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Do Financial Inclusion, Regulatory Quality and Government Effectiveness Matter for Green Development? Evidence from New EU Countries

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Nowadays, the world is facing climate change and environmental problems due to the increasing use of energy resources and environmental emissions. In order to promote green development, financial inclusion is an important factor in the development process. Therefore, this paper examines the effects of financial inclusion, regulatory quality, government effectiveness and economic growth on green development in the new EU countries for the period from 2004 to 2021. In order to obtain empirical results, the pooled mean group and mean group estimator have been employed to check the short-run and long-run effects on green development. The results show a strong relationship between the variables and CO_2 emissions in the long run. The findings support that enhancing the level of financial inclusion and regulatory quality by 1% increases carbon emissions by around 0.3% and 0.4% in the long run. However, government effectiveness and economic growth have a negative effect on CO_2 emissions in the long run, while in the short run economic growth has a positive effect on CO_2 emissions. Based on the empirical results, policymakers should improve financial inclusion and reinforce stringent regulations to enhance green development.

Keywords: *Financial Inclusion; Government Effectiveness; Regulatory Quality; Green Development; New EU Countries.*

Introduction

In early 1990s the European Union began Due to rapid technological change, the expansion of economic and financial activities in the new EU countries is leading to an increase in carbon emissions owing to the high energy demand associated with industrialization and the consumption of goods and services. This poses a critical challenge for addressing climate change as the new EU countries strive to increase their economic and financial activities while reducing carbon emissions. This will accelerate the development of a new concept, i.e., one with a particular focus on environmental protection. In the literature, this concept is called green development, which refers to the integration of sustainable and environmentally friendly practices into economic development. This holistic approach includes the use of clean energy sources, the efficient use of natural resources and the reduction of pollution and waste (Mushafiq, 2023). One of the most important goals of green development is to reduce greenhouse gas emissions, as these gases are one of the main causes of climate change. With the introduction of an ambitious package of measures to mitigate climate and environmental problems under the European Green Deal strategy, all new EU countries are facing a significant change. The main objectives of this strategy are to achieve a carbon-neutral European Union by 2050 and to decouple economic growth and resource use while promoting a green transformation. To implement the Green Deal, existing regulations and standards will be revised and new laws and directives will be developed and implemented over the next few years. The European Commission estimates that at least €1 trillion in green investments will be required over the next ten years.

In addition, the quality of legislation and the effectiveness of government are essential to creating an enabling environment for green development. To promote sustainable practices, enforce environmental standards, and incentivize green investments, a strong regulatory framework and effective policies are needed. Effective regulations can provide clear guidance and incentives for industries to adopt green practices, invest in clean technologies, and reduce their environmental footprint. By setting standards and enforcing compliance, regulatory quality ensures that companies operate in an environmentally responsible manner. Government effectiveness is equally important, as it determines the government's ability to formulate and implement effective environmental policies and programs. An effective government can provide the necessary infrastructure,

resources, and incentives to promote sustainability and mitigate climate change. It can also facilitate coordination among various stakeholders, including businesses, civil society, and international partners, to achieve environmental goals. It is likely that countries with better quality legislation and more effective government will be abler to implement and enforce environmental policies to reduce CO_2 emissions.

An important factor in achieving low-carbon energy sources is financial inclusion. As such, it encompasses many financial sectors whose role is critical in achieving green development. Financial inclusion facilitates the financing of investments in environmental projects at lower costs. When the financial sector is well developed, it becomes easier for companies and individuals to obtain funding for sustainable and green initiatives. This can lead to more investment in renewable energy, energy efficiency, and other environmentally conscious projects. By providing affordable financing options, financial inclusion enables broader participation in green initiatives, contributing to a more sustainable economy and green development. As a result, investments in green technologies are more realistic and accessible. Although the specific link between financial inclusion and CO_2 emissions needs further research, promoting financial inclusion can indirectly help address climate risks by enabling greater investment in sustainable and green projects. In this context, the question arises: What is the relationship between financial inclusion and green development? What are the key drivers of the green development concept in the new EU countries? The answers to these questions are of great importance for the green development of the new EU countries.

Against this background, the purpose of this paper is to examine whether financial inclusion, combined with improvements in regulatory quality, government effectiveness, and economic growth, can reduce climate risks and promote green development in the 11 new EU countries over the period 2004-2021. The selection of the 11 new EU countries for this study is justified by several factors. These countries joined the EU after 2004 and therefore had to adopt the climate policies set by the EU. The transition to a carbon-neutral economy by 2050 is a major challenge overall, but especially for the new EU countries, which have a certain “lag" compared to the more developed or old EU countries. Over the past decade, the new EU countries have undergone a radical transformation from a centrally planned economy to an open market economy, accompanied by significant changes in the political, social, economic, and environmental context. However, compared to the old EU countries, the new EU countries have lower levels of economic development and potential. In addition, the economies of these new EU countries are highly dependent on fossil fuels, and as their economic activity is expected to increase in the coming decades, their energy demand is expected to increase significantly, leading to higher emissions of CO_2 and other greenhouse gases. This situation poses greater risks to the climate and makes it difficult for these countries to achieve the goals of the European Green Deal. The main goal of the Green Deal is to reduce greenhouse gas emissions by 55% by 2030 and become a carbon-neutral continent by 2050. It aims to transform the European energy system, promote clean technologies, and create a more sustainable and competitive economy. This paper contributes to the existing literature in two ways. First, the impact of financial inclusion on CO_2 emissions in the 11 new EU countries has remained largely unexplored in previous studies due to lack of data availability. Second, it has been empirically demonstrated that institutional factors also matter for green development and CO_2 emissions in the 11 new EU countries.

The paper is structured as follows. After a brief introduction, Section 2 presents a theoretical and empirical review of the literature. Section 3 discusses the material and methods used in this paper. Section 4 presents and discusses the results derived from the empirical analysis. Finally, Section 5 provides concluding remarks and policy implications.

Literature Review

In the early 1990s, the European Union began developing measures to mitigate climate change. Although this period was characterized by the carbon/energy proposal, which was rejected by the member states, the 2000s were a time of developing far-reaching climate policies and strategies. An overview of the most important policies and regulations can be found in Table 1 (see Appendix). After all the major policies and regulations, the centerpiece was climate change mitigation policy. The challenge was therefore to integrate climate change adaptation into the main social and economic sectors. Despite several crises, the scope and targets have increased significantly.

In recent years, the concept of green development has been emphasized, although this concept comprises a twin challenge – boosting resource efficiency and maintaining ecosystem resilience. To overcome these challenges, many researchers have examined the linkage between CO_2 emissions, energy consumption, financial inclusion, and green growth (Asafu-Adjaye, 2000; Lee and Chang, 2008; Zhang and Cheng, 2009; Chang, 2010; Belke *et al*., 2011; Wang *et al*., 2011; Li & Song, 2016; Feng, *et al*. 2017; Kim *et al*., 2018; Le *et al*. 2019; Le *et al*. 2020; Liu *et al*. 2021; Zaidi *et al*. 2021; Van *et al*., 2021; Dou and Li, 2022; Fareed *et al*. 2022; Karim *et al*., 2022; Hodzic *et al*., 2023; Dogan *et al*., 2023). In this part, we thus provide a systematic background for our research by dividing the literature review into several subsections. All these subsections are of great importance for answering our research question and defining our hypothesis.

Financial Inclusion and CO_2 Emissions

Research on the relationship between financial inclusion, regulatory quality, government effectiveness and green development is scarce. Therefore, this section reviews the existing literature on financial inclusion and carbon emissions.

In the United Nations Sustainable Development Goals for 2030, financial inclusion is recognized as an important determinant for economic and financial development. Since the demand of everyday life is becoming more digital, the whole financial sector is rapidly growing. Moreover, this will attract more research and development as well as

foreign direct investments, which reduces environmental damage. Consequently, this will promote and support the flow of financial instruments towards developing and implementing sustainable investments, as well as environmental projects and policies. Nevertheless, the scientific research has reached different conclusions regarding the analyzed relationship between financial inclusion and CO_2 emissions.

For instance, Murshed *et al*. (2023) examined whether financial inclusion, energy efficiency improvements, renewable energy use, economic growth, international trade, and urbanization reduced carbon emissions in 22 emerging economies. Using panel data from 2008 to 2018, the results show that financial inclusion is directly associated with higher CO_2 emissions. In contrast, improving energy efficiency and increasing the share of renewable energy in total energy consumption inhibit carbon dioxide emissions. Similar results were found by Murshed *et al.* (2022) in seven emerging economies. Hussain *et al*. (2023) analyzed the relationship between CO_2 emissions and financial inclusion for a panel of 74 countries from 2004 to 2020 based on the Environmental Kuznets Curve. They documented an inverted U-shaped relationship between CO_2 emissions and financial inclusion in developed, emerging, and frontier countries, with the exception of stand-alone countries. In the context of BRICS countries, Dou and Li (2022) concluded that financial inclusion increases CO_2 emissions. Similar results were found by Lin and Wu (2022) for seven emerging economies (E7) and Mukalayi and Inglesi-Lotz (2023) for 39 analysed countries. Fareed *et al*. (2022) conducted a study on the role of innovation activity, financial inclusion, and environmental degradation in the Eurozone. The study used panel data from 27 European countries for the period 1995-2018 and employed the method of moment quantile regression. The results of the study show that financial inclusion contributes to environmental degradation in the Eurozone. However, innovation activity plays a significant and negative moderating role in the relationship between financial inclusion and environmental degradation across all quantile distributions. Zaidi *et al*. (2021) used data on 23 OECD countries and concluded that the implementation of financial inclusion policies has climate-damaging effects by increasing CO_2 emissions. Le *et al*. (2020) examined data from 31 Asian countries and found that positive shocks to variables related to financial inclusion trigger higher CO_2 emissions in the long run, while greater openness to trade reduces CO_2 emissions. Dai *et al*. (2022) explored the impact of financial inclusion on renewable energy consumption for selected regional comprehensive economic partnership countries in the 2004 to 2019 period. In the analysis, they applied control variables such as economic growth, environment-related technologies, and human capital. The results showed that financial inclusion is the key factor of renewable energy promotion both in long and short run.

On the other hand, Amin *et al*. (2022) found that higher financial inclusion helps mitigate CO_2 emissions in the short run, but leads to higher CO_2 emissions in the long run in south Asian countries. In another recent study of seven emerging economies, Qin *et al*. (2021) found that improving financial inclusion leads to CO_2 emission reductions only in the emerging economies with low CO_2 emissions. Liu *et al*. (2022a) also used data from five emerging Asian economies and found that CO_2 emissions tend to decrease in the long term as the number of commercial bank branches per 1000 adults and the share of bank loans to bank deposits increase. According to Du *et al*. (2022), financial inclusion improves the environmental quality of emerging economies because it is negatively associated with CO_2. Using data for Organization of Islamic Cooperation (OIC) countries, Chaudhry *et al*. (2022) found that higher financial inclusion increases and decreases CO_2 emissions in the short run and long run, respectively. Examining the nonlinearity of the relationship between financial inclusion and CO_2 emission nexus in the context of 103 global countries, Renzhi and Baek (2020) found that the relationship has an inverted U-shape, whereby financial inclusion can be considered as a long-term solution to address climate risks. In the initial phase, financial inclusion can improve access to basic financial services and can drive the demand for polluting energy sources, thereby increasing CO_2 emissions. This occurs when economic growth driven by financial inclusion is not coupled with sustainable practices. However, in a later stage, improved financial inclusion leads to financial market development. By granting easier access to affordable financial schemes, financial inclusion can enable investments in green technology and promote the adoption of environmentally friendly practices. Tufail *et al.* (2022) investigated the role of financial inclusion and energy efficiency in promoting green economic system on a sample of BRICS countries from 1990 to 2020. Based on the analysis, it is evident that financial inclusion, imports, and GDP increase CO_2 emissions, while on the other hand energy efficiency and exports decrease CO_2 emissions.

Regluatory Quality and Government Effectiveness

Institutions and their quality are central to economic growth and development. In determining the level of environmental sustainability, the role of regulatory quality and government effectiveness cannot be neglected. Esty and Porter (2005) demonstrated that government effectiveness may also be important in controlling CO_2 emissions. Countries that have efficient government can more effectively enforce government rules and regulations related to CO_2 emissions (Pushak *et al*., 2007). Using a sample of 93 emerging and developing countries over the period 1995-2014, Wawrzyniak and Doryn (2020) found that countries with higher government effectiveness had a significant decrease in CO_2 emissions. The authors argue that environmental protection measures are more efficient when they are accompanied by higher government effectiveness.

In addition, the role of regulatory quality in reaching green development is another area that has not been sufficiently explored in the literature. Effective environmental regulations can help mitigate the negative environmental impacts of energy-related activities. However, the desire to increase economic growth has led some countries to minimize environmental regulations. This is the Pollution Haven Hypothesis (PHH), which states that industrialized nations, in an effort to minimize resource and labor costs, tend to choose locations with lower environmental regulations. This can lead to companies

moving to countries with weaker enforcement or lower environmental standards, resulting in environmentally harmful practices in those regions. In addition, political instability or corruption have led to negative effects of institutions on the environment (Azam *et al*., 2020; Ibrahim and Ajide, 2021). In the study conducted by Adedoyin *et al*. (2020) for BRICS countries, the empirical results show that the interaction of regulatory quality and coal rents produces a significantly positive impact on CO_2 emissions. Nevertheless, Mahmood *et al*. (2022) examined the impact of rule of law and regulatory quality on CO_2 emissions in four South Asian economies from 1996 to 2019, monitoring for renewable energy and income levels in the model. According to their findings, regulatory quality contributes to the reduction of CO_2 emissions, so they recommend that South Asian countries improve regulatory quality to promote a clean environment. Addai *et al*. (2022) explored the relationship between regulatory quality, environmental sustainability, and economic growth in Eastern European economies. They found that that countries with strong regulations have been able to improve environmental quality by controlling unsustainable growth and fossil energy consumption.

Government Effectiveness and CO_2 Emissions

Al-Mulali *et al*. (2022) examined the role of government effectiveness on CO_2 emission in 170 countries. By applying a generalized method of the moment model, results revealed that government effectiveness reduces CO_2 emissions significantly in high and moderate government effectiveness countries while it is not significant in the low government effectiveness countries. Mehmood (2022) analyzed the impact of renewable energy, economic growth, government effectiveness, and foreign investment on CO_2 emissions in selected South Asian countries in the period 1996–2019 and found that a 1% increase in governance reduces carbon emissions by 7.68%. Danish *et al.* (2019) also got similar results for BRICS countries. Abid (2016) investigated the relationship between economic growth and pollution, with a focus on understanding the role of institutional quality in the context of 25 sub-Saharan African countries from 1996-2010. The results indicated that political stability, government effectiveness, democracy, and control of corruption had a negative effect on CO_2 emissions. On the other hand, regulatory quality and the rule of law were found to have a positive effect on CO_2 emissions. However, Gani (2012) used a sample of 99 developing countries to examine the impact of five indicators of institutional quality, e.g., political stability, rule of law, control of corruption, government effectiveness, and regulatory quality, on CO_2 emissions. They found that government effectiveness and regulatory quality have no effect on CO_2 emissions per capita.

In light of the research previously discussed, several gaps in the existing literature have been identified. It is evident that the existing literature has largely overlooked the role of financial inclusion regarding CO_2 emissions in the context of the new EU countries. In terms of addressing climate risks, it is evident that the joint effects of financial inclusion and institutional factors on CO_2 emissions have not yet been comprehensively documented in the literature. Given these gaps, this study seeks to explore the potential joint environmental impacts of financial inclusion, regulatory quality, and government effectiveness in the context of the 11 new EU countries. Therefore, the main hypothesis is that financial inclusion, regulatory quality, and government effectiveness have a significant impact on CO_2 emissions in the 11 new EU countries.

Material and Methods

Sample and Data

This paper uses annual time series data for the 11 new EU countries (represented by Bulgaria, the Czech Republic, Croatia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia) from 2004 to 2021. The time frame of the study is based on the availability of financial inclusion data. The World Bank database was used to collect data on financial inclusion, regulatory quality, and government effectiveness, while the Eurostat database was used for CO_2 emissions and GDP.

Variables

Table 2 lists the variables used in this study and their descriptions.

Table 2

Data Definitions and Sources

Variable	Measurement	Source of data
CO_2	This variable measures carbon dioxide emissions - total (excluding LULUCF and memo items, including international aviation) in thousand	Eurostat
GDP	This variable refers to gross domestic product at market prices in million euro	
FI	This variable refers to financial inclusion measured by access to financial institutions that collect ATM data per 100,000 adults	World Bank
RQ	This variable presents regulatory quality reflecting perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development (percentile rank)	
GOV	This variable presents government effectiveness reflecting perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies (percentile rank)	

Dependent variable. Since CO_2 emissions are an important determinant of environmental performance and the concept of green development, it is defined as a dependent variable in our research. It is also used as a dependent variable in most other research studies. For the

purpose of our research, it measures total carbon dioxide emissions in thousands of tons.

Research Model and Methods

To examine the impact of financial inclusion, regulatory quality, and government effectiveness on green development, the following model is estimated:

$$\text{Model: } CO_{2it} = f(GDP_{it}, FI_{it}, RQ_{it}, GOV_{it}) \quad (1)$$

In addition, the Pooled Mean Group (PMG) estimator of the dynamic heterogeneous panel was applied to the entire panel sample, following the work of Pesaran *et al.* (1999). The PMG estimator is a combination of pooling and averaging the coefficients. It allows the intercept, short-run coefficients, and error variances to differ between groups, but forces the long-run coefficients to be equal across groups. Often, there are valid reasons for expecting the long-run equilibrium relationships between variables to be similar across groups, such as budgetary or solvency constraints that affect all countries similarly. In contrast, the assumption that short-run dynamics and error variances are the same is not as compelling. Simply stated, not introducing equality constraints on short-run slope coefficients also allows for dynamic specification. Taking into account the fact that the 11 European countries analyzed are different with respect to their economic policies, CO_2 emissions are estimated using the PMG estimator.

Results

Descriptive Statistics

Table 3 summarizes the descriptive statistics for the variables analyzed and the countries observed. For each variable, the mean, standard deviation, minimum, and maximum values were calculated. All variables are expressed in natural logarithms.

Table 3

Descriptive Statistics of the Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
CO2	198	67.418,55	88.625,98	7.191,06	339.849,9
GDP	198	100.393,6	111.343,8	9.777,5	576.382,6
FI	198	66,97	24.41	18,29	156,79
RQ	198	77,20	7,76	58,82	93,26
GOV	198	71,29	10,69	42,30	89,42

In the period from 2004 to 2021, the average CO_2 emissions in the new EU countries were 67.41 million tons, with a minimum value of 7.19 million tons in Latvia (2020) and a maximum value of 339.84 million tons in Poland (2017). The average value of GDP was 100.39 million euro. The country with the highest GDP was Poland (576.38 million euro) in 2021, while the lowest value was recorded in Estonia (9.77 million euro) in 2004. Financial inclusion in the new EU member states averaged 66 ATMs per 100,000 adults. The country with the highest financial inclusion was Croatia (156 ATMs per 100,000 adults in 2019), and the country with the lowest financial inclusion was Romania (18 ATMs per 100,000 adults in 2004). This indicates significant differences among the new EU member states in terms of environmental degradation, GDP, and financial inclusion. The highest percentile rank for regulatory quality was achieved in Estonia in 2014 (93.26), and the lowest in Romania in 2005 (58.82). For government effectiveness (percentile rank), the average score was 71.29, with the highest recorded in Estonia in 2021 (89.42), and the lowest in Romania in 2020 (42.30).

Pre-Analysis Results

In the related literature, not much attention has been paid to the selection of an appropriate regression estimator for dealing with cross-sectional dependent (CD) heterogeneous panel data sets. A problem of cross-sectional dependence may arise in the data because of the economic, cultural, and social ties that exist among a selected number of neighboring countries included in the cross-sectional data. If the problem of cross-sectional dependence is overlooked, the results of stationarity, cointegration, and causality may be biased.

Firstly, all variables must be tested for stationarity. The empirical results of the CD and unit root tests are presented in Table 3. After confirming CD in the data, the integrated level of the variables was examined using the cross-sectionally extended Dickey-Fuller (CADF) panel unit root test (Pesaran, 2007) and the cross-sectionally augmented I.P.S. test (CIPS) (Pesaran, 2007). Based on the panel unit root tests presented in Table 4, it can be concluded that almost all series of interest are integrated of order one, or difference stationary.

Table 4

Results of Cross-Sectional and Unit-Root Tests

		CADF		CIPS	
Variable	CD-test	Level	Difference	Level	Difference
lco2	20.98***	-1.937	-2.112	-2.079	-4.034***
lgdp	29.91***	-2.953**	-2.480***	-2.652	-3.146***
lfi	15.86***	-1.993	-1.742	-1.322	-4.006 ***
lrq	1.25	-1.879	-2.170**	-1.509	-4.535***
lgov	2.22*	-1.231	-1.527	-1.977	-4.613***

*Notes: Under the null hypothesis of cross-section independence, CD ~ N (0,1) P-values close to zero indicate data are correlated across panel groups, *, ** and *** denote the statistical significance at the 10%, 5 % and 1% levels.*

Source: Authors' estimates.

Since the focus of this study is on the long-run relationship between financial inclusion, regulatory quality, and government effectiveness with respect to CO_2 emissions, and as all single variables under the analysis have unit root, this relationship can only be consistently estimated if all variables are cointegrated in the long run. With this in mind, the next step in the empirical analysis was to conduct panel cointegration tests. Pedroni, Westerlund, and Kao cointegration tests were conducted. The results of the performed panel cointegration tests are summarized in Table 5.

Table 5

Panel Cointegration Test Results

Pedroni cointegration test		**Westerlund cointegration test**	
	Statistics		Statistics
Modified Phillips-Perron t	3.1093***	Variance ratio	-0.8752
Phillips-Perron t	-2.2232**		
Augmented Dickey-Fuller t	-1.9440**		
Kao cointegration test			
	Statistics		
Modified Dickey-Fuller t	-3.6655***	Unadjusted modified Dickey-Fuller t	-4.6937***
Dickey-Fuller t	-3.0595***	Unadjusted Dickey-Fuller t	-3.4054***
Augmented Dickey-Fuller t	-3.5519***		

*Note: ** and *** denote the statistical significance at the 1% and 5 % levels*
Source: Authors' estimates.

Therefore, it can be concluded that the series of interest are indeed cointegrated in the long run. So, the null hypothesis of no cointegration is strongly rejected in all performed panel cointegration tests (except Westerlund), with statistical significance of 1% and 5%.

Estimation Results

According to the analysis performed, all the variables of interest have a unit root and they are cointegrated in the long run, so the next step of the empirical analysis in this paper was to estimate a following simplified model using the PMG estimator:

$$CO2_{t,i} = \gamma_{0i} + \gamma_{1i}GDP_{t,i} + \gamma_{2i}FI_{t,i} + \gamma_{3i}RQ_{t,i} + \gamma_{4i}Gov_{t,i} + \varepsilon_{t,i}, \quad i = 1,2,\dots,N, t = 1,2,\dots,T \tag{2}$$

The error term capturing the effects of unexpected shocks to carbon dioxide emissions is denoted by $\varepsilon_{t,i}$. The subscripts i and t denote country and time, respectively. Deviations from the long-run relationship given in equation (2) are possible in the short run. Also, following the PMG procedure it is assumed that in the short run, carbon dioxide emissions differ across countries. Thus, this assumption is implemented by using conventional statistical criteria and determining lag length for each variable. For the purpose of simplification, it is assumed here (but relaxed afterwards) that only the first lag of each variable is important for determining carbon dioxide emissions in each country. Thus, the model given in Equation (2) can be written as an autoregressive distributed lag – ARDL (1,1,1,1) model:

$$CO2_{t,i} = \delta_i + \gamma_i CO2_{t-1,i} + \beta_{10i}GDP_{t,i} + \beta_{11i}GDP_{t-1,i} + \beta_{20i}FI_{t,i} + \beta_{21i}FI_{t-1,i} + \beta_{30i}RQ_{t,i} + \beta_{31i}RQ_{t-1,i} + \beta_{40i}Gov_{t,i} + \beta_{41i}Gov_{t-1,i} + \varepsilon_{t,i} \tag{3}$$

Since, in this case, all the variables under analysis are I(1) and co-integrated, the error term $(\varepsilon_{t,i})$ is an I(0) process for all the countries in the sample (i). According to Engle and Granger (1987), there is a clear connection between cointegration and the error-correction mechanism and, since cointegrated variables show great responsiveness to any deviation from long-run equilibrium, an error-correction reparametrization is utilized:

$$\Delta CO2_{t,i} = \varphi_i(CO2_{t-1,i} - \alpha_{0i} - \alpha_{1i}GDP_{t,i} - \alpha_{2i}FI_{t,i} - \alpha_{3i}RQ_{t,i} - \alpha_{4i}Gov_{t,i}) + \beta_{11i}\Delta GDP_{t,i} + \beta_{21i}\Delta FI_{t,i} + \beta_{31i}\Delta RQ_{t,i} + \beta_{41i}\Delta Gov_{t,i}\varepsilon_{t,i} \tag{4}$$

Where:

$$\varphi_i = -(1-\gamma_i), \alpha_{01} = \frac{\delta_i}{1-\gamma_i}, \alpha_{1i} = \frac{\beta_{10i}+\beta_{11i}}{1-\gamma_i}, \alpha_{2i} = \frac{\beta_{20i}+\beta_{21i}}{1-\gamma_i}, \alpha_{3i} = \frac{\beta_{30i}+\beta_{31i}}{1-\gamma_i}, \alpha_{4i} = \frac{\beta_{40i}+\beta_{41i}}{1-\gamma_i} \tag{5}$$

The error-correcting speed of the adjustment term is denoted by φ_i and it is expected to be statistically significant and negative. An important issue that needs to be handled in the empirical analysis of this paper is the dynamic structure of carbon dioxide emissions, assuming that certain economic aspects in each country prevent immediate adjustment of carbon dioxide emissions to changes in the independent variables analyzed, so a panel autoregressive distributed lag model ARDL needs to be used.

Also, a common econometric problem that arises when estimating a carbon dioxide emissions model is the serial autocorrelation problem and the problem of endogenous regressors that are handled here by choosing the appropriate lag structure for dependent and independent variables. In that sense, following the PMG procedure, the first and necessary step was to choose the lag order of the ARDL model by applying the Schwartz Bayesian information criterion (SBC). Even though there was no clear evidence of a most common representation, after choosing a country-

specific lag order of the ARDL model by applying the SBC information criterion, the preferred specification for the whole sample of countries analyzed was an ARDL (1,0,0,0,0), that is: carbon dioxide emission is lagged once, and gross domestic product, financial inclusion, regulatory quality, and government effectiveness are given in levels:

$$CO2_{t,i} = \delta_{01} + \gamma_i CO2_{t-1,i} + \beta_{10i} GDP_{t,i} + \beta_{20i} FI_{t,i} + \beta_{30i} RQ_{t,i} + \beta_{40i} Gov_{t,i} + \varepsilon_{t,i} \quad (6)$$

An error-correction reparametrization of equation (7) is employed:

$$\Delta CO2_{t,i} = \varphi_i (CO2_{t-1,i} - \alpha_{0i} - \alpha_{1i} GDP_{t,i} - \alpha_{2i} FI_{t,1} - \alpha_{3i} RQ_{t,i} - \alpha_{4i} Gov_{t,1}) + \beta_{11i} \Delta GDP_{t,i} + \beta_{21i} \Delta FI_{t,i} + \beta_{31i} \Delta RQ_{t,i} + \beta_{41i} \Delta Gov_{t,i} + \varepsilon_{t,i} \quad (7)$$

and represents the preferred specification to be estimated using the PMG estimator.

Since interest lies in the long-run relationship between carbon dioxide emissions, gross domestic product, financial inclusion, regulatory quality, and government effectiveness, Equation (7) is used as the baseline model which is evaluated using the PMG estimator that allows for heterogeneous short-run dynamics and common long-run gross domestic product, financial inclusion, regulatory quality, and government effectiveness. The results of the estimated baseline model of carbon dioxide emissions for the panel of 11 selected European countries are given in Table 6, along with the specification test of Hausman type.

Table 6

Baseline Model of Carbon Dioxide Emissions (PMG) and Alternative Estimation Result Using MG Estimator

	PMG	**MG**
Speed of adjustment	-0.376*** [0.077]	-0.574*** [0.089]
lgdp	-0.346*** [0.054]	0.342 [0.654]
lfi	0.308*** [0.064]	-0.288 [0.782]
lrq	0.424* [0.224]	3.006 [2.462]
Long-run coefficients		
lgov	-0.529*** [0.093]	-3.656 [3.298]
Short-run coefficients		
Δlgdp	0.634*** [0.084]	0.675*** [0.152]
Δlfi	0.013 [0.141]	0.182 [0.149]
Δlrq	-0.320 [0.237]	-0.503 [0.668]
Δlgov	0.081 [0.099]	0.047 [0.160]
constant	5.150*** [1.158]	5.708 [3.024]
Number of observations	186	186
Number of countries	11	11
Hausman test	$\chi^2(2) = 0.674$	

*Note: Estimations are performed using the PMG and MG estimators of Pesaran et al. (1999); all equations include a constant term; standard errors are in brackets, ***, **, * denote significance at the 1, 5 and 10 percent confidence levels, respectively.*

Source: Authors' estimates.

As stated earlier, the PMG estimator forces the long-run elasticities to be equal across all countries. This cross-country "pooling" leads to efficient and consistent estimates when the constraint actually holds. If, on the other hand, the homogeneity of the slope is empirically rejected, the true model is heterogeneous and the PMG estimates are inconsistent. However, the MG estimator provides consistent estimates of the mean of the long-run coefficients in both cases: when the slope is homogeneous and when it is heterogeneous. This is the reason for applying the Hausman test to the difference between the MG and PMG estimators. According to the test results presented in Table 5, it can be concluded that the PMG estimator, which is efficient under the null hypothesis, is preferable.

According to Table 5, the adjustment coefficient for the panel of 11 EU countries analyzed has the correct negative sign and is statistically significant at a 1% significance level, with the average value of the error correction coefficient (according to the PMG estimator) being -0.376, indicating that the long-run equilibrium of carbon dioxide emissions, GDP, financial inclusion, regulatory quality, and government effectiveness will be reached in about 3 years.

The estimated model suggests that GDP is statistically significant at a 1% significance level in the long run, with an elasticity of carbon dioxide emissions to changes in GDP of 0.346. This means that a 1% increase in GDP causes a 0.346% decrease in CO_2 emissions in the long run. This proves that GDP does not cause environmental degradation in the EU-11 countries. Since the new EU countries have been part of the EU since 2004, they have had to implement many environmental policies and regulations that have decoupled economic growth from CO_2 emissions. One of

the goals of the European Green Deal is to increase economic growth while reducing carbon emissions to achieve net zero emissions by 2050. However, the EU's commitment to reduce greenhouse gas emissions by 55% by 2030 requires a tripling of efforts to reduce fossil fuel consumption and adopt alternative energy sources that promote environmental sustainability and a green environment.

Financial inclusion also has an important impact on carbon emissions in the long run, with a statistically significant and positively signed coefficient (0.308), which means that financial inclusion causes an increase in environmental degradation. It seems that easy access to financial products and services encourages unsustainable practices. This result shows that investors prefer to finance investments that require more fossil energy, which increases CO_2 emissions. The findings are consistent with studies by Murshed *et al*. (2023) for 22 emerging economies, Murshed *et al.* (2022) in seven emerging economies, Hussain *et al.* (2023) for a panel of 74 countries, Dou and Li (2022) for BRICS countries, Lin and Wu (2022) for E7 countries, Fareed *et al*. (2022) for 27 EU countries, and Zaidi *et al.* (2021) for 23 OECD countries.

Besides financial inclusion, regulatory quality also has a significant impact on CO_2 emissions, which means that as the quality of regulation increases, pollution also increases. Regulatory quality captures the perception of the government's ability to formulate and implement sound policies and regulations that enable and promote private sector development. This is where the regulatory aspects of governance become important in creating a framework that requires companies to use cleaner forms of energy and adopt technologies that minimize environmental damage and pollution. This suggests that, in line with the growth aspirations of the new EU countries and in order to reduce CO_2 emissions for green growth and sustainable development, stricter environmental and energy-related regulations are inevitable. The positive relationship between regulatory quality and CO_2 emissions follows an empirical rationale that suggests that environmental policies in the new EU countries seem to be less rigorous and, on the other hand, may hinder environmental improvements. The environmental effects of regulatory quality as obtained in this study are similar to Abid (2016) for 25 sub-Saharan African countries and Adedoyin *et al.* (2020) for BRICS countries, while it contradicts the submission of Mahmood et al. (2022) for four South Asian economies and Addai *et al.* (2022) for Eastern European economies that claim that institutional quality improves environmental quality.

However, monitoring for government effectiveness has a beneficial effect on reducing CO_2 emissions. Specifically, government effectiveness appears to reduce CO_2 emissions by 0.529%. A negative relationship between government effectiveness and emissions was also found by Al-Mulali *et al.* (2022) for 170 countries, Abid (2016) for 25 sub-Saharan African countries, Mehmood (2022) for five South Asian countries and Danish et al. (2019) for BRICS countries, while it contradicts the study of Gani (2012), who found no effects on CO_2 emissions.

Discussion

The main objective of this paper is to analyse whether financial inclusion combined with the quality of regulation, government effectiveness and economic growth can reduce climate risks and promote green development in the 11 new EU countries in the period 2004-2021. The 11 new EU countries were selected for empirical analysis because they joined the EU after 2004 and need to adapt their climate policies by 2050. For these countries, green development is a major challenge that is accompanied by political, social, economic and environmental framework conditions. In addition, the contribution of measures to green development can be considered from a technological, environmental and social perspective. When considering the technological aspect, the main focus is on energy production and use, minimising CO_2 emissions, energy consumption by reducing greenhouse gas emissions (Stankuniene *et al.* 2020), renewable energy sources and the conservation of natural resources. The environmental aspect refers to environmental sustainability and the transition to climate neutrality (Kyriakopoulos, Grigorios and Sebos, 2023; Kyriakopoulos, Grigorios *et al.* 2023a), while the social aspect refers to the creation of energy communities to secure affordable energy for all actors in society (Kyriakopoulos, Grigorios 2022), to achieve the decarbonisation of the EU system, the formation and public acceptance of energy systems based on renewable energy (Kyriakopoulos, Grigorios, 2021) and the circular economy to improve the daily lives of citizens (Kyriakopoulos, Grigorios and Solovev, 2022; Kyriakopoulos, Grigorios 2023b). Consequently, this will reduce energy poverty in low-income households (Streimikiene *et al*. 2020; Streimikiene, *et al.* 2021). Therefore, legislation and documentation of best practices should be transparent and explained in more detail to consumers. They should also be closely linked to technological progress, the protection of workers and the acceptance of local society (Kyriakopoulos, Grigorios, 2021a).

The results of the empirical analysis indicate that carbon dioxide emissions respond in the long run to changes in all the independent variables analysed, i.e. GDP, financial inclusion, regulatory quality and government effectiveness, with the impact of government effectiveness being the most pronounced (with the largest and negative coefficient). On the other hand, GDP has the strongest short-term impact on carbon dioxide emissions, with a positive and statistically significant coefficient at a significance level of 1. In addition, the results show that economic growth and government effectiveness have a significant negative impact on CO_2 emissions, similar to a study by Abid (2016) and Al-Mulali et al. (2022). On the other hand, financial inclusion has an important impact on CO2 emissions in the long run. Overall, financial inclusion is one of the most important determinants in promoting and supporting green development. In order to achieve the desired level of financial inclusion, additional government interventions (Streimikiene *et al.* 2024) and strategies as well as political stability and legislation are essential.

Conclusion and Policy Implications

The EU has adopted the European Green Deal Strategy with an ambitious plan to mitigate climate change and promote sustainable and green development. Various governmental instruments and financial support will be provided to achieve the desired goals. This will lead to green development, in which financial inclusion plays an important role. It helps financial sectors and institutions to grow and provides financial support for green initiatives and investments. Although there is a lack of empirical evidence in the literature regarding the relationship between financial inclusion and green development, this gap has been addressed by this analysis. Using the PMG and mean group estimator, the short- and long-term effects on green development in the 11 new EU countries were examined for the period 2004 to 2021. The analysis yielded interesting results.

The results of the analysis should also be valuable for policymakers, as they point to the following policy implications. In the case of the 11 new EU countries, the transition to a low-carbon economy and the reduction of CO_2 emissions will be particularly challenging due to their current dependence on fossil fuels and their lower level of economic development. These countries may face investment challenges that may slow their progress toward achieving the greenhouse gas emission reduction targets set out in the European Green Deal. Therefore, it is critical for these countries to focus on improving regulatory quality, government effectiveness, and financial inclusion to address the challenges they face in reducing CO_2 emissions and promoting sustainable development. Thus, financial inclusion and regulatory quality appear to be the most significant barriers to effective emissions reduction. Therefore, policymakers in the new EU countries should take a closer look at financial inclusion and regulatory quality. They should formulate and implement green policies and regulations that enable and encourage the development of a green private sector. They should also improve financial inclusion, which can lead to financial market development in which companies are expected to take green measures to reduce CO_2 emissions. Specifically, a new partnership between the government, financial institutions, and industry should be developed to promote green development.

Like any research, this one has its limitations. The most important limitation concerns the data availability of the variables analyzed, since other variables should be included in the analysis. The second limitation lies in the fact that the conclusions were drawn for the whole sample of the 11 new EU countries, with differences between countries. Therefore, the recommendation for future research is to conduct cross-country analyses and examine the impact of financial inclusion on green development in each country separately.

Appendix

Table 1

Overview of Key Policies Measures and Regulations

1990	Report of the Intergovernmental Panel on Climate Change
1993	Directive establishing Specific Actions for Vigorous Energy Efficiency Programme to support energy efficiency
1993	Decision establishing ALTENER Programme to support renewable energy
1993	Decision 93/389/EEC establishing GHG Emissions Monitoring Mechanism
1997	Implementation of Kyoto Protocol
1998 & 1999	Voluntary agreement with car manufactures to reduce emissions and the Landfill Directive 1999/31/EC
2000	European Climate Change Programme (ECCP) was launched
2001	Renewable Electricity Directive
2002	Energy Performance of Buildings Directive
2003	Biofuels and Renewable Fuels in Transport Directive
2003	Emissions Trading Directive
2004	Linking Directive
2004	Combined Heat and Power Directive
2005	Ecodesign Directive
2006	Regulation and Directive on Reduction of Emissions of Fluorinated GHG
2008	Directive on Aviation in the Emissions Trading System
2009	Regulation on CO_2 Emissions from cars
2009	Emissions Trading Directive
2009	Renewable Energy Directive
2010	Energy Performance of Buildings Directive
2012	Energy Efficiency Directive
2015	Carbon Market Stability Reserve Decision
2018	Emissions Trading Directive, Effort Sharing Regulation, Energy Efficiency Directive, Renewable Energy Directive, Governance Regulation
2020	Taxonomy Regulation
2021	European Climate Law
2021	Just Transition Fund Regulation
2023	Carbon Border Adjustment Mechanism
2023	Social Climate Fund Regulation

Source: Authors systematization based on Oberthur & von Homeyer (2023) and Dupont et al. (2023).

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References

Abid, M. (2016). Impact of economic, financial, and institutional factors on CO_2 emissions: Evidence from Sub-Saharan Africa economies. *Utilities Policy,* 41, 85–94. https://doi.org/10.1016/j.jup.2016.06.009

Addai, K., Serener, B., & Kirikkaleli, D. (2022). Environmental Sustainability and Regulatory Quality in Emerging Economies: Empirical Evidence from Eastern European Region. *Journal of the Knowledge Economy*. https://doi.org/10.1007/s13132-022-01000-2

Adedoyin, F. F., Gumede, M. I., Bekun, F. V., Etokakpan, M. U., & Balsalobre-Lorente, D. (2020). Modelling coal rent, economic growth and CO2 emissions: does regulatory quality matter in BRICS economies?. *Science of the Total Environment*, 710. https://doi.org/10.1016/j.scitotenv.2019.136284

Al-Mulali, U., Gholipour, H.F. & Solarin, S. A. (2022). Investigating the environmental Kuznets curve (EKC) hypothesis: does government effectiveness matter? Evidence from 170 countries. *Environment, Development and Sustainability*, 24, 12740-12755. https://doi.org/10.1007/s10668-021-01962-4

Amin, N., Song, H., & Khan, Z. A. (2022). Dynamic linkages of financial inclusion, modernization, and environmental sustainability in South Asia: a panel data analysis. *Environmental Science and Pollution Research*, 1-9. https://doi.org/10.1007/s11356-021-16648-7

Asafu-Adjaye, J. (2000). The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. *Energy Economics,* 22(6), 615-625. https://doi.org/10.1016/S0140-9883(00)00050-5

Azam, M., Hunjra, A. I., Bouri, E., Tan, Y., & Al-Faryan, M. A. S. (2021). Impact of institutional quality on sustainable development: Evidence from developing countries. *Journal of Environmental Management*, *298*. https://doi.org/10.1016/j.jenvman.2021.113465

Belke, A., Dobnik, F., & Dreger, C. (2011). Energy consumption and economic growth: New insights into the cointegration relationship. *Energy Economics*, 33(5), 782-789. https://doi.org/10.1016/j.eneco.2011.02.005

Chang, C. C. (2010). A multivariate causality test of carbon dioxide emissions, energy consumption and economic growth in China. *Applied Energy*, 87(11), 3533-3537. https://doi.org/10.1016/j.apenergy.2010.05.004

Chaudhry, I. S., Yusop, Z., & Habibullah, M. S. (2022). Financial inclusion-environmental degradation nexus in OIC countries: new evidence from environmental Kuznets curve using DCCE approach. *Environmental Science and Pollution Research*, 29(4), 5360-5377. https://doi.org/10.1007/s11356-021-15941-9

Dai, X., Qian, S., & Zhang, J. (2022). Sustainable financial inclusion as a source of green environment? Evidence from selected regional comprehensive economic partnership countries. *Economic Research – Ekonomska istraživanja*, 35(1), 5719-5738. https://doi.org/10.1080/1331677X.2022.2035244

Danish, Baloch, M. A., & Wang, B. (2019). Analyzing the role of governance in CO2 emissions mitigation: The BRICS experience, *Structural Change and Economic Dynamics*, 51, 119-125. https://doi.org/10.1016/j.strueco.2019.08.007

Dogan, E., Hodzic, S., & Fatur Sikic, T. (2023). Do energy and environmental taxes stimulate or inhibit renewable energy deployment in the European Union?. Renewable energy, 202, 1138-1145. https://doi.org/10.1016/j.renene.2022.11.107

Dou, D., & Li, L. (2022). Does sustainable financial inclusion and energy efficiency ensure green environment? Evidence from BRICS countries. *Economic research-Ekonomska istraživanja*, 35(1), 5599-5614. https://doi.org/10.1080/1331677X.2022.2032785

Du, Q., Wu, N., Zhang, F., Lei, Y., & Saeed, A. (2022). Impact of financial inclusion and human capital on environmental quality: evidence from emerging economies. *Environmental Science and Pollution Research*, 29(22), 33033-33045. https://doi.org/10.1007/s11356-021-17945-x

Dupont, C., Moore, B., Boasson, E. L., Gravey, V., Jordan, A., Kivimaa, P., Kulovesi, K., Kuzemko, C., Oberthur, S., Panchuk, D., Rosamond, J., Torney, D., Tosun, J., & von Homeyer, I. (2024). Three decades of EU climate policy: Racing toward climate neutrality?, *WIREs Climate Change*, 15(1), e863. https://doi.org/10.1002/wcc.863

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica: journal of the Econometric Society*, 251-276. https://doi.org/10.2307/1913236

Esty, D. C., & Porter, M. E. (2005). National environmental performance: an empirical analysis of policy results and determinants. *Environment and Development Economics*, 10(4), 391–434. http://www.jstor.org/stable/44379244; https://doi.org/10.1017/S1355770X05002275

Fareed, Z., Rehman, M. A., Adebayo, T. S., Wang, Y., Ahmad, M., & Shahzad, F., (2022). Financial inclusion and the environmental deterioration in Eurozone: the moderating role of innovation activity. *Technology in Society*, 69. https://doi.org/10.1016/j. techsoc.2022.101961

Feng, C., Wang, M., Guan-Chun L., & Jian-Bai, H. (2017). Green development performance and its influencing factors: A global perspective. *Journal of Cleaner Production*, 144, 323-333. https://doi.org/10.1016/j.jclepro.2017.01.005

Gani, A. (2012). The relationship between good governance and carbon dioxide emissions: evidence from developing economies. *Journal of Economic Development*, 37(1), 77. https://doi.org/10.35866/caujed.2012.37.1.004

Hodzic, S., Fatur Sikic, T., & Dogan, E. (2023). Green environment in the EU countries: The role of financial inclusion, natural resources and energy intensity. *Resources policy*, 82, 103476-103486. https://doi.org/10.10.1016/j.resourpol.2023.103476

Hussain, S., Gul, R., Shahzad, J., & Naifar, Nader. (2023). Relationship between financial inclusion and carbon emissions: International evidence. *Heliyon*. 9. https://doi.org/10.1016/j.heliyon.2023.e16472

Ibrahim, R. L., & Ajide, K. B. (2021). The dynamic heterogeneous impacts of nonrenewable energy, trade openness, total natural resource rents, financial development and regulatory quality on environmental quality: Evidence from BRICS economies. *Resources Policy*, 74. https://doi.org/10.1016/j.resourpol.2021.102251

Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of econometrics*, 90(1), 1-44. https://doi.org/10.1016/S0304-4076(98)00023-2

Karim, Z. A., Rosmah, N., Siong, H. L., & Kabir, H. M. (2022). Does Financial Inclusiveness Affect Economic Growth? New Evidence Using a Dynamic Panel Threshold Regression. *Finance Research Letters*, 46(A), 1544-6123. https://doi.org/10.1016/j.frl.2021.102364

Kim, D. W., Jung-Suk, Y., & Kabir H. M., Financial inclusion and economic growth in OIC countries. *Research in International Business and Finance,* 43, 1-14. https://doi.org/10.1016/j.ribaf.2017.07.178

Kyriakopoulos, G. L., & Sebos, I. (2023). Enhancing Climate Neutrality and Resilience through Coordinated Climate Action: Review of the Synergies between Mitigation and Adaptation Actions. *Climate*, 11(5). https://doi.org/10. 3390/cli11050105

Kyriakopoulos, G. L., Sebos, I., Triantafyllou, E., Stamopoulos, D., & Dimas, P. (2023a). Benefits and Synergies in Addressing Climate Change via the Implementation of the Common Agricultural Policy in Greece. *Applied Sciences*, 13(4). https://doi.org/10.3390/app13042216

Kyriakopoulos, Grigorios L. (2023b). Chapter 10 - Circular economy and sustainable strategies: Theoretical framework, policies and regulation challenges, barriers, and enablers for water management. *Water Management and Circular Economy*, 197-230. https://doi.org/10.1016/B978-0-323-95280-4.00014-X.

Kyriakopoulos, Grigorios L. (2022). Energy Communities Overview: Managerial Policies, Economic Aspects, Technologies, and Models. *Journal of Risk and Financial Management*, 15. https:// doi.org/10.3390/jrfm15110521

Kyriakopoulos, G. L., & Solovev, D. B. (2022). Circular Economy (CE) Innovation and Internationalization of Small and Medium Enterprises (SMEs): Geographical Overview and Sectorial Patterns. In: Solovev, D. B., Savaley, V. V., Bekker, A. T., Petukhov, V. I. (eds) Proceeding of the International Science and Technology Conference "FarEastCon 2021". Smart Innovation, Systems and Technologies, 275. Springer, Singapore. https://doi.org/10.1007/978-981-16-8829-4_10

Kyriakopoulos, Grigorios L. (2021). Should low carbon energy technologies be envisaged in the context of sustainable energy systems? In Low Carbon Energy Technologies in Sustainable Energy Systems. Cambridge: Academic Press, 357–389. https://doi.org/10.1016/B978-0-12-822897-5.00015-8

Kyriakopoulos, Grigorios L. (2021a). Environmental Legislation in European and International Contexts: Legal Practices and Social Planning toward the Circular Economy. *Laws*, 10(3). https://doi.org/10.3390/laws10010003

Le, T. H., Chuc, A. T., & Taghizadeh-Hesary, F. (2019). Financial inclusion and its impact on financial efficiency and sustainability: Empirical evidence from Asia. *Borsa Istanbul Review*, 19(4), 310–322. https://doi.org/10.1016/j.bir.2019.07.002

Le, T.H., Le, H.C., & Taghizadeh-Hesary, F., (2020). Does financial inclusion impact CO_2 emissions? Evidence from Asia. *Finance Research Letters,* 34. https://doi.org/ 10.1016/j.frl.2020.101451

Lee, C. C., & Chang, C. P. (2008). Energy consumption and economic growth in Asian economies: a more comprehensive analysis using panel data. *Resource and Energy Economics*, 30(1), 50-65. https://doi.org/10.1016/j.reseneeco.2007.03.003

Li, K., & Song, M. (2016). Green Development Performance in China: A Metafrontier Non-Radial Approach. *Sustainability,* 8(3), 291, https://doi.org/10.3390/su8030219

Lin, S., & Wu, R. (2022). On the nexus between energy efficiency, financial inclusion and environment: Evidence from emerging seven economies using novel research methods. *Economic research-Ekonomska istraživanja*, 35(1), 6756-6779. https://doi.org/10.1080/1331677X.2022.2053362.

Liu, H., Yao, P., Latif, S., Aslam, S., & Iqbal, N. (2021). Impact of Green financing, FinTech, and financial inclusion on energy efficiency. *Environmental Science and Pollution Research*, 1–12. https://doi.org/10.1007/s11356-021-16949-x

Liu, Z., Vu, T. L., Phan, T. T. H., Ngo, T. Q., Anh, N. H. V., & Putra, A. R. S. (2022). Financial inclusion and green economic performance for energy efficiency finance. *Economic Change and Restructuring*, 55(4), 2359-2389. https://doi.org/10.1007/s10644-022-09393-5.

Mahmood, H., Hassan, S., Tanveer, M., & Abdul-Rahim, A. (2022). The Effects of Rule of Law, Regulatory Quality, and Renewable Energy on CO2 Emissions in South Asia. *International Journal of Energy Economics and Policy*, 12(6), 16. https://doi.org/10.32479/ijeep.13468

Mehmood, U. (2022). Renewable energy and foreign direct investment: does the governance matter for CO_2 emissions? Application of CS-ARDL. Environmental Science and Pollution Research, 29, 19816–19822. https://doi.org/10.1007/s11356-021-17222-x

Mukalayi, N. M., & Inglesi-Lotz, R. (2023). Digital financial inclusion and energy and environment: global positioning of sub-Saharan African countries. *Renewable and Sustainable Energy Reviews*, 173. https://doi.org/10.1016/j.rser.2022.113069.

Murshed, M., Ahmed, R., Khudoykulov, K., Kumpamool, C., Alrwashdeh, N. N. F., & Mahmood, H. (2023). Can enhancing financial inclusivity lower climate risks by inhibiting carbon emissions? Contextual evidence from emerging economies. *Research in International Business and Finance*, 65. https://doi.org/10.1016/j.ribaf.2023.101902

Murshed, M., Apergis, N., Alam, M. S., Khan, U., & Mahmud, S. (2022) The impacts of renewable energy, financial inclusivity, globalization, economic growth, and urbanization on carbon productivity: Evidence from net moderation and mediation effects of energy efficiency gains. *Renewable Energy*, 196, 824–838. https://doi.org/10.1016/j.renene.2022.07.012

Mushafiq, M. (2023). Towards green development: Role of researchers. *Innovation and Green Development*, 2(4). https://doi.org/10.1016/j.igd.2023.100075

Oberthur, S., & von Homeyer, I. (2023). From emissions trading to the European Green Deal: The evolution of the climate policy mix and climate policy integration in the EU. *Journal of European Public Policy*, 30(3), 445-468. https://doi.org/10.1080/13501763.2022.2120528

Pedroni, P. (2004). Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric theory*, 20(3), 597-625. https://doi.org/10.1017/S0266466604203073

Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American statistical Association*, 94(446), 621-634. https://doi.org/10.1080/01621459.1999.10474156

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of applied econometrics*, 22(2), 265-312. https://doi.org/10.1002/jae.951

Pushak, T., Tiongson, E. R., & Varoudakis, A. (2007). Public finance, governance, and growth in transition economies: Empirical evidence from 1992-2004. *World Bank Policy Research Working Paper*, No. 4255. https://doi.org/10.1596/1813-9450-4255

Qin, L., Raheem, S., Murshed, M., Miao, X., Khan, Z., & Kirikkaleli, D. (2021). Does financial inclusion limit carbon dioxide emissions? Analyzing the role of globalization and renewable electricity output. *Sustainable. Development,* 29, 1138–1154. https://doi.org/10.1002/sd.2208

Renzhi, N., & Baek, Y. J. (2020). Can financial inclusion be an effective mitigation measure? Evidence from panel data analysis of the environmental Kuznets curve. *Finance Research Letters*, 37. https://doi.org/10.1016/j.frl.2020.101725

Stankuniene, G., Streimikiene, D., & Kyriakopoulos, Grigorios L. (2020). Systematic Literature Review on Behavioral Barriers of Climate Change Mitigation in Households. *Sustainability*, 12(18). https://doi.org/10.3390/su12187369

Streimikiene, D., Lekavicius, V., Balezentis, T., Kyriakopoulos, G. L., & Abrham, J. (2020). Climate Change Mitigation Policies Targeting Households and Addressing Energy Poverty in European Union. *Energies*, 13(13), https://doi.org/10.3390/en13133389

Streimikiene, D., Kyriakopoulos, G., Lekavicius, V., & Siksnelyte-Butkiene, I. (2021). Energy Poverty and Low Carbon Just Energy Transition: Comparative Study in Lithuania and Greece. *Social Indicators* Research, 158, 319–371. https://doi.org/10.1007/s11205-021-02685-9

Streimikiene, D., & Kyriakopoulos, G. (2024). Climate Change Mitigation Performance in the EU Tourism Destination Sector. *Journal of Tourism and Services*, 15(28), 268–284. https://doi.org/10.29036/jots.v15i28.758

Tufail, M., Song, L., Umut, A., Ismailova, N., & Kuldasheva, Z. (2022). Does financial inclusion promote a green economic system? Evaluating the role of energy efficiency. *Economic Research – Ekonomska istrazivanja,* 35(1), 6780-6800. https://doi.org/10.1080/1331677X.2022.2053363

Van, L. T. H., Anh, V., Nhan Thien, N., & Duc Hong, V. (2021). Financial Inclusion and Economic Growth: An International Evidence. *Emerging Markets Finance and Trade*, 57(1), 239-263. https://doi.org/10.1080/1540496X.2019.1697672

Wang, S. S., Zhou, D. Q., Zhou, P., & Wang, Q. W. (2011). CO_2 emissions, energy consumption and economic growth in China: A panel data analysis. Energy Policy, 39(9), 4870-4875. https://doi.org/10.1016/j.enpol.2011.06.032

Wawrzyniak, D., & Doryn, W. (2020). Does the quality of institutions modify the economic growth-carbon dioxide emissions nexus? Evidence from a group of emerging and developing countries. *Economic research-Ekonomska istrazivanja*, 33(1), 124-144. https://doi.org/10.1080/1331677X.2019.1708770

Westerlund, J., (2005). New simple tests for panel cointegration. *Econometric Reviews*, 24(3), 297-316. https://doi.org/10.1080/07474930500243019

Zaidi, S. A. H., Hussain, M., & Zaman, Q. U. (2021). Dynamic linkages between financial inclusion and carbon emissions: evidence from selected OECD countries. *Resources, Environment and Sustainability*, 4. https://doi.org/10.1016/j.resenv.2021.100022

Zhang, X. P., & Cheng, X. M. (2009). Energy consumption, carbon emissions, and economic growth in China, *Ecological Economics,* 68(10), 2706-2712. https://doi.org/10.1016/j.ecolecon.2009.05.011

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