The Role of Size, Capital Adequacy, and Credit of Banking Systems in reducing CO2 Emissions

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ABSTRACT

This study investigates the impact of bank system size, capital adequacy, and credit on CO_2 emissions in 66 selected countries. To this end, a novel method of Quantile Regression by Powell (2020) is applied to panel data from 2000 to 2017. Our findings reveal that Banking system size has a positive impact, while renewable energy consumption and population show a negative and significant impact on CO_2 emissions in all quantiles. Credit and economic growth have a positive and significant impact on lower-emissions countries, and vice versa for high-emissions countries. In contrast, Capital adequacy significantly reduces CO_2 emissions in the lower CO_2 emissions countries (25th to 75th quantiles) and vice versa for the high emissions countries. Furthermore, renewable energy consumption and population exhibit a negative and significant impact across all quantities (25th to 95th percentile). Policymakers can use insights into how banking system-specific characteristics impact CO_2 emissions to see their capacity to reduce such emissions.

● **Keywords:** CO_2 emission; Bank system size; Capital adequacy; Bank credit; Quantile Regression.

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دور حجم الأنظمة المصرفية وكفاية رأس مالها وائتمانها في الحد من انبعاثات ثاني أكسيد الكربون

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■ **ملخص البحث**

تدرس هذه الدراسة تأثير حجم النظام المصرفي، وكفاية رأس المال، والائتمان على انبعاثات ثاني أكسيد الكربون في 66 دولة مختارة. ولتحقيق هذه الغاية، طُبقت طريقة جديدة للانحدار الكمي (Quantile Regression) من قِبل (Powell 2020) على بيانات السلاسل الزمنية المقطعية للفترة من 2000 إلى2017. تكشف نتائجنا أن لحجم النظام المصرفي تأثيرًا إيجابيًا، بينما يُظهر استهلاك الطاقة المتجددة والنمو السكاني تأثيرًا سلبيًا وهامًا على انبعاثات ثاني أكسيد الكربون في جميع الأرباع. كما يُظهر الائتمان والنمو الاقتصادي تأثيرًا إيجابيًا وهامًا على الدول ذات الانبعاثات المنخفضة، والعكس صحيح بالنسبة للدول ذات الانبعاثات المرتفعة. في المقابل، تُقلل كفاية رأس المال بشكل ملحوظ من انبعاثات ثاني أكسيد الكربون في الدول ذات الانبعاثات المنخفضة (من الربع الأول " 25" إلى الربع الثالث "75")، والعكس صحيح بالنسبة للدول ذات الانبعاثات المرتفعة. علاوة على ذلك، يُظهر استهلاك الطاقة المتجددة والنمو السكاني تأثيرًا سلبيًا وهامًا على جميع الارباع (من الربع الأول "25" إلى الرابع "95"). يمكن لواضعي السياسات الاستفادة من هذه المعلومات حول كيفية تأثير خصائص النظام المصرفي على انبعاثات ثاني أكسيد الكربون لتقييم قدرتهم على خفض هذه الانبعاثات.

الكلمات المفتاحية: انبعاثات ثاني أكسيد الكربون؛ حجم النظام المصرفي؛ كفاية رأس مال؛ الائتمان المصرفي؛ الانحدار الكمي.

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1. Introduction

In an era of significant shifts in the global economic and industrial landscape, banking systems play a critical role in mitigating emissions by influencing the flow of financing for polluting businesses. For example, the Postal Savings Bank of China and China Minsheng Bank increased fossil fuel financing in China from 2016 to 2020 from $168 million to $2.2 billion and $1.7 billion to $10.8 billion; it increased over 1,200% and 550%, respectively (Rainforest Action Network, 2021). Further, UK banks and asset managers were responsible for financing 805 million tonnes of CO_2 in 2019 (Greenpeace UK and WWF, 2021). According to CDP[1], the greenhouse gas emissions associated with the activities of financial institutions are more than 700 times higher, on average, than their direct emissions; almost all climate-related impacts and risks of global financial institutions come from financing the broader economy. Also, COP21 (2015) demonstrates the first exhaustive climate agreement explicitly recognizing the need to make financial flows to reduce greenhouse gas emissions and climate-resilient development that satisfies global warming targets and rapid CO_2 emissions (Reghezza et al., 2021).

Most of the world's governments almost allow banks to invest in developing fossil fuels. However, the inculcation of green policies and criteria into bank lending, trading, and investment practices is growing recognized as necessary for achieving the core mandates of international financial organizations. For example, one of the primary purposes of COP21 (2015) was to mobilize financial institutions to help the transition away from fossil fuels. Therefore, the banks must lend money (green loans) to fund renewable energy, such as solar power generation projects. In contrast, Banks should decrease their fossil fuel financing or even stop all financing for coal-fired power plants and coal mining in all countries.

There are several channels through which banking systems' size, credit,

1 CDP (Carbon Disclosure Project) is an international non-profit organization based in the united kingdom, Japan, India, China, Germany, and the united states of America that helps companies and cities disclose their environmental impact. See https://www.bloomberg.com/news/articles/2021-04-27/banks-produce-700-times-more-emissions-from-loans-than-offices

and capital adequacy impact a countries' co2 emissions sources. The expanse in size of the banking system impacts economic growth, finance fossil fuel corporations, and investment in energy-saving technologies (Kishan and Opiela, 2000; Cetorelli and Gambera, 2001; ESRB, 2014; Amuakwa-Mensah et al., 2018; Kakes and Nijskens, 2018; Amuakwa-Mensah and Näsström, 2022). On the other hand, Credit expansion can impact human activities, investment, economic growth, and energy consumption (Sadorsky, 2010; Zhang, 2011; Prochniak and Wasiak, 2017). Also, banking system capital impacts bank lending, funding costs, economic growth, and low-CO2 emission technologies (Martynova, 2015; Fraisse, Lé and Thesmar, 2017; Prochniak and Wasiak, 2017; Gambacorta and Shin, 2018; Reghezza et al., 2021). Therefore, we expect these banking system characteristics to affect CO2 emissions significantly.

Bank decisions play a critical role in restricting the financing to reducing co2 emissions sources, supporting projects for their conversion, and presenting low-Co2 emission technologies. Following the Paris Agreement[2], European banks reallocated credit away from polluting firms. Financial institutions now include climate risks in their evaluation of investment projects due to increased public demand to reduce the impacts of climate change. For instance, the European Investment Bank has chosen to stop funding fossil fuel energy projects by the end of 2021[3]. It has issued energy lending policy guidelines outlining the sorts of EU assistance and energy projects compatible with the bank's goals[4]. In addition, Nordea Bank adopted the recommendation to restrict the financing of businesses that utilize fossil fuels as an energy source

2 - 200 countries signed the 2015 Paris Agreement. It seeks to achieve net-zero emissions by the second half of the century through nationally determined contributions. represents the first comprehensive climate deal that explicitly recognises the need to "make finance flows compatible with a pathway toward climate-resilient development and low greenhouse gas emissions."

3 - The European Investment Bank. EU Bank Launches Ambitious New Climate Strategy and Energy Lending Policy; European InvestmentBank: Luxembourg, 2019. Available online: https://www.eib.org/en/press/all/2019-313-eu-bank-launches-ambitious-newclimate-strategy-and-energy-lending-policy.htm (accessed on 26 October 2021).

4 - The European Investment Bank. EIB Energy Lending Policy: Supporting the Energy Transformation; Nordea Bank: Luxembourg, 2019. Available online: https://www.eib.org/attachments/strategies/eib_energy_lending_policy_en.pdf (accessed on 25 October 2021).2021).

and directed current financing clients that extract thermal coal or use it to generate electricity to stop doing so by 2030.

In this study, we focus on the critical role of banking authorities in reducing co2 emissions sources and supporting low-CO2 emission technologies that require finance to enable and absorb new technology. Therefore, our contribution has two directions: First, we are motivated to examine whether the current size, capital adequacy, and credit of banking systems are good things to continue to reduce CO2 emissions. To the best of our knowledge, with the spread of low-carbon technologies as a vital mechanism to prevent environmental pollution, empirical evidence still needs to be examining this role and how banking activity contributes to climate change. More specifically, we discuss how banking practices as a source of corporate finance impacted CO2 emissions in 66 selected countries from 2000 to 2017. Second, we use a novel QR method by Powell (2020). This methodology can explain the independent variables at any point of the distribution of the Co2 emissions where the quantile technique is not limited to clarifying the mean of the CO2 emissions. Hence, our study question is, does the size of banking systems and its adequacy of capital and credit contribute to reducing cCO2 Emissions? This question leads to three main null hypotheses:

- H0A: The size of banking systems does not contribute to reducing CO2 Emissions.
- H0B: The capital adequacy of banking systems does not contribute to reducing CO2 Emissions.
- H0C: The credit of banking systems does not contribute to reducing CO2 Emissions.

Our findings reveal a homogeneous positive and significant impact of banking system size on CO2 emissions increasingly across all quantiles. On the other hand, credit significantly increases emissions in the lower CO2 emissions countries (quantiles 25 to 50), and credit significantly reduces emissions in the higher CO2 emissions countries (quantiles 75 to 95).

Furthermore, capital adequacy indicates a significant heterogeneous impact; it increases emissions in the higher CO2 emissions countries (quantile 95) while it declines emissions in the lower CO2 emissions countries (25th to 75th quantiles). Economic growth significantly has reduced emissions in the higher CO2 emissions countries (quantile 95) and increased CO2 emissions in the lower emissions countries (quantiles 25 to 75). Lastly, renewable energy use and population negatively and homogeneously significantly impact CO2 emissions across all quantiles.

The remainder of the paper is organized as follows: Section 2 presents the literature review. Section 3 shows the research design, including theoretical framework, data, and research methodology. Section 4 presents the empirical results, data description, and discussions—finally, Section 5, Conclusions and policy recommendations.

2. Literature review

Stakeholders should look at the knowledge of banking systems' environmental performance (i.e. CO2 emission minimization policies and strategies). Specifically, the impact of banking system-specific characteristics on CO2 emission has earned rising attention in the recent literature. Kakes and Nijskens (2018) confirm that big banking system size positively relates to credit volume and the global market share that finances fossil fuel corporations. These raise consumption, investment, economic growth, and energy use, Hence more CO2 emissions. Kakes and Nijskens (2018) found that a rapid expansion of the banking system signals excessive credit growth, excessive reliance on wholesale funding and, thus, financial fragility, and the emergence of Too-Big-to-Fail banks. In addition, ESRB (2014) indicated that a large banking system might facilitate excessive credit supply. Also, Cetorelli and Gambera (2001) emphasize that the aggregate size of banks is crucial for economic growth. Hence, the big banking system implies more money for lending, investment, economic development, and energy consumption, resulting in environmental deterioration. Kakes and Nijskens (2018) explain that the big banking system contributes more to economic growth by improving corporate access to credit and creating lower-cost products and services. Ghosh (2017) indicated that banks in big markets would experience more competitive pressures, forcing them to lower interest rates and increase credit flows. Kishan and Opiela (2000) find that loan supply of bigger-sized systems will be more flexible to monetary policy due to loan supply changes arising from the bank lending channel. In this sense, urgently addressing the problem of financial institutions that are 'too big to fail' should be addressed expeditiously by reducing financial firms' holdings of high-carbon assets and protected from failure to finance energy-saving technology.

Other literature focuses on the banking system size impacts and generally attributes it to economies of scale and scope theory. Large bank systems, for example, may benefit from economies of scale and scope, allowing them to invest in energy-saving technologies (Amuakwa-Mensah et al., 2018). Also, Amuakwa-Mensah and Näsström (2022) found that an increase in bank system size positively and significantly affected the renewable energy consumption share in 124 countries. Their findings highlight the significance of a well-functioning banking system in generating the necessary renewable energy investments to meet future energy demand while simultaneously lowering CO_2 emissions. Furthermore, when banks grow in size, they are better equipped to provide a guarantee or leverage for the state when purchasing energy-efficient technology. Hence, the banking system's size and the large money amounts it provides that is used for lending, investment, energy consumption, and economic development may help explain whether it has a significant in reducing CO_2 emissions.

Credit is one of the main drivers of various manufacturing activities, which contributes to more pollution and degrades the environmental quality. This is because credit expansion supplies more consumer credits and will help individuals consume more durable goods such as automobiles, electronic devices, real property. The consumption will continue to expand as banking systems provide more and more credit and further degrade the environment. For example, Sadorsky (2010) finds that banks via loans make their most significant contributions to climate change as easier access to lending enables customers to purchase more goods and services. On the other hand, more funds boost human activities, encouraging energy consumption and increasing CO_2 emissions. Furthermore, according to Prochniak and Wasiak (2017), credit expansion is facilitative to output growth, which increases co2 emissions. Zhang (2011) also concludes that the loans attract foreign direct investment to accelerate economic growth, consume energy, and add to Co2 emissions.

Furthermore, consumer loan activities allow buying big-ticket items (i.e., automobiles, houses, refrigerators, air conditioners, washing machines, etc.), which consume energy and destroy environmental quality rising Co2 emissions (Sadorsky, 2010). On the other hand, Liang and Teng (2006) found that higher bank loans did not lead to economic development in China. This might explain why the channel for effective capital allocation was not operating properly, with financial assets concentrated in the four major state-owned banks, which transfer a large share of their loans to state-owned corporations under government supervision. Prochniak and Wasiak (2017) also find that the change in domestic credit is a positive and significant factor of economic growth in EU countries, which increases CO_2 emissions. Also, Zhang (2011) show that one of the main reasons Co2 emissions in China is that the bank loans give solid support for corporations to acquire external finance and extend their investment scale.

Following Paris Agreement, Reghezza et al. (2021) find that European banks reallocated credit away from polluting firms. also, banking can have a significant impact combating climate change. Chang et al. (2021) observe that firms with greater environmental liabilities maintain lower financial leverage ratios, with a lower fraction of bank debt in total debt. On other hand, Lins, Servaes and Tamayo (2017) find that during the 2008-2009 financial crisis, high social responsibility firms were able to raise more debt. Also, Chang et al. (2021) show that ceteris paribus, less environmentally responsible firms have a lower fraction of bank debt in total debt, consistent with the notion that banks are more environmentally sensitive than other lenders.

According to a bank capital theory presented by Diamond and Rajan (2000), Bank capital impacts bank safety, the bank's capacity to refinance at a low cost, and the bank's ability to obtain repayment from borrowers or desire to liquidate them. Martynova (2015) suggests that banks facing higher capital requirements can decrease credit supply and reduce credit demand by boosting lending rates, slowing economic growth. According to Prochniak and Wasiak (2017), a rise in bank capital to assets ratio in the EU28 nations causes a slowdown in bank lending, which has a negative impact on GDP dynamics. In contrast. Prochniak and Wasiak (2017) found that the impact of bank capital to assets ratio on economic growth is positive in OECD countries, implying that the banking system's capitalization is beneficial to GDP growth. Also, Fraisse et al. (2017) mention that capital requirements have little impact on bank lending and economic activity.

The impact of bank capital on lending is a key factor in the relationship between financial conditions and real activity. However, the effect of bank capital on lending is not clear-cut. For example, banks with a more extensive equity base lend more. According to Gambacorta and Shin (2018), banks with a higher equity basis lend more, retain more bank profits, and have more bank capital to relieve the financial conditions of final borrowers. Also, Gambacorta and Shin (2018) show that higher bank capital is related to more lending, and the mechanism involved in this channel is reduced funding costs associated with better-capitalized banks. Kishan and Opiela (2000) bank capital can mitigate the impacts of any drop in deposits on lending during periods of monetary tightening. Further, Reghezza et al. (2021) assert that banks with high capital levels, lower credit quality, and low profits are pushing banks out of climate-sensitive systems and towards greener businesses, as they are reacting earlier and more strongly to climate policy actions as a result of recent climate change initiatives, increased awareness of climate change-related risks, and the anticipation of more stringent policies.

In theory, economic growth, total population, and energy usage are among the main critical drivers of global emissions. For example, Bilgili et al.

(2016) indicate that economic growth positively impacts CO2 emissions, and renewable energy consumption has a negative impact on CO2 emissions in 17 OECD countries. Also, Zoundi (2017) reveals that CO2 emissions increase with economic growth, while renewable energy has helped African countries reduce their CO2 emissions. On the other hand, in 74 most carbon emission economies, Sharif et al. (2019) showed that renewable energy negatively affects CO2 emissions and minimizes environmental hazards. Furthermore, in 42-African countries, Apergis et al. (2018) indicate that economic growth increases CO2 emissions, while renewable energy consumption reduces CO2 emissions. Further, in Latin America and the Caribbean region, Koengkan et al. (2021) found that economic growth is positively related to CO2 emissions, while renewable energy consumption negatively relates to it.

In several empirical studies related to the Environmental Kuznets curve hypothesis (EKC), a U-shaped relationship shows that environmental degradation (pollution level) increases first with GDP growth and eventually decreases as the economy develops. For example, Bölük and Mert (2014) show a U-shaped link between environmental pollution and economic growth; renewable energy consumption is an effective method for European Union countries to achieve sustainable growth and improve environmental quality. Salahuddin et al. (2020) illustrate that renewable energy and energy intensity reduce CO2 emissions, while economic growth increases emissions in 34 African countries. In 16 European Union countries, Bekun et al. (2019) discovered that CO2 emissions decreased due to renewable energy consumption. In contrast, Ben Jebli et al. (2015) argue that per capita renewable energy increases per capita emission across 22 Sub- Saharan countries. An increase in real GDP decreases CO2 emissions, and any fluctuation in the use of renewable energy may not affect the degradation of the environmental indicator (CO2) in the long run. Adams and Nsiah (2019) also indicate that renewable energy consumption and economic growth promote CO2 in 28 countries.

Several studies have examined population as the determinant of CO2 emissions but provided mixed evidence. Most studies show a positive relationship between the population and CO_2 emissions, such as in China (Li, Fang and He, 2019), in European countries (Martínez-Zarzoso et al., 2007), and in developed countries (Liddle and Lung, 2010). In contrast, Liu et al. (2015) document that higher population density decreases pollutant emissions in China. Ribeiro et al. (2019) indicate that the densification of large populated urban areas is likely to significantly reduce urban CO_2 emissions in the united states. Fan et al. (2006) examined 208 countries and concluded that population proportion between ages 15 and 64 reduce CO_2 emissions for countries with a high-income level. Also, Dalton et al. (2008) show that population aging may diminish long-term CO_2 emissions in the United States.

Briefly, banking systems play a vital role in mobilizing and distributing financial resources for the economic systems through lending, investment, and other financial services. Therefore, banks that finance fossil fuel corporations shall confirm no potential environmental degradation. For example, the banking system, as a significant credit supplier, can be a prominent player in making finance flows compatible with a pathway toward low greenhouse gas emissions and climate-resilient development. Also, the use of banks clearly to impact climate change and to get it to stop lending money to fossil fuel corporations is the next needed in addressing the industry's material risks that the gas, oil, and coal industries face. Therefore, banks are in a unique situation to either entrench fossil-fuel-based energy production or drive the critical shift to a low-carbon economy.

3. Research Design

3.1. Theoretical Framework

Far from being a hazard to the environment, the banking system appears to be the most critical factor in accelerating a country's economic growth. The banking system offers capital for investment, which boosts growth (Ibrahim, 2016; Kakes and Nijskens, 2018; Ryszard Barczyk, 2018; Xue and Zhang, 2019), and it also allows for the deployment of environmentally friendly technologies, which benefit the global environment and reduces CO2 emissions (ESRB, 2014; Amuakwa-Mensah et al., 2018; Shah et al., 2019). However, the effect of the banking system is executed through bank-specific factors such as size (Kakes and Nijskens, 2018; Amuakwa-Mensah and Näsström, 2022), capital adequacy (Shah, Yasmeen and Padda, 2019; Reghezza et al., 2021), and credit (Chang, 2015; Javid and Sharif, 2016; Prochniak and Wasiak, 2017).

The big banking system contributes more to economic growth by improving corporate access to credit and creating lower-cost products and services (Kakes and Nijskens, 2018). with bank system size, renewable energy consumption increases, reducing CO2 emissions (Amuakwa-Mensah and Näsström, 2022). The bigger-sized systems affects loan supply changes (Kishan and Opiela, 2000). Furthermore, as banks grow in size guarantee for the state to purchase energy-efficient technology, according to Amuakwa-Mensah and Näsström (2022), big bank system size generates the necessary renewable energy investments to meet future energy demand while simultaneously lowering CO2 emissions. Likewise, higher capital requirements slow economic growth due to decrease credit supply and reduced credit demand by boosting lending rates, thus a slowdown in bank lending (Martynova, 2015; Prochniak and Wasiak, 2017). Also, Reghezza et al. (2021) argue that banks with high capital levels, lower credit quality, pushing banks out of climate-sensitive systems and towards greener business. However, more banking credit, facilitative to output growth and people can buy more durable consumer products, rising energy consumption, thereby, more CO2 emissions (Sadorsky, 2010; Chang, 2015).

Following the literature findings and transmission channels, we can be argued that banking systems can potentially affect CO2 emissions through different transmission mechanisms. Therefore, the specifications of the econometric model were adopted to identify the impact of bank system-specific factors on Co2 emission. Also, previous studies have established that various factors (economic growth, renewable energy consumption, and population) significantly impact Co2 emissions, classified as control variables. Following the above discussions, we construct the Co2 emission function as:

$$CO2_t = f(SIZE_t, CRE_t, CAR_t, GDP_t, REC_t, POP_t) \quad (1)$$

We specify the following model to analyse the impact of bank-specific aspects on Co2 emission in selected 66 countries. The functional form established has the following structure:

$$CO2_{i,t} = \beta_t + \beta_1\, GDP_{i,t} + \beta_2\, REC_{i,t} + \beta_3 POP_{i,t} + \beta_4 SIZE_{i,t} + \beta_5 CRE_{i,t} + \beta_6 CAR_{i,t} + \varepsilon_{ij,t} \quad (2)$$

Where $CO2_{i,t}$ represents CO2 emissions for country *i at time t,* $GDP_{i,t}$ is GDP per capita growth, $REC_{i,t}$ is Renewable energy consumption, $POP_{i,t}$ is Population, $SIZE_{i,t}$ is banking system size, $CRE_{i,t}$ is banking system credit, and $CAR_{i,t}$ is banking system capital adequacy in our model set-up. The coefficients β_1, β_2, β_3, β_4 , β_5 and β_6 show the marginal effect of the explanatory variables. t denotes time and $\varepsilon_{ij,t}$ is the error term.

3.2. Data

This paper uses the annual panel data spanning from 2000 to 2017 to test the impact of banking system-specific aspects on CO2 emission in selected 66 countries[5]. The study period was long and chosen based on the availability of sufficient and reliable data from the countries, and excluding the later period that lacked data. Our variables include the natural logarithm of CO2 emissions as a dependent variable is a widely-used environmental pollution measure in the literature (see, e.g., Silva et al., 2012; Shahbaz et al., 2013; Shah et al., 2019; Amuakwa-Mensah and Näsström, 2022), while size, credit, and capital adequacy of the banking system as independent variables. In addition, the GDP growth, renewable energy consumption, and population as control

5 - The countries include United Kingdom, United States, France, Germany, Italy, Portugal, Romania, Russia, China, Japan, Sweden, Switzerland, Austria, Canada, Netherlands, Australia, Finland, Brazil, Ecuador, Turkey, Albania, Argentina, Armenia, Belarus, Belgium, Bolivia, Bosnia and Herzegovina, Bulgaria, Chile, Colombia, Costa Rica, Croatia, Czech, Republic, Denmark, Dominican Republic, Egypt, Salvador, Fiji, Ghana, Greece, Iceland, India, Indonesia, Ireland, Korea, Latvia, Lithuania, Luxembourg, Malaysia, Mexico, Nigeria, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Singapore, Slovak Republic, South Africa, Spain, Thailand, Uganda, Ukraine, Uruguay, and Venezuela.

variables. These variables' definition and their measurements and sources are given in Table 1.

Table 1 Definition of Variables

Symbol	Name	Measurement	Units	Source
CO2	CO2 emissions	logarithm of CO2 emissions per capita.	kt	WDI
GDP	Real gross domestic product	GDP per capita growth (annual)	%	WDI
REC	Renewable energy consumption	Renewable energy consumption to total final energy consumption	%	WDI
POP	Population	logarithm of total population.	%	WDI
SIZE	Banking system size	Total banks assets to GDP ratio.	%	WDI
CRE	Banking system credit	Bank credit to bank deposits ratio.	%	WDI
CAR	Banking system capital adequacy	Bank capital to assets ratio	%	WDI

Notes: WDI is World Development Indicators. kt is metric tons per capita

3.3. Research methodology

The central limit theorem is used in most empirical analyses ignore the normality of the variables. Eventually, the inference and a policy cannot be created if the variables are not normal. Even large samples with left- or right-skewed data cannot portray normalcy since the series with ideal value is not in the canter, such as CO2 emissions. In recent years, Powell (2020) proposed Quantile regression for panel data with non-additive fixed effects, keeping the non-separable disturbance term associated with Quantile estimation and laying the groundwork for this research. We have adapted the panel quantile regression method developed by Powell (2020).

The quantile regression has many advantages, such as its suitability for heteroscedasticity models, more resistance to outliers, and handling heterogeneity in data acquired from diverse sources, places, and periods without making many assumptions (Xue and Zhang, 2019). Therefore, the QR efficiently uses time and cross-sectional data to increase data variability and reduce Multicollinearity—the estimation results in lower sensitivity to outliers and multimodality and is more robust. Also, the fundamental skill of this technique is having a full framework and a highly comprehensive investigation of the interaction between variables over an extensive range. Furthermore, unlike the mean regression method, it does not need data to follow a specific distribution when estimating different impacts at different quantiles of the response variable such as the 10th, 25th, 50th, 75th, and 90th quantiles (Waldmann, 2018; Staffa et al., 2019). Thus, the method has recently acquired popularity and awareness in different sectors, including economics, finance, medical, and sociology science[6].

Given a set of explanatory variables ($X_{i,t}$), the quantile can be expressed as the conditional distribution of the explained variable ($lnCO2_{i,t}$), and the equation can be written as:

$$Q_T\left(\frac{lnCO2}{X_{i,t}}\right) = \beta_T + \mu_T X_{i,t} + \beta_T\, \varepsilon_{i,t} \quad (3)$$

The vector of unobserved variables is denoted by ($X_{i,t}$), Using the following objective functions, the coefficient in Eq. (3) is estimated by minimizing the absolute value of residuals:

$$Q_T(\mu_T) = min_\mu \sum_{i=1}^{n} [|\, lnCO2_{i,t} - \mu_T X_{i,t}|]$$

$$= min_\mu \left[\sum_{i,d\ lnCO2_{i,t} \geq \mu X_i}^{n} |lnCO2_{i,t} - \mu_T X_{i,t}| + \sum_{i:d\ lnCO2_{i,t} < X_{i,t}}^{n} (1-T)|lnCO2_{i,t} - \mu_T X_{i,t}| \right] \quad (4)$$

6 See e.g. Qin et al., (2010), Qin and Reyes (2011), Qin (2012), Liu et al. (2013), Koenker (2017), Wang et al. (2018), and Yu et al. (2022).

In fixed effect regression, Koenker (2004) employed shrinkage approach to estimate the vector of individual effects, although this method cannot capture the influence of unidentified components. Canay (2011) presented the two-step structure of a fixed effect panel quantile regression, based on Koenker's (2004) technique. The expected mean of $\varepsilon_{i,t}$ and coefficients are estimated to obtain fixed additive effects in the first stage. Then, estimated additive fixed effects are subtracted from the original explained variables in the second stage, followed by the standard quantile regression is used. On the other hand, the addition of additive fixed effects alters the structure of a model. Powell (2015) presented the panel quantile regression with a nonadditive fixed effect to overcome this disadvantage. The significant advantage of this methodology is that it eliminates the requirement to estimate additive fixed effects (α_i) in the underlying model individually.

Instead of X_{it} α_i given $D_{i,t}$, panel quantile regression offers estimates of the distribution of the outcome variable $X_{i,t}$ given $D_{i,t}$. The influence of policy variables on the result distribution is not adequately explained in the additive fixed-effect model, according to Powell (2015). As a result, the Powell (2015) methodology generates point estimates that are consistent small T. The following is the model's specification:

$$X_{i,t} = \sum_{j=1}^{s} D'_{it}\, \delta_j\, (\varepsilon^*_{it}) \tag{5}$$

Where $X_{i,t}$ is the outcome variable, δ_j is the parameter of interest, $D_{i,t}$ is the vector of independent variables, and ε^*_{it} is the disturbance term, which can be a function of several error terms, some of which are fixed and others of which are random. Panel quantile regression dependent on conditional restrictions for the h^{th} quantile of $X_{i,t}$.

$$P(X_{i,t} \le D'_{it}\,\delta(\square) \mid D_{it}) = \square \tag{6}$$

The outcome variable's probability is less than the quantile function is the same for all D_{it} and equal to $\square$ in Equation (6). Furthermore, this probability can vary between individuals and also within individuals using panel quantile regression estimators. Finally, this approach is based on conditional and unconditional restrictions, which are expressed as:

$$P(X_{i,t} \leq D_{it}^{'}\delta(□)|D_{it}) = P(X_{i,t} \leq D_{is}^{'}\delta(□)|D_{it}) \quad (7)$$

$$P(X_{i,t} \leq D_{it}^{'}\delta(□)|D_{it}) = □ \; and \; D_i = (D_{i1}, \ldots\ldots, D_{i□}) \quad (8)$$

Powell (2016) proposes the group of instruments $Y = i(Y_{1i}, \ldots.. Y_i)$ for developing estimators, noting that the identification conditions are met trivially in the presence of exogenous explanatory variables (i.e., $D_i = Y_i$).. GMM is used for the estimate, and the sample moment for practical estimation is specified as:

$$\hat{J}(a) = \frac{1}{N}\sum_{i=1}^{N} J_i(a) \quad with \; J_i(a) = \frac{1}{T}\{\sum_{i=1}^{T}(Y_{1i} - \bar{Y}_{1i})[1(X_{i,t} \leq D_{it}^{'}a)]\} \quad (9)$$

Where

$$\bar{Y}_i = \frac{1}{T}\sum_{i=1}^{T} Y_{1i}$$

Using (9), parameter set is stated as:

$$A \equiv \{a \,|□ - \frac{1}{N} \leq \frac{1}{N}\sum_{i=1}^{N}(1(X_{i,t} \leq D_{it}^{'}a) \leq □\} \quad for\; all\; t. \quad (10)$$

Finally, the parameters are calculated as:

$$\hat{a}\,(□) = \text{argmin}_{a\in A}\,\hat{J}\,(a)\hat{B}\hat{J}\,(a) \quad (11)$$

The above model is estimated using the Markov Chain Monte Carlo (MCMC) approach for some weighting matrix . Therefore, we employ the methods of Powell (2020) in our empirical study.

4. Empirical results

4.1. Data Description

Our study begins the analysis by documenting the summary statistics of our variables in Table 2. The four metrics: Mean (average), S.D. (standard deviation), Min (lowest value), and Max (highest value) are fundamental descriptive statistics used to summarise data. They define the central tendency and range of a dataset, with S.D. showing how tightly data clusters around the mean. The S.D is mostly small (close to zero), which means that the data are very close to the mean, i.e., homogeneous. While Min/Max indicates that the data is within a given range (mean) and that there are no outliers. Further, the correlation tests between the variables are shown in Tables 3 and 4. GDP, REC, POP, and CAR are all inversely associated with LCO2. In addition, LCO2 has a strong relationship with CRE and SIZE. However, because the variance inflation factors (VIF) are all smaller than 10, none of the correlations among the independent variables raises concerns about Multicollinearity (Nachane, 2006).

Table 2 Descriptive statistics of the main variables.

Variable	Obs	Mean	S.D.	Min	Max
CO2	1,155	1.341	1.016	-2.894	3.245
REC	1,155	0.230	0.201	0.005	0.954
POP	1,155	16.767	1.643	12.547	21.057
GDP	1,155	0.027	0.035	-0.144	0.240
SIZE	1,155	0.741	0.456	0.020	2.614
CAR	1,155	0.090	0.034	0.006	0.261
CRE	1,137	1.048	0.526	0.142	5.818

Table 3 Correlation Matrix

	CO2	SIZE	CRE	CAR	REC	GDP	POP
CO2	1						
SIZE	0.543	1					
CRE	0.192	0.460	1				
CAR	-0.340	-0.493	-0.097	1			
REC	-0.731	-0.268	0.022	0.193	1		
GDP	-0.104	-0.260	-0.081	0.195	0.003	1	
POP	-0.098	-0.074	-0.158	-0.101	-0.071	0.025	1

Table 4 Multicolinearity Test: Variance Inflation Factor (VIF)

Variable	SIZE	CAR	CRE	REC	GDP	POP	Mean VIF
VIF	1.91	1.4	1.36	1.12	1.09	1.05	1.32
1/VIF	0.52	0.72	0.74	0.89	0.92	0.95	

4.2. Discussion

We start the discussion of the results by investigating the impact of bank size, capital adequacy, and Credit Risk on Co2 Emissions by employing a panel quantile regression model. The Quantile estimation is more resilient than least-square estimation when dealing with outliers and non-normal errors. Powell (2014, 2015) created a generalized quantile estimator, further expanded for panel data quantile regressions with fixed effects by the same author in 2020[7]. The results were reported at different quantiles (from 25th to 95th) of Co2 emissions as a dependent variable shown in Table 5.

Table 8 shows that bank size (SIZE) has a positive and significant impact on Co2 emission; this impact turns out to be consistently almost increasing for all quantiles, where the coefficient of Bank size at the 25th to 95th percentiles is increasing. Furthermore, the results indicate that the positive impact of bank size on high Co2 emissions is increased compared to a low one, confirming that Bank size encourages Co2 emissions and drives the deterioration of the environment. Big banking systems prevent banks from exploiting economies of scale, facilitate excessive credit supply, implies more money available for lending and economic growth; these findings are in line with Kishan and Opiela (2000), ESRB (2014), and Kakes and Nijskens (2018). When sufficiently big, banking systems improve economic efficiency by finding productive opportunities and converting savings into the necessary investment to finance such opportunities. However, resource allocation may

7 This is accomplished using Powell (2020)'s STATA-package (qregpd), which uses a Markov chain Monte Carlo (MCMC) estimation approach to estimate standard errors. The algorithm performs 1000 drawings with a 0.5 acceptance rate.

become inefficient, raising consumption, investment, economic growth, and energy use, increasing CO2 emissions.

The impact of credit (CRE) shows mixed results on Co2 emissions. The quantile regression results show that the impact of credit risk is negative and significant in the higher Co2 emission countries (70 and 95 quantiles). These findings are consistent with the idea that banks are more environmentally sensitive than other lenders (See e.g., Lins et al., 2017; Chang et al., 2021; Reghezza et al., 2021). According to their social responsibility, banking systems significantly impact climate change by reallocating credit from polluting firms. Nevertheless, in countries with lower Co2 emissions (25th and 50th quantiles), the coefficients are positive and statistically significant, indicating that credit risk enlarges Co2 emissions and drives the deterioration of the environment. These findings are in line with Sadorsky (2010) Prochniak and Wasiak (2017) Prochniak and Wasiak (2017), Credit expansion attracts foreign direct investment accelerates economic growth, and induces customers to purchase more goods and services, thereby boosting human activities, which consume energy and add to Co2 emissions.

Capital adequacy (CAR) has a mixed impact on Co2 emissions. The quantile regression results show that the impact of capital adequacy is negative and statistically significant and turns out to be consistently decreasing in the 25^{th} to 75^{th} quantiles. Higher capital adequacy boosts lending rates, diminishes the supply and demand of credit, and causes a slowdown in bank lending and economic growth (Martynova, 2015; Prochniak and Wasiak, 2017; Reghezza et al., 2021), where banking systems with a high capital adequacy level push banks out of climate-sensitive systems and towards greener businesses. This means pushing for a reorientation of capital allocation concerning meeting reducing CO2 emissions targets to achieve net-zero emissions (Reghezza et al., 2021). However, in the 95^{th} quantile, the coefficient is positive; this finding aligns with (Gambacorta and Shin, 2018). Banking systems with a higher equity basis lend more, reduce funding costs, and enhance investment activities, thus, economic growth and consumption. This result confirms that high capital adequacy countries are enough to contribute to increasing the Co2 emission significantly and drive environmental pollution. This leads us to conclude that the current credit and capital adequacy rationalization of banking systems may benefit society in environmental terms, and its drawbacks can easily be overcome, such as sound policies and due diligence efforts.

Table 5 Quantile regression results.

Dependent variable:CO2	Quantile Coefficient			
	25%	50%	75%	95%
SIZE	0.480***	0.423***	0.613***	0.731***
	(0.002)	(0.004)	(0.000)	(0.026)
CRE	0.117***	0.023***	-0.011***	-0.046***
	(0.002)	(0.006)	(0.000)	(0.017)
CAR	-0.058***	-0.029***	-0.034***	0.025***
	(0.000)	(0.001)	(0.000)	(0.004)
GDP	0.044***	1.122***	0.128***	-1.767***
	(0.016)	(0.145)	(0.002)	(0.361)
REC	-0.036***	-0.038***	-0.030***	-0.025***
	(0.000)	(0.000)	(0.000)	(0.001)
POP	-0.015***	-0.062***	-0.126***	-0.067***
	(0.001)	(0.002)	(0.000)	(0.003)

***, **, and * indicate significance at 1%, 5%, and 10%, respectively. The brackets represent the standard deviation.

The GDP growth (GDP) has a mixed impact on Co2 emissions. The quantile regression results show that the impact of GDP growth is negative and statistically significant emissions in the higher CO2 emissions countries (quantile 95). This result confirms that high GDP Growth is enough to decrease the Co2 emission significantly and improve the environment, where growth can improve environmental quality. Increased incomes, for example, provide the resources for public services such as sanitation and electricity. However, in the 25^{th} to 70^{th} quantiles, the coefficients are positive and statistically significant. These findings are in line with (Bilgili et al. (2016), Zoundi (2017), Apergis et al. (2018), and Sharif et al. (2019). Therefore, it is essential to consider these differences when energy policy is developed across countries.

Renewable energy consumption (REC) negatively and significantly impacts Co2 emissions across all quantities. However, the coefficient of Renewable energy consumption at the 25th, 50th, 75th, and 95th percentiles are not the same, meaning that the impact of Renewable energy consumption across the different quantiles is plunging. Furthermore, the results indicate that the negative impact of renewable energy consumption on low Co2 emissions countries is high compared to higher Co2 emissions countries (see, e.g., Bölük and Mert, 2014; Salahuddin et al., 2020), indicating that renewable energy consumption mitigating Co2 emissions and improving the environment and contributes to achieving the emission-reduction targets for society. Moreover, governments that want to encourage renewable energy infrastructure and consumption should adopt rules that better coordinate the banking system's efforts to support new energy projects and reduce CO2 emissions.

The population (POP) impact on Co2 emission is negative and significant across all quantities. This finding reveals that population expansion is not the positive driving force behind climate change. However, having more people does not always imply increased emissions from fossil fuel usage. Instead, people may find ways to reduce their consumption and satisfy their requirements without using fossil fuels, improved agricultural technology, or population control Policy such as China. These results are consistent with Fan et al. (2006), Dalton et al.(2008), Liu et al. (2015), and Ribeiro et al. (2019), where high population density, densification of largely populated urban areas, and high-income level with population ages (15 to 64) reduces CO2 emissions. Further, the coefficient of POP at the 25^{th}, 50^{th}, 75^{th}, and 95^{th} percentiles is not the same, meaning that the impact of POP across the various quantiles is gradually increasing. Therefore, our results indicate that the negative impact of POP is lower on low Co2 emissions countries compared to higher Co2 emissions countries.

In sum, the bank system is critical to achieving a net-zero carbon future. Nevertheless, the banks make their most significant contribution to climate change through their loans and investment portfolios. The industry faces pressure to pare back lending to oil firms, where the biggest banks are so heavily stuck with fossil fuel assets that they cannot stop financing those companies without putting their stability at risk. Therefore, big banks may either be enablers for polluting sectors, providing finance for extraction and drilling to the world's largest polluters. On the other hand, banks are known for pressuring businesses to reduce emissions by monitoring and reporting carbon emissions associated with their loans and investments and fostering low-carbon industries. Also, the real economy shift will need a significant infusion of money aimed at decarbonizing the economy and improving resilience, which only the banking system can enable and provide.

5. Robustness tests

We perform a robustness test to check the robustness of our results. We perform the same analysis using dynamic panel-data estimation, two-step system GMM method of Arellano & Bover (1995) and Blundell & Bond (1998). In Table 5, we use alternative GMM models. Overall, we observe that the findings of the system GMM method do not differ significantly either in sign or significance from the results of the Quantile regression method. Further, the significance of the system GMM results depends on the absence of autocorrelation and the validity of the instrument matrix. Our model shows that autocorrelation tests AR (1) residuals are correlated with order (1), but not at AR (2). Also, Hansen tests indicate the validity of the instruments matrix.

Table 6 Dynamic panel-data estimation, two-step system GMM

Dependent variable: CO2	Coefficient	Standard Error	t. statistic	P-Value
Lag.CO2	0.792	0.015	53.640	0.000
SIZE	0.149	0.015	10.240	0.000
CRE	-0.101	0.018	-5.470	0.000
CAR	-0.003	0.010	-3.280	0.002
GDP	0.535	0.040	13.280	0.000
REC	-0.011	0.001	-13.030	0.000
POP	-0.037	0.010	-3.900	0.000
Constant	1.184	0.183	6.490	0.000
Arellano-Bond test for AR(1)				0.000
Arellano-Bond test for AR(2)				0.164
Hansen test				0.159

6. Conclusion and Policy Implications

The most critical challenge to evolving towards reducing CO2 emissions is that infrastructure and operating costs are required to overcome energy-intensive investment in fossil fuels. Therefore, it is vital to have banking system-specific characteristics that help develop the eco-friendly industrial sector. Thus, this article examines the impact of banking system-specific aspects (bank size, capital adequacy, and credit) along with some other control variables, such as renewable energy consumption, economic growth, and population, on CO2 emissions in 66 selected countries. To this end, a novel method of Quantile Regression of Powell (2020) is applied for panel data from 2000 to 2017.

Based on the quantile regression results, we reveal a homogeneous positive and significant impact of banking system size on CO2 emissions across all quantiles, indicating that banking system size has a damaging effect on the environment. The bigger size of the banking system increases excessive credit growth and overreliance on wholesale funding that raises consumption, investment, economic growth, energy use, and finance fossil fuel corporations, leading to more CO2 emissions. On the other hand, banking system credit significantly increases emissions in the 25^{th} and 50^{th} quantiles (i.e., lower emissions countries), indicating that credit drives various manufacturing activities, attracts foreign direct investment to accelerate economic growth, and encourages energy consumption through individuals consuming more durable goods such as automobiles, and electronic devices. At the same time, banking system credit significantly reduces emissions in the 70^{th} and 95^{th} quantiles (i.e., higher emissions countries), indicating that banks reallocated credit away from polluting firms or that firms have more significant environmental responsibility. Furthermore, the banking system's capital adequacy indicates a significant heterogeneous impact; it reduces CO2 emissions in the 25^{th} to 75^{th} quantiles, indicating that banks with high capital levels, lower credit quality, and low profits are pushing banks out of climate-sensitive systems and towards greener businesses. At the same time, banking system capital adequacy increases CO2 emissions in the 90th quantile (i.e., higher emissions countries).

Regarding other explanatory variables (economic growth, renewable energy consumption, and population), we find that economic growth has a positive and significant impact on CO2 emissions in all quantiles, except a negative and significant impact in the 95^{th} quantile (i.e., higher emissions countries). This suggests that further economic growth exacerbates environmental degradation in the low and middle emitting countries. Therefore, policymakers must consider the trade-off between economic growth and environmental quality. Furthermore, renewable energy use and population negatively and homogeneously significantly impact CO2 emissions across all quantiles, indicating that generating renewable energy is crucial for reducing emissions and meeting the Paris Climate Agreement's goal of limiting global temperature rise to 1.5 ^{0}C.

Decision-makers should take adequate steps to promote banking systems to optimize the loan structures to encourage energy-saving and Co2 emissions reduction, with confirming the bank's commitment to social responsibility by pursuing and increasing environmental and social risk management. Against this context, there must be a clear role for regulators in supporting the banking systems in alignment with the goals of the Paris Agreement. Rather than targeting banking systems directly, policies to reduce CO2 emissions should address the underlying risk factors. For example, incentives that increase banking system size may be reduced, such as tax incentives. Also credit expansion, by reducing the guarantees of environmentally friendly companies. In addition, macroprudential instruments such as the countercyclical capital buffer and additional requirements can also help in strengthening the banking systems' role.

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