Second, in line with existing literature, we find that financial development contributes to improving environmental quality and its impact increases by moving from lower to higher emission countries. Third, further heterogeneity is observed regarding financial openness. We note that the degree of financial openness of a country is associated with environmental degradation, but this is not observed in countries with the highest and lowest emissions. Fourth, our analysis does not support the hypothesis that a financially sound banking system - as proxied by the ROA - is associated with environmental degradation. Finally, our results confirm existing literature regarding the impact of the level of GDP, population and fossil fuel consumption on environmental degradation and the existence of the EKC relationship.

These results are generally robust for alternative model specifications and by considering the direct and indirect effect mechanism. Interestingly, we find that, on the one hand, climate-related financial policies, both long-term and short term have a negative direct (and total) impact on CO₂ emissions, thus improving environmental quality. On the other hand, we observe possible positive indirect effects that might imply a worsening of the environmental quality. This positive effect is observed for high emission countries in the presence of short-term policies and low-emission countries in

the presence of long-term policies.

Based on these empirical results, several important conclusions can be drawn. First, building on the evidence that climate-related financial policies can play a role in the mitigation strategy of G20 countries, they should be more actively promoted at the global level. Second, our study suggests that countries should not also increase the number of measures implemented in this policy area but also aim for specific types of measures to witness improvements in environmental quality. Indeed, our investigation shows that the policies' impact on environmental quality has been larger for quantiles characterized by countries adopting mandatory prudential measures and credit allocation policies. Moreover, this effect has been observed for the older stock of policies. Policies implemented more recently are mostly aimed at defining criteria and guidelines for green banking rather than actively mobilizing green finance; this might explain the smaller impact on CO₂ emissions. Third, in our view, the evidence that shows no role - or a smaller role - of CRFPs in the bottom of the CO₂ distribution points to the need for a greater engagement of lower emission countries, such as Argentina, Turkey, Australia, in climate-related financial policymaking to achieve their mitigation objectives.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Conceptualization: PD; Methodology: PD, MD; Formal analysis and investigation: PD, MD; Writing - original draft preparation: PD, MD; Writing - review and editing: PD, MD; Software: MD; Supervision: PD; All authors read and approved the final manuscript.

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References

- Acaravci, A. and I. Ozturk (2010). On the relationship between energy consumption, co2 emissions and economic growth in europe. *Energy* 35(12), 5412–5420.
- Acheampong, A. O. (2019). Modelling for insight: does financial development improve environmental quality? *Energy Economics* 83, 156–179.
- Adams, S. and A. O. Acheampong (2019). Reducing carbon emissions: the role of renewable energy and democracy. *Journal of Cleaner Production* 240, 118245.
- Al-Mulali, U., C. N. B. C. Sab, and H. G. Fereidouni (2012). Exploring the bi-directional long run relationship between urbanization, energy consumption, and carbon dioxide emission. *Energy* 46(1), 156–167.
- Alkhathlan, K. and M. Javid (2013). Energy consumption, carbon emissions and economic growth in saudi arabia: An aggregate and disaggregate analysis. *Energy Policy* 62, 1525–1532.
- Amel-Zadeh, A. and G. Serafeim (2018). Why and how investors use esg information: Evidence from a global survey. *Financial Analysts Journal* 74(3), 87–103.
- Ameli, N., P. Drummond, A. Bisaro, M. Grubb, and H. Chenet (2019). Climate finance and disclosure for institutional investors: why transparency is not enough. *Climatic Change*, 1–25.
- Anonymized (2021). Climate-related financial policymaking in the g20: a panel dataset. *Data in Brief* In press.
- Apergis, N. and I. Ozturk (2015). Testing environmental kuznets curve hypothesis in asian countries. *Ecological Indicators* 52, 16–22.
- Apergis, N. and J. E. Payne (2010). The emissions, energy consumption, and growth nexus: evidence from the commonwealth of independent states. *Energy policy* 38(1), 650–655.
- Batten, S., R. Sowerbutts, and M. Tanaka (2016). Let’s talk about the weather: the impact of climate change on central banks. Technical report, Bank of England.
- Berchin, I. I., S. A. Da Silva, P. Bocquillon, V. H. Fornasari, L. P. C. Ribeiro, J. M. P. Ribeiro, J. B. S. O. de Andrade, et al. (2018). Contributions of public policies to greening sugarcane ethanol production in brazil. In *Towards a Sustainable Bioeconomy: Principles, Challenges and Perspectives*, pp. 375–393. Springer.
- Bhaskaran, R. K., I. W. K. Ting, S. K. Sukumaran, and S. D. Sumod (2020). Environmental, social and governance initiatives and wealth creation for firms: An empirical examination. *Managerial and Decision Economics*.
- Boermans, M. A. and R. Galema (2019). Are pension funds actively decarbonizing their portfolios? *Ecological economics* 161, 50–60.
- Buchner, B. K., P. Oliver, X. Wang, C. Carswell, C. Meattle, and F. Mazza (2017). Global landscape of climate finance 2017. Technical report, Climate Policy Initiative.
- Campiglio, E. (2016). Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low-carbon economy. *Ecological Economics* 121, 220 – 230.
- Campiglio, E., Y. Dafermos, P. Monnin, J. Ryan-Collins, G. Schotten, and M. Tanaka (2018). Climate change challenges for central banks and financial regulators. *Nature Climate Change* 8(6), 462.
- Carney, M. (2015). Breaking the tragedy of the horizon - climate change and financial stability (speech). *Bank of England, Speech*.
- Chenet, H., J. Ryan-Collins, and F. van Lerven (2021). Finance, climate-change and radical uncertainty: Towards a precautionary approach to financial policy. *Ecological Economics* 183, 106957.
- Chinn, M. D. and H. Ito (2010). The chinn-ito index. *A de jure measure of financial openness*. Online version http://web.pdx.edu/~ito/Chinn-Ito_website.htm, 243–76.
- Claessens, S. and E. Feijen (2007). *Financial sector development and the millennium development goals*. The World Bank.
- Coeuré, B. (2018). Monetary policy and climate change, speech by b. coeuré, member of the executive board of the ecb, at a conference on “scaling up green finance: The role of central

- banks". *European Central Bank*.
- COP (2015). Adoption of the paris agreement. *UN-Framework Convention on Climate Change*.
- Dasgupta, P. (2021). The economics of biodiversity: The dasgupta review. *London: HM Treasury*.
- Dasgupta, S., B. Laplante, and N. Mamingi (2001). Pollution and capital markets in developing countries. *Journal of Environmental Economics and management* 42(3), 310–335.
- De Haas, R. and A. A. Popov (2019). Finance and carbon emissions. *ECB Working Paper*.
- Della Croce, R., C. Kaminker, and F. Stewart (2011). The role of pension funds in financing green growth initiatives.
- den Elzen, M., T. Kuramochi, N. Höhne, J. Cantzler, K. Esmeijer, H. Fekete, T. Fransen, K. Keramidas, M. Roelfsema, F. Sha, et al. (2019). Are the g20 economies making enough progress to meet their ndc targets? *Energy policy* 126, 238–250.
- D’Este, P., S. Iammarino, M. Savona, and N. von Tunzelmann (2012). What hampers innovation? revealed barriers versus deterring barriers. *Research policy* 41(2), 482–488.
- DNB (2017). Waterproof? an exploration of climate-related risks for the dutch financial sector. *De Nederlandsche Bank, working paper*.
- Dombrovskis, V. (2017). Greening finance for sustainable business. *Speech by Vice-President for the Euro and Social Dialogue, Financial Stability and Financial Services Valdis Dombrovskis* (SPEECH/17/5235).
- Dong, K., G. Hochman, Y. Zhang, R. Sun, H. Li, and H. Liao (2018). Co2 emissions, economic and population growth, and renewable energy: Empirical evidence across regions. *Energy Economics* 75, 180–192.
- D’Orazio, P. and P. Löwenstein (2020). Mobilising investments in renewable energy in germany: which role for public investment banks? *Journal of Sustainable Finance & Investment*, 1–24.
- D’Orazio, P. and L. Popoyan (2019). Fostering green investments and tackling climate-related financial risks: Which role for macroprudential policies? *Ecological Economics* 160, 25 – 37.
- ECB (2020). Ecb report on institutions’ climate-related and environmental risk disclosures. Technical report, European Central Bank - Banking Supervision.
- El Ghoul, S., O. Guedhami, C. C. Kwok, and D. R. Mishra (2011). Does corporate social responsibility affect the cost of capital? *Journal of Banking & Finance* 35(9), 2388–2406.
- Elderson, F. (2018). From mission to supervision: putting sustainable prosperity on the agenda of the dutch central bank. Ise sustainable finance leadership series.
- Eskander, S. M. and S. Fankhauser (2020). Reduction in greenhouse gas emissions from national climate legislation. *Nature Climate Change* 10(8), 750–756.
- Farhani, S. and I. Ozturk (2015). Causal relationship between co 2 emissions, real gdp, energy consumption, financial development, trade openness, and urbanization in tunisia. *Environmental Science and Pollution Research* 22(20), 15663–15676.
- Fase, M. M. and R. Abma (2003). Financial environment and economic growth in selected asian countries. *Journal of Asian economics* 14(1), 11–21.
- FT (2020). Christine lagarde wants key role for climate change in ecb review. Technical report, The Financial Times, 27 November 2020.
- Galaz, V., J. Gars, F. Moberg, B. Nykvist, and C. Repinski (2015). Why ecologists should care about financial markets. *Trends in Ecology & Evolution* 30(10), 571–580.
- Geddes, A., T. S. Schmidt, and B. Steffen (2018). The multiple roles of state investment banks in low-carbon energy finance: An analysis of australia, the uk and germany. *Energy policy* 115, 158–170.
- GoI (1998). Act of the republic of indonesia number 7 of 1992 concerning banking as amended by act number 10 of 1998. Technical report, Government of Indonesia.
- Gök, A. (2020). The role of financial development on carbon emissions: a meta regression analysis. *Environmental Science and Pollution Research*, 1–19.
- Grossman, G. M. and A. B. Krueger (1995). Economic growth and the environment. *The quarterly journal of economics* 110(2), 353–377.
- Hafner, S., A. Jones, A. Anger-Kraavi, and J. Pohl (2020). Closing the green finance gap—a systems perspective. *Environmental Innovation and Societal Transitions* 34, 26–60.

- He, J. and P. Richard (2010). Environmental kuznets curve for co2 in canada. *Ecological Economics* 69(5), 1083–1093.
- Heller, N. E. and E. S. Zavaleta (2009). Biodiversity management in the face of climate change: a review of 22 years of recommendations. *Biological conservation* 142(1), 14–32.
- HLEG (2018). Final report on financing a sustainable european economy. *Interim Report - High-Level Expert Group on Sustainable Finance*.
- IEA (2018). World energy investment 2018. *Publishing Paris*, <https://www.iea.org/publications/freepublications/publication/WEIO2014.pdf>.
- IEA (2020). Global co2 emissions in 2019. *International Energy Agency*.
- IPCC (2014). Climate change 2014: Synthesis report. Technical report, Intergovernmental Panel on Climate Change.
- IPCC (2018). Global warming of 1.5 degrees: summary for policymakers. Technical report, Intergovernmental Panel on Climate Change.
- Jalil, A. and M. Feridun (2011). The impact of growth, energy and financial development on the environment in china: a cointegration analysis. *Energy Economics* 33(2), 284–291.
- Jebli, M. B., S. B. Youssef, and I. Ozturk (2016). Testing environmental kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in oecd countries. *Ecological Indicators* 60, 824–831.
- Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of econometrics* 90(1), 1–44.
- Kaufmann, D., A. Kraay, and M. Mastruzzi (2011). The worldwide governance indicators: Methodology and analytical issues1. *Hague journal on the rule of law* 3(2), 220–246.
- Kelejian, H. H. (1971). Two-stage least squares and econometric systems linear in parameters but nonlinear in the endogenous variables. *Journal of the American Statistical Association* 66(334), 373–374.
- Khan, A. Q., N. Saleem, and S. T. Fatima (2018). Financial development, income inequality, and co 2 emissions in asian countries using stirpat model. *Environmental Science and Pollution Research* 25(7), 6308–6319.
- Kim, D.-H., Y.-C. Wu, and S.-C. Lin (2020). Carbon dioxide emissions and the finance curse. *Energy Economics* 88, 104788.
- Koenker, R. (2004). Quantile regression for longitudinal data. *Journal of Multivariate Analysis* 91(1), 74–89.
- Krueger, P., Z. Sautner, and L. T. Starks (2020). The importance of climate risks for institutional investors. *The Review of Financial Studies* 33(3), 1067–1111.
- Lane, P. (2019). Climate change and the irish financial system. *Bank of Ireland* 1.
- Lanoie, P. and M. Roy (1997). *Can capital markets create incentives for pollution control?* The World Bank.
- Le Quéré, C., R. M. Andrew, P. Friedlingstein, S. Sitch, J. Hauck, J. Pongratz, P. A. Pickers, J. I. Korsbakken, G. P. Peters, J. G. Canadell, et al. (2018). Global carbon budget 2018. *Earth System Science Data* 10(4), 2141–2194.
- Le Quéré, C., J. I. Korsbakken, C. Wilson, J. Tosun, R. Andrew, R. J. Andres, J. G. Canadell, A. Jordan, G. P. Peters, and D. P. van Vuuren (2019). Drivers of declining co 2 emissions in 18 developed economies. *Nature Climate Change* 9(3), 213–217.
- Lee, J.-M., K.-H. Chen, and C.-H. Cho (2015). The relationship between co2 emissions and financial development: evidence from oecd countries. *The Singapore Economic Review* 60(05), 1550117.
- Li, Y., M. Gong, X.-Y. Zhang, and L. Koh (2018). The impact of environmental, social, and governance disclosure on firm value: The role of ceo power. *The British Accounting Review* 50(1), 60–75.
- Lokuwaduge, C. S. D. S. and K. Heenetigala (2017). Integrating environmental, social and governance (esg) disclosure for a sustainable development: An australian study. *Business Strategy and the Environment* 26(4), 438–450.
- Machado, J. A. and J. S. Silva (2019). Quantiles via moments. *Journal of Econometrics* 213(1), 145–173.

- Mazzucato, M. and G. Semieniuk (2018). Financing renewable energy: Who is financing what and why it matters. *Technological Forecasting and Social Change* 127, 8 – 22.
- Meyerson, F. A. (1998). Population, development and global warming: averting the tragedy of the climate commons. *Population and environment* 19(5), 443–463.
- Monnin, P. (2018). Central banks and the transition to a low-carbon economy. Technical report, Discussion note 2018/1. Zurich: Council on Economic Policies.
- Nagelkerken, I. and S. D. Connell (2015). Global alteration of ocean ecosystem functioning due to increasing human co2 emissions. *Proceedings of the National Academy of Sciences* 112(43), 13272–13277.
- Nasreen, S., S. Anwar, and I. Ozturk (2017). Financial stability, energy consumption and environmental quality: Evidence from south asian economies. *Renewable and Sustainable Energy Reviews* 67, 1105–1122.
- Ng, A. W. (2018). From sustainability accounting to a green financing system: Institutional legitimacy and market heterogeneity in a global financial centre. *Journal of Cleaner Production* 195, 585–592.
- NGFS (2017). Charter of the central banks and supervisors network for greening system. *Network for Greening the Financial System*.
- NGFS (2019). A call for action - climate change as a source of financial risk, first comprehensive report. *Network for Greening the Financial System*.
- Ozturk, I. and A. Acaravci (2013). The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in turkey. *Energy Economics* 36, 262–267.
- Pao, H.-T. and C.-M. Tsai (2011). Multivariate granger causality between co2 emissions, energy consumption, fdi (foreign direct investment) and gdp (gross domestic product): evidence from a panel of bric (brazil, russian federation, india, and china) countries. *Energy* 36(1), 685–693.
- Park, Y., F. Meng, and M. A. Baloch (2018). The effect of ict, financial development, growth, and trade openness on co 2 emissions: an empirical analysis. *Environmental Science and Pollution Research* 25(30), 30708–30719.
- Pedroni, P. (2004). Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the ppp hypothesis. *Econometric theory*, 597–625.
- Pesaran, M. H. (2004). General diagnostic tests for cross-sectional dependence in panels. *Empirical Economics*, 1–38.
- Peters, G., R. Andrew, J. Canadell, P. Friedlingstein, R. Jackson, J. Korsbakken, C. Le Quéré, and A. Peregon (2020). Carbon dioxide emissions continue to grow amidst slowly emerging climate policies. *Nature Climate Change* 10(1), 3–6.
- Phillips, P. C. and D. Sul (2003). Dynamic panel estimation and homogeneity testing under cross section dependence. *The Econometrics Journal* 6(1), 217–259.
- Rasoulinezhad, E. and B. Saboori (2018). Panel estimation for renewable and non-renewable energy consumption, economic growth, co 2 emissions, the composite trade intensity, and financial openness of the commonwealth of independent states. *Environmental Science and Pollution Research* 25(18), 17354–17370.
- Rogoff, K. (1999). International institutions for reducing global financial instability. *Journal of Economic perspectives* 13(4), 21–42.
- Sachs, J. D., W. T. Woo, N. Yoshino, and F. Taghizadeh-Hesary (2019). Why is green finance important? *ADB Working Paper* 917 (2019).
- Sadorsky, P. (2014). The effect of urbanization on co2 emissions in emerging economies. *Energy Economics* 41, 147–153.
- Sahay, R., M. Čihák, P. N’Diaye, and A. Barajas (2015). Rethinking financial deepening: Stability and growth in emerging markets. *Revista de Economía Institucional* 17(33), 73–107.
- Scheffer, M., V. Brovkin, and P. M. Cox (2006). Positive feedback between global warming and atmospheric co2 concentration inferred from past climate change. *Geophysical research letters* 33(10).
- Schnabel, I. (2020). When markets fail – the need for collective action in tackling climate

- change speech by isabel schnabel, member of the executive board of the ecb at the european sustainable finance summit, frankfurt am main, 28 september 2020. *European Central Bank*.
- Schoenmaker, D. and R. Van Tilburg (2016). What role for financial supervisors in addressing environmental risks? *Comparative Economic Studies* 58(3), 317–334.
- Scholtens, B. (2017). Why finance should care about ecology. *Trends in Ecology & Evolution* 32(7), 500–505.
- Shahbaz, M., H. Mallick, M. K. Mahalik, and P. Sadorsky (2016). The role of globalization on the recent evolution of energy demand in india: Implications for sustainable development. *Energy Economics* 55, 52–68.
- Sheraz, M., X. Deyi, J. Ahmed, S. Ullah, and A. Ullah (2021). Moderating the effect of globalization on financial development, energy consumption, human capital, and carbon emissions: evidence from g20 countries. *Environmental Science and Pollution Research*, 1–19.
- Solomon, S., G.-K. Plattner, R. Knutti, and P. Friedlingstein (2009). Irreversible climate change due to carbon dioxide emissions. *Proceedings of the national academy of sciences* 106(6), 1704–1709.
- Steckel, J. C., M. Jakob, C. Flachsland, U. Kornek, K. Lessmann, and O. Edenhofer (2017). From climate finance toward sustainable development finance. *Wiley Interdisciplinary Reviews: Climate Change* 8(1), e437.
- Steffen, W., J. Rockström, K. Richardson, T. M. Lenton, C. Folke, D. Liverman, C. P. Summerhayes, A. D. Barnosky, S. E. Cornell, M. Crucifix, et al. (2018). Trajectories of the earth system in the anthropocene. *Proceedings of the National Academy of Sciences* 115(33), 8252–8259.
- Stern, D. I. (2004). The rise and fall of the environmental kuznets curve. *World development* 32(8), 1419–1439.
- Stern, N. H., S. Peters, V. Bakhshi, A. Bowen, C. Cameron, S. Catovsky, D. Crane, S. Cruickshank, S. Dietz, N. Edmonson, et al. (2006). *Stern Review: The economics of climate change*, Volume 30. Cambridge University Press Cambridge.
- Tamazian, A., J. P. Chousa, and K. C. Vadlamannati (2009). Does higher economic and financial development lead to environmental degradation: evidence from bric countries. *Energy policy* 37(1), 246–253.
- Tamazian, A. and B. B. Rao (2010). Do economic, financial and institutional developments matter for environmental degradation? evidence from transitional economies. *Energy economics* 32(1), 137–145.
- TCFD (2018). Tcfd: 2018 status report. *Task Force on Climate-related Financial Disclosures*.
- Thoma, j., W. C. F. M. A. S. and H. Chenet (2016). Transition risk toolbox: Scenarios, data, and models. *2 Degree Investing Initiative*.
- Vermeulen, R., E. Schets, M. Lohuis, B. Kölbl, D.-J. Jansen, and W. Heeringa (2019). The heat is on: A framework for measuring financial stress under disruptive energy transition scenarios.
- Volz, U. (2017). On the role of central banks in enhancing green finance. *UN Environment Inquiry Working Paper 17/01*.
- Wang, F., S. Yang, A. Reisner, and N. Liu (2019). Does green credit policy work in china? the correlation between green credit and corporate environmental information disclosure quality. *Sustainability* 11(3), 733.
- Wang, H. (2017). New multilateral development banks: Opportunities and challenges for global governance. *Global Policy* 8(1), 113–118.
- Wang, N., H. Zhu, Y. Guo, and C. Peng (2018). The heterogeneous effect of democracy, political globalization, and urbanization on pm2. 5 concentrations in g20 countries: Evidence from panel quantile regression. *Journal of cleaner production* 194, 54–68.
- Wang, Y. and Q. Zhi (2016). The role of green finance in environmental protection: Two aspects of market mechanism and policies. *Energy Procedia* 104, 311–316.
- Wang, Z. and J. Sarkis (2017). Corporate social responsibility governance, outcomes, and financial performance. *Journal of Cleaner Production* 162, 1607–1616.

- Weidmann, J. (2020). Combating climate change - what central banks can and cannot do? *Speech at the European Banking Congress*.
- Westerlund, J. (2007). Testing for error correction in panel data. *Oxford Bulletin of Economics and statistics* 69(6), 709–748.
- Widyawati, L. (2020). A systematic literature review of socially responsible investment and environmental social governance metrics. *Business Strategy and the Environment* 29(2), 619–637.
- Xing, C., Y. Zhang, and Y. Wang (2020). Do banks value green management in china? the perspective of the green credit policy. *Finance Research Letters* 35, 101601.
- Yadav, R. and G. Pathak (2013). Environmental sustainability through green banking: A study on private and public sector banks in india. *OIDA International Journal of Sustainable Development* 6(08), 37–48.
- Yeh, J.-C. and C.-H. Liao (2017). Impact of population and economic growth on carbon emissions in taiwan using an analytic tool stirpat. *Sustainable Environment Research* 27(1), 41–48.
- You, W.-H., H.-M. Zhu, K. Yu, and C. Peng (2015). Democracy, financial openness, and global carbon dioxide emissions: heterogeneity across existing emission levels. *World Development* 66, 189–207.
- Yu, E. P.-y., B. Van Luu, and C. H. Chen (2020). Greenwashing in environmental, social and governance disclosures. *Research in International Business and Finance*, 101192.
- Zafar, M. W., S. Saud, and F. Hou (2019). The impact of globalization and financial development on environmental quality: evidence from selected countries in the organization for economic co-operation and development (oecd). *Environmental Science and Pollution Research* 26(13), 13246–13262.
- Zaidi, S. A. H., M. W. Zafar, M. Shahbaz, and F. Hou (2019). Dynamic linkages between globalization, financial development and carbon emissions: Evidence from asia pacific economic cooperation countries. *Journal of Cleaner Production* 228, 533–543.
- Zhang, Y.-J. (2011). The impact of financial development on carbon emissions: An empirical analysis in china. *Energy policy* 39(4), 2197–2203.
- Zhou, X. and C. Feng (2017). The impact of environmental regulation on fossil energy consumption in china: Direct and indirect effects. *Journal of Cleaner Production* 142, 3174–3183.

Appendix A. Additional graphs

Figure A1.: Average Population, GDP and CO₂ emission in G20 by country (2000-2017).

Figure A2.: CO₂ emissions by country and adoption of climate-related financial policies (2000-2017).

Figures

Figure 1

Distribution of CO2 emissions by country (2000-2017).

Figure 2

Stock of climate-related financial policies adopted by country at the end of 2017 (top graph). Number of climate-related financial policies adopted per year during 2000-2017 in G20 (bottom graph). Source: authors' elaboration on data retrieved from Anonymized (2021). Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 3

Method of Moments Panel Quantile Regression results

Figure 4

The direct, indirect and total effect of short term (left plot) and long term (right plot) CRFPs on the CO2 distribution

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