# Global Assessment of Banks' Capacity to Support the Expansion of Renewable Energy

Gláucia Fernandes Vasconcelos*

Layla dos Santos Mendes†

Marcelo Martins Tachy ‡

**Abstract**

Substantial investments in renewable energy technology are needed to achieve sustainable development goals, reduce reliance on fossil fuels, and ensure access to clean and stable energy. However, securing funding for these initiatives is challenging, relying heavily on extensive financial support from banks. In response to this challenge, this article establishes a relationship between market-based default risk measures, such as Distance-to-Default (DD) and Distance-to-Capital (DC), and the proportion of renewable energy in a country's total energy supply. We collected data from a sample of 1,373 international banks across 27 countries from 2009 to 2022, using an ordinary linear fixed-effect model. After reviewing the literature, we categorized the study into two homogeneous sub-panels based on income group classification (developed or emerging countries). Overall, our results indicate that increasing the share of renewable energy in a country's total energy supply significantly reduces bank default risk. For developed countries, an increase in renewable energy generation, an expansion in bank size, and a decrease in $CO_2$ emissions have

*Assistant Professor of Finance at the COPPEAD Graduate School of Business, Federal University of Rio de Janeiro. E-mail: glaucia.fernandes@coppead.ufrj.br

†Professor of Finance at the EPGE Brazilian School of Economics and Finance, Getulio Vargas Foundation. layla.mendes@fgv.br

‡Master researcher at the COPPEAD Graduate School of Business, Federal University of Rio de Janeiro. E-mail: mmtac@hotmail.com

positive effects on the possibility of bank default risk. On the other hand, our results show an inverse relationship for banks in emerging countries. Economic growth and bank size emerge as other significant determinants of bank default risk. To ensure the robustness of our findings, we conducted several tests, all of which validated our results. In conclusion, our study underscores the crucial role of a banking system in facilitating investments in renewable energy.

**Keywords:** Renewable Energy, Bank Risk, Developing Countries, Panel data

**JEL codes:** G10, G21, G28, Q01, Q43

# 1 Introduction

In recent years, electricity generation from renewable sources has rapidly increased (Hassan et al., 2024). For example, the contribution of solar photovoltaics to global electricity generation grew from 1 TWh in 2000 to 435 TWh in 2017 (Energy, 2018). However, to achieve the 2°C target outlined in the Paris Agreement, an ongoing shift from fossil fuels to renewable energy is essential. By 2040, global $CO_2$ emissions must be slashed by half from their current levels (IEA, 2019). Addressing this twofold challenge necessitates substantial investments in renewable energy technology, which demands backing from financial institutions. To meet the sustainable development scenario, it's estimated that annual global investments in renewable energy will need to surge by 97 percent compared to current levels (Energy, 2018).

Banks are expected to play a key part in assisting a country's shift to renewable energy and strengthening its financial resilience to environmental risks (Mazzucato and Semieniuk, 2018). Nevertheless, high exposure of the banking sector to renewable energy could cause concern for their survival, which may hinder their active engagement in this sector (Safarzyńska and van den Bergh, 2017a). Unless this fear of default is addressed, the required financial participation of banks in renewable energy will hardly reach the required level.

This study evaluates panel data of listed banks and the share of renewable energy (REN) in the total energy supply of 27 countries from 2009 to 2022. Our results show a significant positive relationship between REN and two measures of bank-specific credit risk (i.e., distance to default [DD] and distance to capital [DC]). Our results align with Choudhury et al. (2021), showing that increasing REN significantly reduces banks' default risk. However, this study further tests the risks banks face in emerging and developing countries, finding that while the risk of default is decreasing for banks in developed countries, it is increasing for those in emerging countries. This contrasts with Amuakwa-Mensah and Näsström (2022), which argued that improved banking sector performance enhances renewable energy consumption in middle-low-income countries. These results remain consistent with a large number of robustness tests, including using alternative measurements of renewable investment, using alternative proxies of bank-specific credit risk, breaking down the sample between more and less polluting countries, controlling for bank, country, and year fixed effects, excluding the global crisis during Covid-19, and using alternative estimation techniques (i.e., GMM regression, propensity score matching).

Our work is closely related to research by Choudhury et al. (2021) and Nadeem et al. (2017) that considered an analysis of bank-specific credit risk worldwide using the DD and DC measures. However, our paper is different from theirs in four important aspects. First, we expanded our sample to cover 38 countries and 2174 banks, representing a 90% increase in the number of banks and a 2,618% increase in the number of countries included (Choudhury et al., 2021). Therefore, our findings captured the nuances of global economic factors associated with REN in managing risk. Second, Choudhury et al. (2021) did not comment on the role of emerging countries in REN and bank risk. Our findings explored this theory, highlighting that merely increasing investment in renewable sources in underdeveloped countries does not provide robust evidence of risk reduction. Third, Choudhury et al. (2021) and Nadeem et al. (2017) had different proxies than the present study. We rely on more robust measures to capture investment in renewables (i.e., the share of low carbon in the total primary energy supply and public investment) and to capture country-level fluctuations regarding gross domestic product (GDP) and population growth. Fourth, in contrast to Choudhury et al. (2021) and Nadeem et al. (2017), we assessed Pearson's correlation to select the best World Bank indicator among the countries.

Our findings contribute to both REN and risk management literature. This study contributes to calls for sectorial-focused studies by investigating REN's growth role in banking's risk of default. It further provides an excursion to prior literature that heavily focused on renewable energy technologies in the non-financial sector. Our paper also contributes to the inconclusive debate over emerging countries and firm risk. Finally, although investment in renewable energy in emerging countries is linked with lower technology costs, evidence concerning which sources of REN affect a firm's outcome is limited.

The rest of the paper is organized as follows. Section 2 reviews the literature and outlines the research hypotheses to be examined. Section 3 delves into the methodology, covering the measurement of variables, model estimation, and data analysis procedures. In Section 4, several robustness tests are outlined. Section 5 concludes the study by discussing the results and their implications for policy.

# 2 Theoretical rationale and hypothesis development

## 2.1 Renewable Energy Investments

Policy developments, increased environmental awareness and the urgent need to address climate change have significantly transformed the history of investment in renewable energy in recent decades. The global increase in investments in renewable energy sources – such as solar, wind, hydro and biomass – reflects a collective movement towards sustainable development and the reduction of carbon emissions. The role of government policies and incentives in defining investments in renewable energy and the implications for the risk environment of the banking sector becomes fundamental.

Commitment to renewable energy has historically been spurred by recognition of the finite nature of fossil fuels and the environmental consequences of their consumption. The oil crises of the 1970s served as a warning, leading to initial explorations of alternative energy sources. However, it was only at the end of the 20th century and the beginning of the 21st century that significant political changes and technological advances began a more pronounced transition to renewable energy. Countries around the world have begun implementing policies designed to promote the adoption of renewable energy, ranging from subsidies and tax incentives to mandates for the use of renewable energy (Cui et al., 2018).

The impact of government rules and benefits is vital in guiding investments in renewable energy, adjusting the risk versus reward scenario. Government-backed strategies such as feed-in tariffs, renewable energy portfolio standards and tax incentives amplify the appeal of investing in green energy initiatives, ensuring stable profits and decreasing financial risks. These policies, by offsetting the higher initial costs and mitigating the perceived risks of renewable energy projects, encourage banks and other financial institutions to allocate capital to these ventures (Gatzert and Kosub, 2016).

Political stability, technological advances, market demand for renewable energy and the global economic climate are some of the many factors that influence the risk environment for banks when considering investments in renewable energy. Particularly political and regulatory risks are very worrying, as political changes can have enormous effects on the viability of renewable energy projects. The introduction of supportive policies can mitigate these risks, while political uncertainty can exacerbate them, making risk management a critical analysis for banks involved in renewable energy financing (Hulshof and Mulder, 2020).

Aligning financial returns with positive environmental impacts provides a unique opportunity for banks to engage in sustainable financing through this shift to renewable energy. The literature highlights cases where green loans have not only reduced credit risk but also improved banks' environmental and financial performance, as seen in the case of China's green credit policy (Cui et al., 2018).

However, the inherent risks associated with renewable energy investments, such as technological risks, market competition and dependence on subsidies, require a cautious approach, emphasizing the need for comprehensive risk assessment and innovative financing models (Safarzyńska and van den Bergh, 2017a).

## 2.2 Banks' role

Renewable energy projects require a substantial initial investment. Banks and other financial institutions are crucial in bridging this funding gap through a variety of financial instruments and models. For example, green bonds and loans have emerged as essential tools, offering a way for investors to get involved in environmentally sustainable projects. The positive correlation between green loans and reduced credit risk highlights the dual benefit of such instruments in promoting environmental sustainability and financial performance. Cui et al. (2018) examined China's green credit policy, concluding that green loans carry lower credit risk than non-green loans, thereby improving banks' environmental and financial performance. This positive correlation between green loans and the reduction in non-performing loan ratios suggests that institutional pressures, such as the Chinese Green Credit Policy, can effectively mitigate financial risks while promoting environmental sustainability.

However, the volatile nature of renewable energy sources and their dependence on fluctuating market prices present significant risks. Energy markets are inherently unstable due to variable demand, regulatory changes and fluctuations in fuel prices, directly impacting the profitability and risk profile of renewable energy investments. Gatzert and Kosub (2016) investigate the political and regulatory uncertainties that exacerbate these risks, requiring innovative risk management and transfer solutions to promote sustainable growth. They highlight how political and regulatory risks present major barriers to investments in renewable energy in Europe, a sentiment shared by (Abba et al., 2022) in the context of developing countries, particularly in Sub-Saharan Africa. These studies illustrate that, regardless of economic development, uncertainty and variability in political and regulatory frameworks are universal challenges that require innovative risk management and financing solutions.

Additionally, the challenges of renewable energy projects – from technological reliability to issues of maintenance and network integration – pose additional risks that can interfere with the financial health of the banks involved. These operational risks are intrinsically linked to the financial performance of renewable energy projects, affecting loan repayment rates and, by extension, credit risk for banks. Such challenges highlight the need for comprehensive risk assessments and mitigation strategies to safeguard financial stability (Safarzyńska and van den Bergh, 2017a).

Diversity and innovation are necessary to face these challenges, through different renewable energy financing models. Public-private partnerships, for example, have been fundamental in mobilizing public funds to attract private investment, thus sharing the risk and increasing the viability of renewable projects. Furthermore, the role of government policies, such as feed-in tariffs and tax incentives, in stabilizing the renewable energy market cannot be overstated. (Taghizadeh-Hesary and Yoshino, 2020) argue for leveraging public financial institutions and financial instruments, such as indirect taxes and green credit guarantee schemes, to increase the attractiveness of investment in renewable energy projects. Mazzucato and Semieniuk (2018) discuss how public financial actors in developed countries are more willing to invest in higher-risk renewable energy technologies, contributing to the directionality of innovation in the sector. This willingness to embrace risk for the sake of innovation contrasts with the situation in many developing countries, where investments often focus on more established renewable technologies due to greater sensitivity to risk and limited financial resources for speculative ventures.

The banking sector's involvement in renewable energy financing is not only aimed at mitigating risks, but also taking advantage of the opportunities that the global shift towards sustainability presents. Innovative financing solutions, effective risk management strategies and a stable policy environment are needed. If equipped with the right tools and strategies, aligning financial objectives with environmental sustainability, banks can play a transformative role in this transition.

## 2.3 Renewable Energy and Banking Risks

The relationship between renewable energy investments and banking risks has received significant attention in academic and financial circles, especially considering the global push towards sustainable development. Empirical analyzes exploring this relationship have produced diverse results, reflecting the complex interaction of economic, environmental and regulatory factors that influence the risk profile of the banking sector.

The methodologies used in these studies ranged from quantitative analyzes of loan performance and risk metrics to qualitative assessments of policy impacts on banking stability. For example, the Analytical Hierarchy Process was used by Zhou and Yang (2020) to classify investment risks in distributed wind energy, highlighting the importance of stable electricity pricing policies in mitigating risks. These methodologies reveal the complex nature of assessing banking risks related to renewable energy, encompassing not only financial metrics but also political and regulatory environments.

The variation in results between different countries and regions can be largely attributed to economic, environmental and regulatory peculiarities. Both developed and developing countries face significant policy and regulatory risks, which impact the financing of renewable energy projects. For example, in BRICS countries, Zeng et al. (2017) identified specific challenges, including financing constraints and investment shortages for small and medium-sized enterprises, which are less prevalent in developed economies. Developed countries, as highlighted by Safarzyńska and van den Bergh (2017a), face financial stability risks arising from rapid investments in renewable energy, reflecting the complex integration of renewable energy into existing financial and energy systems. This contrast highlights the significant impact of regional peculiarities on the relationship between investments in renewable energy and banking risks.

Existing studies, although extremely valuable, end up being limited by their regional focus, given the different market characteristics, technological trends and regulatory policies of each region. This study aims to address these limitations by carrying out an analysis of the returns and possible risks associated with investing in green energy, but from the point of view of Brazilian banks. This study will give us a deeper look at how investing in renewable energy affects bank returns on a global scale.

## 2.4 Hypothesis

We postulate our first hypothesis in line with the resource dependence theory and acknowledge energy source differences in decision-making.

*H1*: Expansion in the share of renewable energy in the total energy supply of a country decreases the likelihood of banks facing defaults.

The underlying assumption that supports Hypothesis 1 is the positive relationship between renewable energy and firm profitability. According to the model proposed by Safarzyńska and van den Bergh (2017b), an increase in profitability tends to increase the likelihood of a company honoring a bank loan, thus reducing the risk of default for the bank. On the other hand, if the company chooses to purchase renewable energy from external sources instead of producing it internally, its improved profitability can increase the likelihood of paying off energy-related expenses, thus benefiting the supplying power plants. Consequently, these plants will be in a more favorable position to honor their obligations to the bank, also helping to reduce the risk of default. In any case, promoting renewable energy financing has the potential to help banks mitigate their risk of default.

However, scholars also asserted that the governments of many developing countries have taken measures to commit and ensure a reduction of carbon emissions, emphasizing the transformation to renewable energy as a key strategy (Zeng et al., 2017; Amendolagine et al., 2019; Wang et al., 2022). Nonetheless, despite these efforts, the financial constraints prevailing in many of these countries are sometimes an almost impossible challenge. In this case, private sector engagement is a necessity rather than an option, as this sector can facilitate and aid in renewable energy investment with strong benefits for the country and non-government businesses. But, as Unep (2007, 2004) highlights, developing countries use public and concessional resources to attain the aid of the private sector, even though this does not fully address the different challenges or risks that the private sector experiences. On the other hand, Cicea et al. (2014) points out that the use of these instruments to engage the private sector has the dual benefit of being more sustainable and minimizing the instability that this could bring to the industry; while augmenting the competitiveness of the renewable energy market. Therefore, we postulate the following hypothesis to fill this literature gap:

*H2*: The relationship between the share of renewable energy in a country's total energy supply and bank-specific credit risk will be more pronounced in developed countries than in emerging countries.

# 3 Data and methodology

## 3.1 Data

We collected renewable energy data from the International Energy Agency (IEA) for 2009–2022. We started in 2009, when IEA started its coverage. Following this, we collected information on bank financial characteristics from Eikon Thomson Reuters. Data on world governance indicators, gross domestic product, and population were obtained from the World Bank website. We used the Eikon Thomson Reuters for the information to capture bank-specific credit risk (i.e., the processes mentioned in Section 3.2; DD and DC). Merging all data yielded a final sample of 12,717 bank-year observations across 27 countries. The list of the number of banks by country used in our analysis is demonstrated in Table 1.

<Insert Table 1 around here.>

## 3.2 Variable definitions

### 3.2.1 Dependent variables

We capture bank-specific credit risk using different distance to risk-based models. In the literature, two categories of default risk indicators are identified: accounting-based and market-based. Accounting-based measures include Z-score, nonperforming assets ratio, profitability ratio, and leverage ratio, while market-based measures include the Kealhofer Merton Vasicek (KMV) DD, equity returns, equity volatility, and market capitalization to total debt. Merton (1974) first introduced DD in his seminal work, referring to the distance between the bank's given position and default position where default is a position in which the bank's asset value goes under the liability value threshold (Milne, 2014). Later studies extended the same model by introducing DC (Ji et al., 2019). DC shows the capital buffer drilled before reaching the default Harada and Ito (2011).

Although accounting-based measures have been extensively studied regarding financial stability and their relationship with market competition, there is limited literature on market-based measures like DD (Khan and Ahmad, 2022). Market-based measures, such as DD, offer advantages over accounting-based measures by incorporating forward-looking information from the stock market, reflecting market perceptions of a bank's performance (Denzler et al., 2006; Nadeem et al., 2017; Kabir and Worthington, 2017). This paper adopts the DD and DC measures to calculate bank-specific credit risk.

Theoretically, DD refers to a position where a firm's market value of assets $A_t$ is lesser than its value of liability $L_t$ (Dar and Qadir, 2019). Following Choudhury et al. (2021), Eq. (1) presents the $DD_t$ at time $t$:

$$DD_t = -\frac{ln(L_t) - [ln(A_t) + (\mu - 0.5\sigma_A^2) \cdot (T-t)]}{\sigma_A \sqrt{T-t}} \tag{1}$$

where parameter $\mu$ is the expected drift in the asset $A_t$, modelled by the risk-free return, and $\sigma_A$ is the asset volatility.

The DC is an alternative credit risk measure based on a different approach than DD but has its roots in the credit risk structural model. It uses the prompt corrective action (PCA) and Basel framework's capital adequacy ratio (CAR) to fine-tune DD, where CARt is at least 8%. Following Chan-Lau and Sy (2007) and Eq. (1), we can derive $DC_t$ in Eq. (2):

$$DC_t = \left[ ln \left( \frac{A_t}{\frac{1}{1-CAR_t} Lt} \right) + (\mu - 0.5\sigma_A^2)T \right] \left( \sigma_A \sqrt{T} \right)^{-1} \tag{2}$$

### 3.2.2 Explanatory variables

Data on the share of renewable energy in a country's total primary energy supply (REN) were sourced from the official International Energy Agency website. Although we acknowledge the possible heterogeneous effect of bank's default risk on the disaggregated renewable energy sources (such as solar and wind), our study focuses on the total renewable energy as a share of the total energy supply due to data limitation for the countries and the time period considered in this study.

In this paper, we use five variables related to bank performance from Eikon Thomson Reuters to estimate the relationship between bank default and the proportion of renewable energy in a country's supply. These are return on equity (ROE) (Trad et al., 2017), the size of the bank (natural logarithm of total assets), the leverage of the company (debt ratio) (Capasso et al., 2020), the price-to-book ratio (PB ratio) (Switzer et al., 2018), and revenue growth (Stiroh, 2006).

Regarding control variables used, Omri and Nguyen (2014) have studied the determinants of renewable energy consumption. They find GDP to have effects on renewable energy consumption but show heterogeneous results across the different income groups. In this paper, GDP growth serves as a measure of output. Population growth is included as a control variable as it has been proven to have a significant effect on energy use (Li and Lin, 2015; Amuakwa-Mensah and Näsström, 2022). Some variables in the data contain missing values making the panel unbalanced. Data on renewable energy and other macroeconomic variables are collected from the World Bank's World Development Indicator (WDI).

### 3.2.3 Regression Model

We use the following regression model to examine the effect of an increase in renewable energy proportion in a country's primary energy supply on bank-specific credit risk:

$$CR_{i,t} = \alpha + \varphi REN_{i,t} + \gamma^{'} C_{i,t} + \varepsilon_{i,t} \tag{3}$$

where $i$ represents the bank and $t$ represents the time (i.e., year). The dependent variable $CR_{i,t}$ is one of the bank-specific credit risk variables ($DD_t$ and $DC_t$) defined in Eqs. (1) to (2). $REN_{i,t}$ represents the main independent variable of interest (i.e., REN). The vector $C_{i,t}$ represents a comprehensive set of $k$ control variables; $\alpha$ is a constant, and $\varphi$ and $\gamma$ are the estimated coefficients for the $REN_{i,t}$ and $k$ control variables, respectively; $\varepsilon_{i,t}$ is the residual of the model. Since bank risk varies across different banks and over time, we included bank and year-fixed effects in all our regressions, except when mentioned otherwise.

As pooled OLS regression estimates the model assuming the underlaying relationship as static, its results could be invalid if the actual relationship among the variables is found to be dynamic. To test the nature of the relationship between REN and DD, we estimated the dynamic model (Eq. 4) using OLS regression after controlling the same bank-specific and country-specific variables.

$$CR_{i,t} = \alpha + \beta CR_{i,t-1} + \varphi REN_{i,t} + \gamma^{'} C_{i,t} + \varepsilon_{i,t} \tag{4}$$

Lagged estimator ($CR_{i,t-1}$) was added in the regression model to test the dynamic nature of the model (Nadeem et al., 2017).

# 4 Empirical Analysis

## 4.1 Descriptive statistics

We present the descriptive statistics in Table 2, followed by the Pearson correlation matrix for all the variables in our study in Table 3.

<Insert Tables 2 and 3 around here.>

In order to further limit the influence of outliers, we winsorize bank-control variables in the model at the 5th and 95th percentiles. That is, we replace any observation below the 5th percentile with the 5th percentile and any observation above the 95th percentile with the 95th percentile.

In addition, we used a formal test to ensure that the multicollinearity problem was adequately addressed. We calculated the variance inflation factor (VIF) for each independent variable in our models. The largest VIF values are 1.87 and 1.91, which confirms that there is no multicollinearity problem in our sample because it is far from 5 (Studenmund and Cassidy, 1997).

## 4.2 Baseline results

First, we tested the Breusch and Pagan Lagrangian multiplier test for random effects for both dependent variables used in the main model specification (DD and DC), and the null hypothesis that variances across entities are zero was rejected (DD: LM = 31229.49, $p < 0.001$; DC: LM = 8610.47, $p < 0.001$), so the random effect model can deal with heterogeneity better than pooled OLS. Then, we estimated the Hausman test to select the appropriate estimation method. Rejecting the null hypothesis ($p < 0.00$, for both dependent variables) results in the most appropriate method being fixed effects. We also use robust standard errors in our estimations in order to ensure that the covariance estimator handles heteroscedasticity of unknown form.

The results obtained from Eq. (4) appear in Table 4 that summarizes the empirical results for our main bank-specific credit risk measures, distance to default risk (DD) and distance to capital risk (DC).

<Insert Table 4 around here.>

In full estimation, we found a positive and statistically significant at 1% level the relation between DD and the share of renewable energy in the total energy supply of a country. The same result was found to DC and REN. In other words, countries that expand investments in renewable energy reduce banks' default risk by increasing DD and DC, thus confirming the H1 hypothesis proposed in this study and corroborating with previous literature (Choudhury et al., 2021).

Additionally, we split up the sample in developed and emerging countries to test the hypotheses H2 and present the estimated results in Table 5. For developed countries, we find the same results, REN coefficient is positive and significant, which implies that ceteris-paribus, more investment in renewable energy, reduces the chances of default of that bank. On the other hand, this effect is negative and significant for emerging countries. This result is probably due to the fact that banks in emerging markets perceive higher risks associated with financing renewable energy projects, leading to a reluctance to extend credit or invest in this sector.

<Insert Table 5 around here.>

# 5 Robustness

We performed several tests to confirm the robustness of our baseline findings, such as: matching, alternative explanation variables, covid-19, $CO_2$ emission and the generalized method of moment (GMM).

We use Mahalanobis distance matching (MDM) and propensity score matching (PSM) to match banks from developed countries to banks of emerging countries on several covariates. In the end, we had a sample of 4,034 observations being 2,562 from developed countries and 1472 from emerging countries. Figure 1 shows the balancing of the sample among the covariates: bank Size, leverage, ROE, PB ratio, and revenue growth. Table 6 shows the results that reproduce our main findings and confirm our hypotheses H2, thus lending credibility to our results.

<Insert Figure 1 and Table 6 around here.>

Although renewable energies are generally considered to be more sustainable and environmentally friendly, the term "low carbon" can cover a broader range of energy sources that, although not renewable, have relatively low carbon emissions. As the relationship between "share of low carbon" and DD was similar but less strong than the relationship initially observed with REN (see Table 7), this indicates that banks are responding more positively to renewable energies than to other low-carbon energy sources. A similar result can be seen for emerging and developed economies.

An increase in public investment in renewable energy could indicate a stronger commitment on the part of the government to the energy transition. This could lead banks globally to perceive that there is a favorable environment for growth and sustainability in the renewable energy sectors, which could increase confidence in the economy and, by extension, reduce banks' perceived risk of default. However, in emerging countries, financial resources can be limited and allocated less efficiently. A significant increase in investments in renewable energies can lead to competition for these resources, thus reducing the availability of credit for other sectors of the economy. This can negatively affect the ability of companies and individuals to honor their financial commitments, increasing the risk of bank defaults.

<Insert Table 7 around here.>

To explain the impact of the COVID pandemic on banks' credit risk, we estimate the main model, which includes periods before and after the mentioned pandemic. In our sample, the pre-pandemic period is between 2017-2019, and the post-pandemic period is 2020-2022. We follow the same estimation pattern of Eq. 4 with a full sample model as shown in Table 8. The coefficients of the REN are positive and significant at the 1% level, which corroborates the main findings.

<Insert Table 8 around here.>

For the analysis of countries with different levels of $CO_2$ emissions, our results indicate a significant and positive relationship between the financial stability of banks and the adoption of renewable energies in countries belonging to the fourth quantile. The transition to renewable energy can be driven by government policies and regulations that promote environmental sustainability. These policies can include financial incentives for clean energy projects, such as subsidies, tax exemptions, and renewable energy targets. By supporting the adoption of renewable energy, these policies can contribute to the financial stability of banks by reducing the risk associated with energy investments.

<Insert Table 9 around here.>

We estimate our models using the two-step generalized method of moments (GMM) estimator based on Arellano and Bond (1991), allowing us to control for endogeneity using instruments. Specifically, we have used all the right-hand-side variables in the models, lagged up to four times, as instruments in the difference equations[1]. The results in Table 10 portray that the REN is positive and significant for both credit risk measures, DD and DC, thus confirming our main findings in Hypotheses H1.

<Insert Table 10 around here.>

[1]We need to define the number of lags because an extensive instrument collection overfits endogenous variables even as it weakens the Hansen test of the instruments' joint validity (Roodman, 2009).

## 5.1 Implications

Based on our results, renewable energy consumption, globally and for the two income groups, is significantly affected by the majority of the banking performance variables. We have summarised our results from Tables 4 to 10 in Table 11 for DD and Table 12 for DC to ease comparative discussion on the effects of banking performance indicators on renewable energy generation.

<Insert Tables 11 and 12 around here.>

These results have significant implications for understanding the factors that influence bank default risk in different economic contexts. The relationship between the share of renewable energy in primary energy supply (REN) and the risk of bank default varies between developed and emerging countries. While in developed countries REN reduces the risk of default, in emerging countries it increases the risk. This suggests that the transition to renewable energies may be more advantageous for banks in more mature economies, where economic and regulatory conditions may be more favorable for sustainable investments. Financial factors such as Bank Size, Debt to ratio, ROE, Revenue growth and GDP growth have a general effect of reducing the risk of bank default in all the contexts analyzed. This suggests that the financial health of banking institutions, their operating performance and economic growth are key elements in determining default risk.

# 6 Discussion and Conclusion

Renewable energy forms a large part of the energy mix for power generation in many countries. Global efforts to combat climate change are forcing companies to prioritize the reduction of carbon emissions through adopting renewable energy sources, making financing renewable energy a vital necessity. Renewable energy targets have been set in more than 164 nations (Philip et al., 2022), but developing countries face substantial challenges in transitioning to renewable sources. These include financing, knowledge management, legal framework and implementation, as well as the need for political leadership and transparency.

This document focuses on economic understanding, highlighting the challenges faced by banks in developed and emerging countries in intensifying renewable energy participation in the energy matrix. Limited resources in developing countries often force these nations to persist with outdated financial methods and tools. As many developed countries increase their financial support efforts, a better understanding of the economic implications will empower policymakers and decision-makers. This understanding is key to maximizing the benefits of renewable energy deployment.

Developed countries have strengthened investor confidence by setting reliable and time-sensitive renewable energy targets. These targets not only chart the course of renewable energy development in today's energy sector but also provide a roadmap for future financing tools. Recognizing that policy implementation alone may not be enough, developing countries often take a multi-pronged approach to ensure a stable investment environment and help address non-economic barriers, such as social and environmental concerns.

One of the biggest challenges that new financial trends face in developing countries is the perception of risk due to the inaccurate and sometimes misleading knowledge that some developing countries have regarding the cost and generation of renewable energy and the decisions based on policymakers (Mazzucato and Semieniuk, 2018). This is due to a lack of government transparency and methodology, along with a lack of reliable data, resources, and assumptions used to make cost calculations. Developing countries find themselves at a crossroads regarding investments in the clean technology sector. Therefore, securing funding for projects from local or international sources can be a key step in creating and growing the renewable energy sector.

Creating a favorable investment environment is key to overcoming financing barriers and attracting investors, with the majority of new investments coming from private sources. Policymakers and international financial institutions must employ appropriate policy and fiscal tools to stimulate private sector investment, while public funding remains a significant catalyst and must be increased. Ultimately, an analysis of financing mechanisms adapted to the specific circumstances of each country is needed, as there is no one-size-fits-all approach. Furthermore, it is essential to recognize that financial tools alone cannot drive a country's transition to renewable energy; a collaborative effort involving government, industry, the population, various sectors, business plans, technology, education and resources is needed.

## 6.1 Conclusion

This research investigates the association between bank performance and the share of renewable energy in total primary energy supply, focusing on balance sheet financial performance indicators (i.e., return on assets, bank size, debt ratio, PB ratio, and revenue growth). We focus on a global panel dataset of 27 countries and consider the classification by income group of the countries. We apply the fixed-effect OLS technique to account for the potential serial correlation associated with our panel model.

We conclude that switching to renewable sources reduces banks' risk of default. This result can be interpreted through Safarzyńska and van den Bergh (2017a), which argues that when banks release money to the corporate sector to invest in renewable energy, this increases the profitability of the borrowing companies and the likelihood that they will repay the bank loans. Investing in renewable energy allows companies to align their business goals with stakeholder interests, which increases the company's social acceptance (Dowling and Pfeffer, 1975) and, in turn, allows it to obtain premium prices for its products, thereby increasing profitability (Miles and Covin, 2000).

By dividing the data set into two income categories (developed and developing countries), we detected some differences between the categories in the role that renewable energy generation plays in the banking sector's default risk. The results for developed panels largely follow the same pattern, while the results for developing countries stand out in this study. According to our results, bank default risk in developing countries is significantly and positively affected by the increase in renewable generation. The share of renewable energy generation in developing countries is increased by a high return on assets, an increase in bank size, and financial stability.

The effect of renewable energy generation on banking risk across income groups points to an important direction for targeted policies based on countries' income class, with the aim of stimulating growth in renewable energy consumption. While we are cautious about interpreting our results for the global sample, our results support the argument that the banking sector plays an important role in renewable energy consumption. As more data becomes available in the future, the research could be extended to re-examine the effect of banking performance on the various types of renewable energy, such as solar, wind, hydro, and biomass, focusing on various countries, especially non-OECD countries. This is because the different sources require varying investment sizes and have different associated risk levels.

# References

Abba, Z., Balta-Ozkan, N., and Hart, P. (2022). A holistic risk management framework for renewable energy investments. *Renewable and Sustainable Energy Reviews*, 160:112305.

Amendolagine, V., Presbitero, A. F., Rabellotti, R., and Sanfilippo, M. (2019). Local sourcing in developing countries: The role of foreign direct investments and global value chains. *World Development*, 113:73–88.

Amuakwa-Mensah, F. and Nässtrröm, E. (2022). Role of banking sector performance in renewable energy consumption. *Applied Energy*, 306:118023.

Arellano, M. and Bond, S. (1991). Some tests of specification for panel data: Monte carlo evidence and an application to employment equations. *The review of economic studies*, 58(2):277–297.

Capasso, G., Gianfrate, G., and Spinelli, M. (2020). Climate change and credit risk. *Journal of Cleaner Production*, 266:121634.

Chan-Lau, J. A. and Sy, A. N. (2007). Distance-to-default in banking: A bridge too far? *Journal of Banking Regulation*, 9:14–24.

Choudhury, T., Kamran, M., Djajadikerta, H. G., and Sarker, T. (2021). Can banks sustain the growth in renewable energy supply? an international evidence. *The European Journal of Development Research*, pages 1–31.

Cicea, C., Marinescu, C., Popa, I., and Dobrin, C. (2014). Environmental efficiency of investments in renewable energy: Comparative analysis at macroeconomic level. *Renewable and Sustainable Energy Reviews*, 30:555–564.

Cui, Y., Geobey, S., Weber, O., and Lin, H. (2018). The impact of green lending on credit risk in china. *Sustainability*, 10(6):2008.

Dar, A. A. and Qadir, S. (2019). Distance to default and probability of default: an experimental study. *Journal of Global Entrepreneurship Research*, 9(1):1–12.

Denzler, S. M., Dacorogna, M. M., Müller, U. A., and McNeil, A. J. (2006). From default probabilities to credit spreads: Credit risk models do explain market prices. *Finance Research Letters*, 3(2):79–95.

Dowling, J. and Pfeffer, J. (1975). Organizational legitimacy: Social values and organizational behavior. *Pacific sociological review*, 18(1):122–136.

Energy, I. G. (2018). Co2 status report 2017. international energy agency. 2017c.

Gatzert, N. and Kosub, T. (2016). Risks and risk management of renewable energy projects: The case of onshore and offshore wind parks. *Renewable and Sustainable Energy Reviews*, 60:982–998.

Harada, K. and Ito, T. (2011). Did mergers help japanese mega-banks avoid failure? analysis of the distance to default of banks. *Journal of the Japanese and International Economies*, 25(1):1–22.

Hassan, Q., Viktor, P., Al-Musawi, T. J., Ali, B. M., Algburi, S., Alzoubi, H. M., Al-Jiboory, A. K., Sameen, A. Z., Salman, H. M., and Jaszczur, M. (2024). The renewable energy role in the global energy transformations. *Renewable Energy Focus*, 48:100545.

Hulshof, D. and Mulder, M. (2020). The impact of renewable energy use on firm profit. *Energy economics*, 92:104957.

IEA, S. D. S. (2019). Sustainable development scenario. https://www.iea.org/weo/weomodel/sds/. Accessed: 2024-03-15.

Ji, G., Kim, D. S., and Ahn, K. (2019). Financial structure and systemic risk of banks: Evidence from chinese reform. *Sustainability*, 11(13):3721.

Kabir, M. N. and Worthington, A. C. (2017). The 'competition–stability/fragility'nexus: A comparative analysis of islamic and conventional banks. *International Review of Financial Analysis*, 50:111–128.

Khan, M. A. and Ahmad, W. (2022). Fresh evidence on the relationship between market power and default risk of indian banks. *Finance Research Letters*, 46:102360.

Li, K. and Lin, B. (2015). Impacts of urbanization and industrialization on energy consumption/co2 emissions: does the level of development matter? *Renewable and Sustainable Energy Reviews*, 52:1107–1122.

Mazzucato, M. and Semieniuk, G. (2018). Financing renewable energy: Who is financing what and why it matters. *Technological Forecasting and Social Change*, 127:8–22.

Merton, R. C. (1974). On the pricing of corporate debt: The risk structure of interest rates. *The Journal of finance*, 29(2):449–470.

Miles, M. P. and Covin, J. G. (2000). Environmental marketing: A source of reputational, competitive, and financial advantage. *Journal of business ethics*, 23:299–311.

Milne, A. (2014). Distance to default and the financial crisis. *Journal of financial stability*, 12:26–36.

Nadeem, M., Zaman, R., and Saleem, I. (2017). Boardroom gender diversity and corporate sustainability practices: Evidence from australian securities exchange listed firms. *Journal of Cleaner Production*, 149:874–885.

Omri, A. and Nguyen, D. K. (2014). On the determinants of renewable energy consumption: International evidence. *Energy*, 72:554–560.

Philip, L. D., Emir, F., and Udemba, E. N. (2022). Investigating possibility of achieving sustainable development goals through renewable energy, technological innovation, and entrepreneur: a study of global best practice policies. *Environmental Science and Pollution Research*, 29(40):60302–60313.

Roodman, D. (2009). A note on the theme of too many instruments. *Oxford Bulletin of Economics and statistics*, 71(1):135–158.

Safarzyńska, K. and van den Bergh, J. C. (2017a). Financial stability at risk due to investing rapidly in renewable energy. *Energy Policy*, 108:12–20.

Safarzyńska, K. and van den Bergh, J. C. (2017b). Integrated crisis-energy policy: Macro-evolutionary modelling of technology, finance and energy interactions. *Technological Forecasting and Social Change*, 114:119–137.

Stiroh, K. J. (2006). New evidence on the determinants of bank risk. *Journal of Financial Services Research*, 30:237–263.

Studenmund, A. and Cassidy, H. (1997). Multicollinearity. In *Using Econometrics: A Practical Guide*, pages 274–277. Addison-Wesley, Boston, Mass.

Switzer, L. N., Tu, Q., and Wang, J. (2018). Corporate governance and default risk in financial firms over the post-financial crisis period: International evidence. *Journal of International Financial Markets, Institutions and Money*, 52:196–210.

Taghizadeh-Hesary, F. and Yoshino, N. (2020). Sustainable solutions for green financing and investment in renewable energy projects. *Energies*, 13(4):788.

Trad, N., Trabelsi, M. A., and Goux, J. F. (2017). Risk and profitability of islamic banks: a religious deception or an alternative solution? *European Research on Management and Business Economics*, 23(1):40–45.

Unep, E. p. (2004). Financial risk management instruments for renewable energy projects. https://energy-base.org/app/uploads/2020/03/1.SEFI-Financial-Risk-Management-Instruments-for-Renewable-Energy-Projects-2004.pdf. Accessed: 2024-03-15.

Unep, E. p. (2007). Global trends in sustainable energy investment 2007: analysis of trends and issues in the financing of renewable energy and energy efficiency in oecd and developing countries. https://wedocs.unep.org/handle/20.500.11822/7958. Accessed: 2024-03-15.

Wang, S., Wang, X., and Chen, S. (2022). Global value chains and carbon emission reduction in developing countries: does industrial upgrading matter? *Environmental Impact Assessment Review*, 97:106895.

Zeng, S., Liu, Y., Liu, C., and Nan, X. (2017). A review of renewable energy investment in the brics countries: History, models, problems and solutions. *Renewable and Sustainable Energy Reviews*, 74:860–872.

Zhou, S. and Yang, P. (2020). Risk management in distributed wind energy implementing analytic hierarchy process. *Renewable Energy*, 150:616–623.

# A Figures and Tables

Table 1: List of countries

| Country | Number of banks | Number of observations |
|---|---|---|
| Argentina | 6 | 41 |
| Australia | 35 | 282 |
| Austria | 8 | 81 |
| Brazil | 20 | 236 |
| Canada | 29 | 279 |
| Chile | 8 | 92 |
| China | 96 | 660 |
| Denmark | 15 | 176 |
| Finland | 6 | 57 |
| France | 19 | 218 |
| Germany | 13 | 132 |
| Greece | 5 | 52 |
| India | 186 | 1664 |
| Indonesia | 59 | 534 |
| Italy | 20 | 203 |
| Japan | 103 | 1129 |
| Korea | 29 | 265 |
| Mexico | 9 | 99 |
| Netherlands | 4 | 34 |
| New Zealand | 5 | 39 |
| Norway | 40 | 353 |
| Spain | 6 | 66 |
| Sweden | 12 | 92 |
| Switzerland | 18 | 212 |
| Thailand | 37 | 112 |
| Turkey | 18 | 199 |
| United States of America | 567 | 5410 |
| Total | 1,373 | 12,717 |

Table 2: Summary statistics

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| DD | 12717 | 79.65 | 52.27 | -7.19 | 196.92 |
| DC | 12717 | 26.73 | 31.74 | -2.9 | 108.51 |
| REN | 12717 | .13 | .13 | .01 | .72 |
| Share of Low Carbon | 12717 | .19 | .14 | .04 | .74 |
| PI Total (solar and wind) | 8149 | .18 | .31 | 0 | 1 |
| PI Trends in Renewables | 8383 | .39 | .27 | 0 | 1 |
| $CO_2$ emission | 12448 | 3493.01 | 2852.87 | 27.92 | 11969.25 |
| ibrd | 12717 | .29 | .45 | 0 | 1 |
| size | 12717 | 21.79 | 2.72 | 15.12 | 26.27 |
| Debt ratio | 12717 | 1.52 | 1.67 | .01 | 6.21 |
| ROE | 12717 | .08 | .08 | -.14 | .26 |
| PB ratio | 12717 | 1.4 | 1.32 | .1 | 6.09 |
| Revenue growth | 12717 | .85 | 2.12 | -4.96 | 3.43 |
| Government effectiveness | 12717 | 53.53 | 23.34 | .59 | 99.52 |
| GDP growth | 12717 | 2.62 | 3.09 | -11.17 | 11.74 |
| Population | 12717 | .62 | .46 | -1.85 | 2.25 |

Figure 1: Bias reduction due to Propensity Score Matching

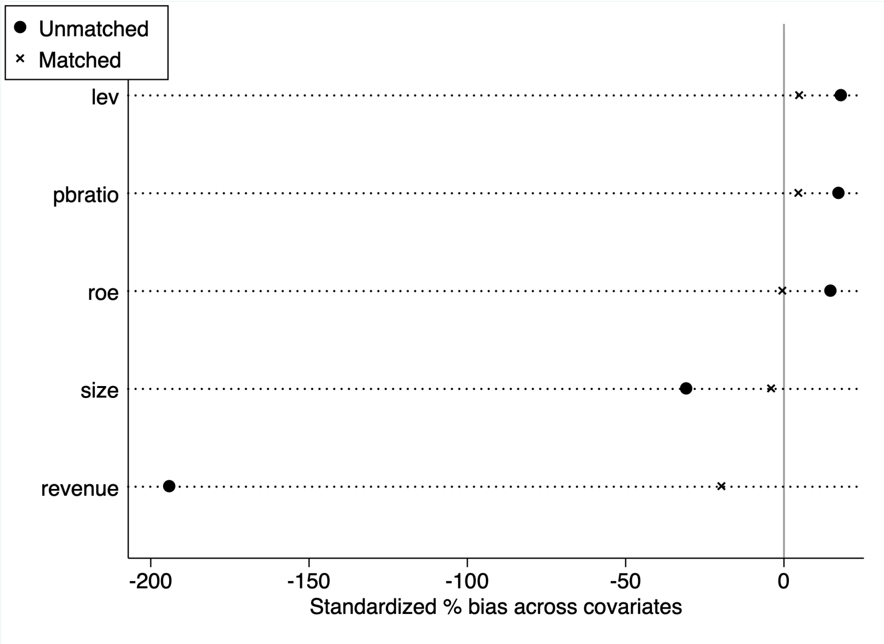

Table 3: Cross-correlation table

| Variables | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. | 15. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. dd | | | | | | | | | | | | | | | |
| 2. dc | 0.352 | | | | | | | | | | | | | | |
| 3. REN | 0.112 | 0.030 | | | | | | | | | | | | | |
| 4. Share od Low Carbon | 0.149 | -0.059 | 0.893 | | | | | | | | | | | | |
| 5. PI Total (solar and wind) | -0.077 | 0.151 | 0.016 | -0.084 | | | | | | | | | | | |
| 6. PI Trends in Renewables | 0.001 | 0.070 | -0.138 | -0.095 | 0.167 | | | | | | | | | | |
| 7. $CO_2$ emission | 0.137 | -0.094 | -0.322 | -0.235 | -0.075 | -0.040 | | | | | | | | | |
| 8. Emerging countries | -0.224 | 0.376 | -0.069 | -0.279 | 0.310 | -0.056 | -0.036 | | | | | | | | |
| 9. Bank size | 0.364 | 0.022 | 0.091 | 0.120 | -0.072 | -0.010 | 0.010 | -0.156 | | | | | | | |
| 10. Debt ratio | 0.006 | 0.050 | 0.219 | 0.159 | 0.088 | -0.016 | -0.164 | 0.088 | 0.260 | | | | | | |
| 11. ROE | 0.154 | 0.157 | 0.049 | 0.044 | -0.048 | 0.006 | 0.071 | 0.040 | 0.228 | 0.123 | | | | | |
| 12. PB ratio | -0.125 | 0.010 | -0.106 | -0.102 | -0.043 | 0.028 | -0.006 | 0.066 | -0.195 | 0.011 | 0.183 | | | | |
| 13. Revenue growth | 0.286 | -0.186 | 0.091 | 0.280 | -0.184 | 0.044 | 0.104 | -0.704 | 0.422 | 0.063 | 0.183 | -0.126 | | | |
| 14. Government effectiveness | 0.258 | -0.382 | 0.329 | 0.425 | -0.214 | 0.018 | -0.170 | -0.806 | 0.231 | 0.065 | -0.057 | -0.114 | 0.542 | | |
| 15. GDP growth | -0.079 | 0.250 | -0.114 | -0.186 | 0.139 | 0.247 | 0.157 | 0.422 | -0.123 | 0.015 | 0.084 | 0.049 | -0.324 | -0.395 | |
| 16. Population | -0.148 | 0.193 | 0.102 | 0.057 | 0.132 | -0.010 | -0.103 | 0.360 | -0.269 | 0.098 | 0.089 | 0.178 | -0.309 | -0.320 | 0.158 |

Table 4: Results of estimation main model

| | DD | DC |
|---|---|---|
| REN | 25.87*** | 54.48*** |
| | (4.458) | (13.24) |
| Bank size | 0.937*** | 0.0431 |
| | (0.215) | (0.593) |
| Debt ratio | 0.290*** | 1.087*** |
| | (0.0750) | (0.246) |
| ROE | 5.549*** | 20.75*** |
| | (0.932) | (2.793) |
| PB ratio | -0.0400 | 0.233 |
| | (0.0715) | (0.194) |
| Revenue growth | 0.553*** | 2.184*** |
| | (0.130) | (0.418) |
| Government effectiveness | -0.194*** | -0.665*** |
| | (0.0222) | (0.0646) |
| GDP growth | 0.369*** | 1.225*** |
| | (0.0181) | (0.0591) |
| Population | -0.320 | -0.508 |
| | (0.328) | (1.031) |
| $DD_{t-1}$ | 0.235*** | |
| | (0.0459) | |
| $DC_{t-1}$ | | 0.167*** |
| | | (0.0348) |
| Constant | 43.37*** | 40.96** |
| | (6.262) | (15.05) |
| Observations | 12717 | 12717 |
| $R^2$ | 0.185 | 0.139 |
| Bank FE | Yes | Yes |

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: Results of estimation: divide sample in developed and emerging countries

| | DD | | DC | |
|---|---|---|---|---|
| | Emergent | Developed | Emergent | Developed |
| REN | -62.96*** | 45.36*** | -313.7*** | 151.2*** |
| | (11.81) | (5.209) | (26.18) | (18.13) |
| Bank size | -0.935* | 1.081** | -4.032*** | -0.135 |
| | (0.471) | (0.335) | (0.969) | (0.861) |
| Debt ratio | 0.520*** | 0.333*** | 1.145*** | 1.426*** |
| | (0.130) | (0.0984) | (0.332) | (0.326) |
| ROE | 3.941* | 4.597*** | 15.26*** | 15.90*** |
| | (1.771) | (1.078) | (3.663) | (3.653) |
| PB ratio | -0.418*** | 0.250* | -0.514* | 0.782** |
| | (0.113) | (0.0973) | (0.216) | (0.281) |
| Revenue growth | 0.0799 | 1.185*** | 0.0626 | 4.709*** |
| | (0.192) | (0.184) | (0.532) | (0.582) |
| Government effectiveness | 0.0186 | -0.187*** | -0.282*** | -0.554*** |
| | (0.0472) | (0.0252) | (0.0520) | (0.0742) |
| GDP growth | 0.230*** | 0.372*** | 0.691*** | 1.274*** |
| | (0.0262) | (0.0306) | (0.0563) | (0.119) |
| Population | -3.257** | -0.350 | -11.69*** | -1.504 |
| | (1.227) | (0.390) | (2.767) | (1.316) |
| $DD_{t-1}$ | 0.169** | 0.239*** | | |
| | (0.0611) | (0.0266) | | |
| $DC_{t-1}$ | | | 0.0861* | 0.204*** |
| | | | (0.0339) | (0.0218) |
| Constant | 76.18*** | 43.32*** | 175.0*** | 19.68 |
| | (11.55) | (8.812) | (22.69) | (21.92) |
| Observations | 3637 | 9080 | 3637 | 9080 |
| $R^2$ | 0.144 | 0.241 | 0.343 | 0.151 |
| Bank FE | Yes | Yes | Yes | Yes |

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6: Results of estimation: Mahalanobis and propensity score matching

| | DD | | DC | |
|---|---|---|---|---|
| | Emergent | Developed | Emergent | Developed |
| REN | -57.16*** | 26.41** | -307.7*** | 113.2*** |
| | (16.60) | (8.549) | (31.85) | (33.62) |
| Government effectiveness | 0.0495 | -0.275*** | -0.319*** | -0.742*** |
| | (0.0540) | (0.0379) | (0.0581) | (0.130) |
| GDP growth | 0.235*** | 0.448*** | 0.754*** | 1.670*** |
| | (0.0328) | (0.0603) | (0.0645) | (0.224) |
| Population | -1.623 | 2.209*** | -7.598* | 9.669*** |
| | (1.504) | (0.619) | (3.154) | (2.265) |
| $DD_{t-1}$ | 0.203* | 0.300** | | |
| | (0.0879) | (0.0926) | | |
| $DC_{t-1}$ | | | 0.128** | 0.385*** |
| | | | (0.0452) | (0.0692) |
| Constant | 50.46*** | 59.93*** | 89.46*** | 35.10** |
| | (7.858) | (9.314) | (6.753) | (12.89) |
| Observations | 2562 | 1472 | 2562 | 1472 |
| $R^2$ | 0.123 | 0.178 | 0.317 | 0.173 |
| Bank FE | Yes | Yes | Yes | Yes |

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7: Results of estimation: alternative measure of independent variable

| | DD | DC | DD | DC | DD | DC |
|---|---|---|---|---|---|---|
| Panel A: full sample | | | | | | |
| Share of Low Carbon | 14.07*** | 12.86 | | | | |
| | (3.691) | (11.50) | | | | |
| PI Trends in Renewables | | | | | 1.828*** | 6.772*** |
| | | | | | (0.165) | (0.704) |
| Observations | 12717 | 12717 | 8149 | 8149 | 8383 | 8383 |
| $R^2$ | 0.182 | 0.137 | 0.405 | 0.420 | 0.379 | 0.439 |
| Panel B: emergent countries | | | | | | |
| Share of Low Carbon | -58.99*** | -274.8*** | | | | |
| | (9.778) | (23.24) | | | | |
| PI Trends in Renewables | | | | | -0.521* | 0.0706 |
| | | | | | (0.209) | (0.872) |
| Observations | 3637 | 3637 | 2749 | 2749 | 2028 | 2028 |
| $R^2$ | 0.144 | 0.332 | 0.265 | 0.363 | 0.360 | 0.445 |
| Panel C: developed countries | | | | | | |
| Share of Low Carbon | 31.31*** | 93.06*** | | | | |
| | (3.990) | (13.34) | | | | |
| PI Trends in Renewables | | | | | 2.060*** | 8.116*** |
| | | | | | (0.190) | (0.756) |
| Observations | 9080 | 9080 | 5400 | 5400 | 6355 | 6355 |
| $R^2$ | 0.233 | 0.142 | 0.635 | 0.595 | 0.480 | 0.558 |

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 8: Results of estimation: COVID period

| | DD | DC |
|---|---|---|
| REN | 129.2*** | 498.9*** |
| | (11.10) | (40.11) |
| POST COVID | -3.508*** | -15.82*** |
| | (0.307) | (1.024) |
| REN * POST COVID | 3.752*** | 9.587*** |
| | (0.849) | (2.470) |
| Bank size | 1.944*** | 2.366* |
| | (0.420) | (1.087) |
| Debt ratio | 0.624*** | 2.939*** |
| | (0.125) | (0.399) |
| ROE | 4.839*** | 22.58*** |
| | (1.458) | (4.226) |
| PB ratio | 0.167 | 0.301 |
| | (0.0911) | (0.283) |
| Revenue growth | 0.575** | 1.061 |
| | (0.195) | (0.625) |
| Government effectiveness | -0.0232 | -0.202** |
| | (0.0302) | (0.0636) |
| GDP growth | 0.263*** | 0.820*** |
| | (0.0216) | (0.0790) |
| Population | -0.312 | 1.374 |
| | (0.439) | (1.519) |
| $DD_{t-1}$ | 0.00513 | |
| | (0.0158) | |
| $DC_{t-1}$ | | -0.0659*** |
| | | (0.0188) |
| Constant | 19.62* | -85.48*** |
| | (9.169) | (24.71) |
| Observations | 7475 | 7475 |
| $R^2$ | 0.084 | 0.091 |
| Bank FE | Yes | Yes |

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 9: Results of estimation: $CO_2$ emission

| | DD | | DC | |
|---|---|---|---|---|
| | Q1 | Q4 | Q1 | Q4 |
| REN | 6.250 | 61.01*** | -27.48 | 196.9*** |
| | (5.651) | (17.94) | (15.29) | (40.81) |
| Bank size | 0.350 | 1.177*** | 0.542 | 0.946* |
| | (0.347) | (0.347) | (0.910) | (0.447) |
| Debt ratio | 0.342* | -0.178 | 0.700 | 0.0803 |
| | (0.140) | (0.0979) | (0.382) | (0.257) |
| ROE | -0.924 | 3.342** | 7.385 | 3.000 |
| | (2.399) | (1.064) | (5.602) | (1.660) |
| PB ratio | -0.488* | 0.535*** | -0.375 | 1.028*** |
| | (0.196) | (0.106) | (0.341) | (0.240) |
| Revenue growth | 0.540* | 0.172 | 1.417* | 0.674 |
| | (0.257) | (0.275) | (0.707) | (0.392) |
| Government effectiveness | 0.00331 | -0.202*** | -0.146* | 0.0964 |
| | (0.0220) | (0.0544) | (0.0613) | (0.0755) |
| GDP growth | 0.483*** | 0.413*** | 1.714*** | 0.823*** |
| | (0.0455) | (0.0509) | (0.141) | (0.122) |
| Population | 1.754** | 1.395 | 10.98*** | -5.419 |
| | (0.604) | (1.645) | (1.971) | (4.479) |
| $DD_{t-1}$ | 0.258* | 0.901*** | | |
| | (0.109) | (0.114) | | |
| $DC_{t-1}$ | | | 0.192** | 1.378*** |
| | | | (0.0668) | (0.0595) |
| Constant | 41.27** | -22.54* | 13.32 | -49.25*** |
| | (12.49) | (9.082) | (20.75) | (8.755) |
| Observations | 2963 | 2668 | 2963 | 2668 |
| $R^2$ | 0.121 | 0.817 | 0.186 | 0.919 |
| Bank FE | Yes | Yes | Yes | Yes |

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10: Results of estimation: GMM dynamic panel estimator

| | DD | DC |
|---|---|---|
| REN | 34.79** | 34.95*** |
| | (10.70) | (5.441) |
| Bank size | 3.671*** | 1.259* |
| | (0.912) | (0.566) |
| Debt ratio | -4.604*** | 0.477 |
| | (0.928) | (0.663) |
| ROE | 31.90*** | 47.36*** |
| | (9.635) | (6.487) |
| PB ratio | -1.985** | -0.430 |
| | (0.752) | (0.442) |
| Revenue growth | 2.511** | -0.914 |
| | (0.811) | (0.489) |
| Government effectiveness | 0.265*** | -0.476*** |
| | (0.0652) | (0.0388) |
| GDP growth | 0.600*** | 0.969*** |
| | (0.124) | (0.0909) |
| Population | -1.311 | 2.972* |
| | (2.182) | (1.216) |
| Constant | -19.25 | 11.09 |
| | (19.23) | (12.19) |
| Observations | 13928 | 13928 |
| Number of banks | 1512 | 1512 |
| Hansen test p-value | 0.127 | 0.850 |

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 11: Summary of DD results for all panels.

| Variable | G. | D | M. D | E | M. E | Covid | $CO_2$.Q4 | GMM |
|---|---|---|---|---|---|---|---|---|
| REN | ✓ + | ✓ + | ✓ + | ✓ - | ✓ - | ✓ + | ✓ + | ✓ + |
| Bank size | ✓ + | ✓ + | | ✓ - | | ✓ + | ✓ + | ✓ + |
| Debt ratio | ✓ + | ✓ + | | ✓ + | | ✓ + | | ✓ - |
| ROE | ✓ + | ✓ + | | ✓ + | | ✓ + | ✓ + | ✓ + |
| PB ratio | | ✓ + | | ✓ - | | | ✓ + | ✓ - |
| Rev. growth | ✓ + | ✓ + | | | | ✓ + | | ✓ + |
| Gov. effect. | ✓ - | ✓ - | ✓ - | | | | ✓ - | ✓ + |
| GDP growth | ✓ + | ✓ + | ✓ + | ✓ + | ✓ + | ✓ + | ✓ + | ✓ + |
| Population | | | ✓ + | ✓ - | | | | |
| $DD_{t-1}$ | ✓ + | ✓ + | ✓ + | ✓ + | ✓ + | | ✓ + | |
| Share of LCR | ✓ + | ✓ + | | ✓ - | | | | |
| PI | ✓ + | ✓ + | | ✓ - | | | | |
| Post C. | | | | | | ✓ - | | |
| REN * PC | | | | | | ✓ + | | |

✓ Denotes statistical significance. $(-)/(+)$ denotes the sign (negative or positive) of the effect of potential determinants on the renewable energy consumption.

Table 12: Summary of DC results for all panels.

| Variable | G. | D | M. D | E | M. E | Covid | $CO_2$.Q4 | GMM |
|---|---|---|---|---|---|---|---|---|
| REN | ✓ + | ✓ + | ✓ + | ✓ - | ✓ - | ✓ + | ✓ + | ✓ + |
| Bank size | | | | ✓ - | | ✓ + | ✓ + | ✓ + |
| Debt ratio | ✓ + | ✓ + | | ✓ + | | ✓ + | | |
| ROE | ✓ + | ✓ + | | ✓ + | | ✓ + | | ✓ + |
| PB ratio | | ✓ + | | ✓ - | | | ✓ + | |
| Rev. growth | ✓ + | ✓ + | | | | | | |
| Gov. effect. | ✓ - | ✓ - | ✓ - | ✓ - | ✓ - | ✓ - | | ✓ - |
| GDP growth | ✓ + | ✓ + | ✓ + | ✓ + | ✓ + | ✓ + | ✓ + | ✓ + |
| Population | | | ✓ + | ✓ - | ✓ - | | | ✓ + |
| $DC_{t-1}$ | ✓ + | ✓ + | ✓ + | ✓ + | ✓ + | ✓ - | ✓ + | |
| Share of LCR | | ✓ + | | ✓ - | | | | |
| PI | ✓ + | ✓ + | | | | | | |
| Post C. | | | | | | ✓ - | | |
| REN * PC | | | | | | ✓ + | | |

✓ Denotes statistical significance. $(-)/(+)$ denotes the sign (negative or positive) of the effect of potential determinants on the renewable energy consumption.