Achieving Carbon-Neutrality in MENA Countries: Does Financial Inclusion Matter?

Said, Rabie; Acheampong, Alex O.

Published in:
Journal of Environment and Development

DOI:
10.1177/10704965231225780

Article

The Journal of Environment & Development
2024, Vol. 33(2) 312–336

DOI: 10.1177/10704965231225780
journals.sagepub.com/home/jed
Sage

Achieving Carbon-Neutrality in MENA Countries: Does Financial Inclusion Matter?

Rabie Said[1] and Alex O. Acheampong[2]

Abstract

This study examines the relationship between financial inclusion, renewable energy, and CO_2 emissions using data from 11 Middle East and North Africa (MENA) countries from 2004 to 2019. Evidence from fixed effects-ordinary least squares (FE-OLS), dynamic ordinary least squares (DOLS), fully modified ordinary least squares (FMOLS), and canonical correlation regression (CRR) showed that financial inclusion contributes significantly to decarbonization. Country-specific analysis indicated that financial inclusion is associated with mitigating CO_2 emissions in Egypt, Israel, Qatar, and Tunisia while significantly spurring CO_2 emissions in Algeria, Lebanon, and Saudi Arabia. In addition, renewable energy contributes significantly to decarbonization in MENA, especially in Algeria, Lebanon, Tunisia, and Turkey. We recommend that policies promoting financial inclusion and renewable energy usage would contribute to the attainment of the carbon-neutrality goal by MENA countries.

Keywords

financial inclusion, CO_2 emissions, renewable energy, MENA, panel data

Introduction

This study examines the role of financial inclusion and renewable energy in decarbonization. Financial inclusion implies that all individuals and businesses have

[1]La Trobe University, Melbourne, VIC, Australia
[2]Bond University Bond Business School, Gold Coast, QLD, Australia

Corresponding Author:
Rabie Said, Plenty Road and, Kingsbury Dr, Bundoora, Kingsbury, La Trobe University, Melbourne, VIC 3086, Australia.
Email: r.said@latrobe.edu.au

access to a range of financial products and services, such as transactions, payments, savings, credit, and insurance, to satisfy their needs in a reasonable, suitable, reliable, and sustainable manner (World Bank, 2018). Accordingly, higher access to these financial services is supposed to accelerate the rate of economic growth and decrease income inequality through offering chances to all people in the society; thus, a prominent level of financial inclusivity within a country can be considered an indicator of its economic stability (Sahay et al., 2015). The increasing interest in this study area stems from increasing policymakers' awareness of the benefits of inclusive financial systems. International organizations have played a vital role in this context. For instance, in 2005, the United Nations adopted the aim of building inclusive financial systems around the globe and specified 2005 as the Year of Microcredit.[1] According to the Global Findex Database 2021, financial inclusion has increased significantly over the last decade. For instance, the global account ownership rate has increased from 50% in 2011 to 76% in 2021. Additionally, account ownership in developing countries improved by 30 percentage points, from 42% in 2011 to 71% in 2021—a more than 70% rise.[2]

The question that motivates this study is "*Has the improvement in financial development and specifically financial inclusion been associated with mitigation or contribution to carbon (CO_2) emissions*? In theory, the effect of financial inclusion on CO_2 emissions is mixed. On the one hand, Du et al. (2022) argue that financial inclusion significantly reduces energy emissions by promoting technological advancements in the energy supply to diminish pollution. On the other hand, higher financial inclusion promotes manufacturing and industrial activities, which may contribute to a higher level of CO_2 emissions that, in turn, increases global warming (Jensen, 1996). Whereas there is a different theoretical argument on the impact of financial inclusion on environmental pollution, the empirical findings are also contradictory (Mehmood, 2022; Shahbaz et al., 2022). For instance, Le et al. (2020), Fareed et al. (2022), and Ozturk and Ullah (2022) discovered that financial inclusion brings about environmental pollution in Asia, Europe, and Belt and Road initiative countries. Conversely, Du et al. (2022), Liu et al. (2022), and Wang et al. (2022) indicated that financial inclusion leads to a decrease in environmental pollution in emerging economies, including China.

Besides, the discussion on the importance of renewable energy in promoting environmental sustainability has remained unresolved. While some empirical studies suggest (see, e.g.,, Aydoğan & Vardar, 2020; Jamil et al., 2022; Wang et al., 2021) that renewable energy reduces CO_2 emissions per capita, other studies such as Boontome et al. (2017); Nathaniel and Iheonu (2019); and Twumasi (2017) showed that renewable energy has a negligible effect on environmental pollution.

This study, therefore, contributes to the literature by assessing the effect of financial inclusion on renewable energy-CO_2 emissions link utilizing data from 11 Middle East and North Africa (MENA) countries from 2004 to 2019. In view of the aim of this paper, several questions arouse the authors' interest. *(1) How does financial inclusion affect the environment in the MENA region? (2) Does the effect of financial inclusion on the environment vary across MENA countries? (3) Does renewable energy negatively* *impact the environment in the MENA region as a panel? (4) Does the relationship between renewable energy and CO_2 emissions vary across MENA countries?*

This study is motivated to focus on the MENA region for the following reasons. First, financial systems in the MENA region have enhanced in terms of credibility, security, depth, and diversity since the 1990s (Didier & Schmukler, 2013; Gaies et al., 2019; Kar et al., 2011). The banking sector has developed, stock markets have increased, and trade in derivative markets has multiplied. Significant progress has been made in financial inclusion by expanding payment, savings, and credit services for lower-income households and microenterprises. Nevertheless, despite this progress, there appears to be important room for additional enhancement in financial inclusion in the region. For instance, whereas the proportion of adults with bank accounts improved by around 46% in the MENA region between 2011 and 2021, only 48.092% of the total adult population had bank accounts in this region in 2021. This region's level of account ownership not only lags with respect to high-income countries and the world average but also when compared to similar countries in terms of economic development. For example, MENA lags behind Latin American countries (see Table 1).

Second, CO_2 emissions per capita in the region have also risen over the last two decades. According to the World Bank (2022), CO_2 emissions per capita were 4.4 metric tons in 2004. By 2010, that amount increased to 5.4 metric tons and then continued to rise to 5.6 metric tons by 2015 before it fell slightly to 5.4 metric tons in 2019 (see Figure 1).

Also, renewable energy production has improved in the MENA region in recent years. According to Belaid et al. (2021), the region's investment in renewable energy development increased from USD 1.2 billion in 2008 to USD 11 billion in 2016. Jordan, for instance, has approximately 15.7% of installed renewable energy, targeted to increase to 20% by 2025, and a current 6.5% of generated renewable energy. Algeria currently has 10 Megawatts (MW) of wind energy produced, which is expected to increase to 23% of the total energy produced by 2030, and 410 MW of solar energy produced, expected to increase to 62% of the total energy produced by 2030. Renewable energy share in the MENA region is expected to increase to 30% of the total energy produced by 2030. However, MENA is still far behind other parts of the world,

Table 1. Percentage of the Adult Population With an Account at a Financial Institution.

Region	2011	2014	2017	2021
MENA region	32.958	—	43.42	48.092
Latin America	39.383	51.912	55.144	73.552
East Asia and Pacific	59.852	71.997	73.694	82.852
OECD	89.987	94.017	94.68	97.193
Europe and Central Asia (excluding high-income)	44.819	57.787	65.294	77.792
East Asia and Pacific (excluding high-income)	55.075	69.136	70.619	80.273
The Whole World	50.628	62.003	68.516	76.196

Source: Global Findex database 2021.

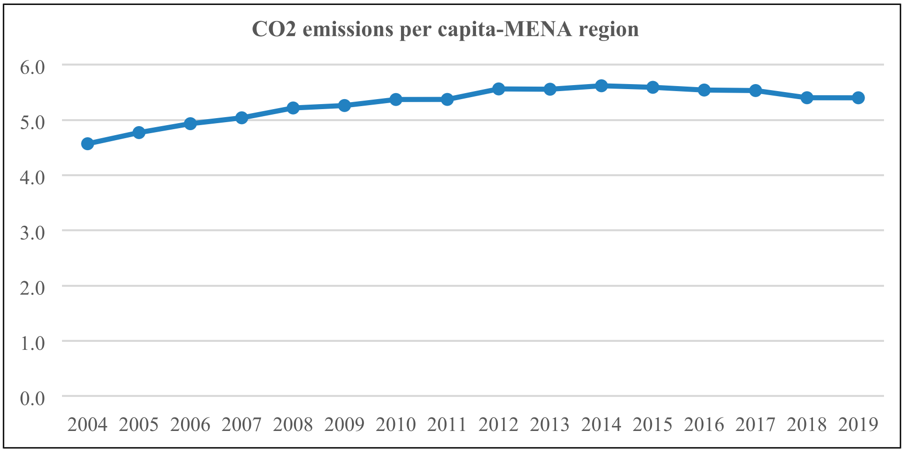

Figure 1. Trend of carbon emissions in the MENA region. Source: World Bank.

which are taking far bigger steps to increase their renewable footprint and phase out the use of fossil fuels (Belaid et al., 2021). Finally, despite various studies examining the link between environmental pollution and renewable energy, it's rare to find empirical studies examining the influence of financial inclusion in the relationship between renewable energy and CO_2 emissions for a panel of MENA countries.

Given the motivation for the study, this paper contributes to the literature in several ways. As far as the authors' knowledge, this is the first study examining the influence of financial inclusion in the connection between renewable energy and environmental pollution, using a series of econometric techniques such as dynamic ordinary least squares (DOLS), fully modified ordinary least squares (FMOLS), and canonical correlation regression (CCR) techniques, particularly for the MENA region. The empirical findings show that financial inclusion significantly reduces CO_2 emissions in the MENA region. The study further concludes that renewable energy contributes significantly to CO_2 emission reduction in the region.

Second, the study contributes to the literature by performing a country-specific analysis of the role of financial inclusion in renewable energy-CO_2 emissions links. From a policy point of view, the country-specific analysis is warranted because of the variation in financial inclusion, renewable energy, and CO_2 emissions among the MENA countries examined. For CO_2 emissions alleviation policy design, appropriate policy recommendations could be recommended based on country-specific estimates. The empirical evidence from the country-specific analysis reveals that financial inclusion has a significant negative effect on CO_2 emissions for Egypt, Israel, Qatar, and Tunisia, whereas it has a positive effect on CO_2 emissions in Algeria, Lebanon, and Saudi Arabia, with no significant effect in Morocco and Turkey. Furthermore, the results show that renewable energy has a significant negative impact on per capita CO_2

emissions in Algeria, Lebanon, Tunisia, and Turkey, with no significant impact in Egypt, Israel, Morocco, Qatar, and Saudi Arabia.

The remainder of this paper is structured as follows. Section 2 presents reviews of the existing literature. Section 3 describes the research methodology, data resources, and estimation techniques. Section 4 presents and discusses the main results. Section 5 contains the concluding remarks and policy implications.

Literature Review

Financial Inclusion and CO_2 Emissions

This section presents an overview of both theoretical and empirical studies on the link between CO_2 emissions and financial inclusion. In theory, there are two main conflicting opinions about the effect of financial inclusion on the environment. The first school of thought contends that financial inclusion could worsen the quality of the environment. Financial inclusion assists economic agents such as households and firms in improving access to financial resources to support their consumption and production activities (Jensen, 1996). For example, financial inclusion could enable households to obtain and consume durable items such as fridges, televisions, and washing machines and enable firms to expand their factories and buy new machinery that consumes a large amount of energy and hence contributing to the rise of CO_2 emissions (Le et al., 2020; Zaidi et al., 2021).

Nasir et al. (2019), for example, assess the influence of financial development on environmental degradation utilizing data from 5 ASEAN countries from 1982 to 2014. The empirical findings from different estimation techniques show that financial development contributes to increased environmental degradation. Khan et al. (2019) examine the association between financial development and CO_2 emissions by employing seemingly unrelated regression (SUR), three-stage least squares regression, and two-step GMM and two-step system GMM approaches for a sample of 193 countries from 1990 to 2017. The results reveal that financial development decreases CO_2 emissions when private credit sector is used as a proxy of financial development, but it decreases CO_2 emissions when credit provided by banks is used as a proxy of financial development.

Le et al. (2020) point out that the relationship between financial inclusion and CO_2 emissions is positive using a large sample of Asian countries. Fareed et al. (2022) opine that financial inclusion contributes to the increase in CO_2 emissions in the Eurozone from 1995 to 2018. Using a panel quantile regression to investigate the relationship between renewable energy consumption, carbon emission, and financial development in a large sample of 192 countries, Khan et al. (2020) indicate that financial development positively influences CO_2 emissions while renewable energy negatively affects CO_2 emissions. Additionally, Ozturk and Ullah (2022) examine the impact of financial inclusion on CO_2 emissions of 42 emerging economies from 2007 to 2019; the empirical results indicate that financial inclusion reduces environmental quality due to the growth of CO_2 emissions in these countries. Mehmood (2022), utilizing a cross-sectional autoregressive distributed lag approach (CSARDL), explores the relationship between CO_2 emissions and financial inclusion in four South Asian countries from 1990 to 2017. The empirical findings show that financial inclusion increases CO_2 emissions. Moreover, Amin et al. (2022) investigated the association between financial inclusion and environmental pollution in South Asia from 1998 to 2019. They reveal that financial inclusion brings about higher CO_2 emissions. Singh et al. (2022) indicate that financial inclusion increased CO_2 emissions in India from 2008 to 2018. Similarly, Tian and Li (2022) argue that financial inclusion significantly and positively influences CO_2 emissions using a sample of G20 economies from 2005 to 2018.

In contrast to the first school of thought, the second school of thought claims that financial inclusion improves the quality of the environment through technological advancements in the energy supply (Tamazian et al., 2009). For instance, using the Bayer–Hanck cointegration test, Umar et al. (2020) investigate the association between financial development and environmental pollution in China. The results reveal that CO_2 emissions and financial development are significantly and negatively associated in the long run. Atsu and Adams (2021) investigated the relationship between financial development and CO_2 emissions for the BRICS countries (Brazil, Russia, India, China, and South Africa) from 1984 to 2017. Based on cross-sectionally augmented ARDL (CS-ARDL) and Fully Modified Ordinary Least Squares (FMOLS) estimation techniques, the empirical findings indicate that financial development mitigates CO_2 emissions. Khan and Ozturk (2021) examine the effects of financial development on CO_2 emissions using a sample of 88 countries from 2000 to 2014. Based on five proxies of financial development, the estimated results contend that financial development brings about better environmental quality. Using the augmented mean group (AMG) estimation approach, Usman et al. (2021) contend that financial development helped reduce environmental degradation in 15 emitting countries from 1990 to 2017. Using Pooled Mean Group Autoregressive Distributed Lag (PMG/ARDL) estimator, Baloch et al. (2021) explore the relationship between financial development, economic growth, energy innovation, and environmental pollution for a sample of OECD countries from 1990 to 2017. The results indicate that financial development promotes energy innovation and improves environmental quality.

Furthermore, based on autoregressive distributed lag (ARDL) bounds, Kirikkaleli et al. (2022) contend that financial development and renewable energy consumption reduce the consumption-based CO_2 emissions in Chile. Du et al. (2022) discovered that financial inclusion has a negative connection with CO_2 emissions, suggesting that enhancing financial inclusion encourages environmental sustainability. Moreover, Liu et al. (2022) infer that financial inclusion can play a key role in China's fight against global warming. Furthermore, Shahbaz et al. (2022) study the impact of financial inclusion on CO_2 emissions at national and provincial levels in China. They show that enhancements in financial services can decrease pollutant and CO_2 emissions. Also, Wang et al. (2022) probe the influence of digital financial inclusion on CO_2 emissions in China. The empirical evidence shows that financial inclusion positively impacts CO_2 emissions of local cities but adversely impacts neighboring cities. Finally, based on fixed effects and the Arellano–Bover/Bundell Bond dynamic panel approaches, Shobande and Ogbeifun (2022) indicate that financial development was central in lowering CO_2 emissions in the sample of 24 OECD countries from 1980 to 2019. Table 2 summarizes the effect of financial inclusion on CO_2 emissions.

Renewable energy and CO_2 Emissions

The research on the link between renewable energy and CO_2 emissions is key because it helps policymakers gain further insights into attaining Sustainable Development Goals (SDGs). The effect of renewable energy on environmental quality is becoming a fundamental question in the current energy economic literature. Several countries have implemented strategies to boost their renewable energy share in the total energy mix. For example, ASEAN countries have been increasing their renewable energy share by investing in various renewable energy sources such as geothermal, biomass, solar, wind, and hydroelectric (Fahim et al., 2023a). The ASEAN has enacted regulations and incentives to stimulate businesses and individuals to adopt renewable energy in the future (Fahim et al., 2023a). The expansions in renewable energy sources are aimed at hastening the transition towards a low-carbon economy.

The empirical literature on how renewable sources affect CO_2 emissions can be divided into three key streams. The first stream states that renewable energy has a mitigation effect on CO_2 emissions. Using fully modified ordinary least square (FMOLS) and dynamic ordinary least square (DOLS) models for estimation with annual data from the years 1990 to 2019, Jamil et al. (2022) show that there is a significant and negative connection between renewable energy and CO_2 emissions in the context of G-20 countries. Aydoğan and Vardar (2020) assess the impact of renewable energy on CO_2 emissions for seven emerging economies, namely, Brazil, China, India, Indonesia, Mexico, Russia, and Turkey over the period 1990–2014 and a negative relationship is found between CO_2 emissions and renewable energy consumption. Using data from top ten renewable energy nations, Wang et al. (2021) explore the relationship between renewable energy and CO_2 emissions. Long-run estimates indicate that renewable energy consumption leads to lessening CO_2 emissions. Employing the dynamic Autoregressive Distributed Lag (ARDL) model to examine the relationship between renewable energy and CO_2 emissions from 1980 to 2018, Abbasi et al. (2021) show that renewable energy has a negative and statistically significant impact on CO_2 emissions. Using a two-step GMM estimator for top carbon-intense countries over the period 2000–2015, Mirziyoyeva and Salahodjaev (2022) show that renewable energy has a significant negative effect on CO_2 emissions. Salahodjaev et al. (2022) investigate the relationship between renewable energy and CO_2 emissions in Europe and Central Asia countries over the period 1990–2015; the results indicate that renewable energy has a negative and statistically significant impact on CO_2 emissions. For instance, when renewable production increases by 10 percentage points, CO_2 per capita emissions are reduced by 4.1%.

The second stream of empirical studies contends that renewable energy worsens CO_2 emissions. For instance, Bulut (2017) explores the effect of renewable energy on CO_2 emissions in Turkey. The author shows that CO_2 emissions and renewable energy are positively associated. In addition, using a panel cointegration analysis of 107

Table 2. Overview of Related Literature Published.

Authors	Period	Countries	Methodology	Main result
Le et al. (2020)	2004–2014	31 Asian countries	Model by Hoechle (2007) procedure for	FI increases CO_2 emissions
Qin et al. (2021)	2004–2016	7 Emerging countries	Quantile regression analysis	FI increases CO_2 emissions
Zaidi et al. (2021)	2004–2017	OECD countries	Common Correlated Effects Estimator technique	FI increases CO_2 emissions
Amin et al. (2022)	1998–2019	4 South Asian countries	ARDL model, fixed-effect model, and GMM	FI increases CO_2 emissions
Chaudhry et al. (2022)	2004–2018	40 OIC countries	Dynamic Common Correlated Effects (DCCE)	FI increases CO_2 emissions
Dong et al. (2022)	2004–2018	China	Spatial econometric model	FI increases CO_2 emissions
Du et al. (2022)	2004–2019	18 Emerging countries	Panel quantile regression approach	FI decreases CO_2 emissions
Fareed et al. (2022)	1995–2018	27 European countries	Nonparametric econometric technique	FI increases CO_2 emissions
Liu et al. (2022)	1995–2019	5 Asian emerging economies	Panel ARDL approach	Bank branches and bank credit increase CO_2 emissions
Mehmood (2022)	1990–2017	4 South Asian countries	CSARDL approach	FI increases CO_2 emissions
Ozturk and Ullah (2022)	2007–2019	42 BRI countries	Pooled ordinary least squares (OLS), two-stage least squares (2SLS), and generalized method of moments approaches (GMM)	FI increases CO_2 emissions
Liu et al. (2022)	1995–2019	China	ARDL technique	FI decreases CO_2 emissions
Shahbaz et al. (2022)	2011–2017	China	Generalized least squares method (GLS)	FI decreases CO_2 emissions
Singh et al. (2022)	2008–2018	India	ARDL approach	FI increases CO_2 emissions
Tian and Li (2022)	2005–2018	G20 nations	CSARDL approach	FI increases CO_2 emissions
Wang et al. (2022)	2011–2017	China	A spatial econometric model	FI positively impacts CO_2 emissions but negatively impacts neighbouring cities

countries from 1990 to 2013, Nguyen and Kakinaka (2019) show that renewable energy consumption is positively and significantly associated with CO_2 emissions in low-income countries.

The last stream of empirical studies reports renewable energy wields negligible effects on CO_2 emissions. Twumasi (2017) studies the link between CO_2 emissions and renewable energy, and the results reveal that increasing renewable energy production does not essentially contribute to reducing CO_2 emissions. Boontome et al. (2017) examine the effect of renewable energy on CO_2 emissions in Thailand for the years 1971–2013. The empirical findings suggest that renewable energy is insignificantly related to CO_2 emissions. Nathaniel and Iheonu (2019) study the effect of renewable energy consumption on CO_2 emissions in 19 Sub-Saharan countries from 1990 to 2014. The results based on the augmented panel mean group (APMG) show that renewable energy exerts an insignificant impact on CO_2 emissions. Similarly, Dong et al. (2020) investigated the relationship between renewable energy and CO_2 emissions in 120 countries from 1995 to 2012. The study notes that renewable energy has an insignificant impact on CO_2 emissions, and higher rates of GDP growth may mediate this. Furthermore, using both fully modified ordinary least square (FMOLS) and vector error correction model (VECM) estimation techniques, Saidi and Omri (2020) examine the relationship between renewable energy and CO_2 emissions using data from 15 major renewable energy-consuming countries over the period 1990–2014. The results indicate that there is no causal relationship between CO_2 emissions and renewable energy. Table 3 summarizes the effect of renewable energy on CO_2 emissions. Overall, this review indicates that the wide variety of empirical models utilized in these studies has yielded inconclusive results.

Literature Gaps

By reviewing the literature related to financial inclusion, energy renewable consumption, and CO_2 emissions, although many authors have focused on the impact of financial inclusion on the environment, some academic gaps are still in place. First, while the previous literature investigates the association between finance and environmental pollution in different regions/countries across the globe, very few studies have investigated this association in the MENA region. Second, previous studies have often examined the panel effects of financial inclusion and renewable energy on CO_2 emissions. However, the main aim of this study is not only to focus on the relationships between financial inclusion, renewable energy, and CO_2 emissions as a panel but also to uncover a country-specific analysis across several countries in the MENA region. This paper fills the gaps and explores the connection between financial inclusion, renewable energy, and environmental pollution across 11 MENA countries.

Table 3. Overview of Related Literature Published.

Authors	Period	Countries	Methodology	Main result
Bulut (2017)	1970–2013	Turkey	FMOLS and DOLS estimators	RE increases CO_2 emissions
Boontome et al.(2017)	1971–2013	Thailand	Cointegration and causality model	No significant relationship
Twumasi (2017)	1990–2009	USA	Multivariate analysis	No significant relationship
Nathaniel and Iheonu (2019)	1990–2014	Africa	Augmented Mean Group (AMG) technique	No significant relationship
Nguyen and Kakinaka (2019)	1990–2013	107 Countries	DOLS and FMOLS estimation techniques	RE increases CO_2 emissions
Aydoğan and Vardar (2020)	1990–2014	7 Emerging economies	OLS, FMOLS, and DOLS method	RE decreases CO_2 emissions
Dong et al. (2020)	1995–2012	120 countries	Panel cointegration test	No significant relationship
Saidi and Omri (2020)	1990–2014	15 Major renewable energy-consuming countries	VECM and FMOLS techniques	No significant relationship
Abbasi et al. (2021)	1980–2018	Thailand	ARDL model	RE decreases CO_2 emissions
Wang et al. (2021)	1980–2014	Top ten renewable energy countries	FMOLS, DOLS, and Granger causality	RE decreases CO_2 emissions
Jamil et al. (2022)	1990–2019	G-20 countries	DOLS and FMOLS	RE decreases CO_2 emissions
Mirziyoyeva and Salahodjaev (2022)	2000–2015	Top carbon-intense countries	GMM estimator	RE decreases CO_2 emissions
Salahodjaev et al. (2022)	1990–2015	Europe and Central Asia countries	GMM estimator	RE decreases CO_2 emissions

Model Specification, Data Resources, and Estimation Techniques

Model Specification

The main objective of this study is to investigate the effects of financial inclusion and renewable energy on CO_2 emissions. This study uses an empirical model specified in equation (1). This empirical model is consistent with the models employed in the preceding literature (Le et al., 2020; Liu et al., 2022; Shahbaz et al., 2022).

$$\boldsymbol{ln\,CO_{2it} = \theta_1 + \beta_1 fi_{it} + \beta_2 lnre_{it} + \beta_3 lngdppc_{it} + \beta_4 lnto + \varepsilon_{it}} \tag{1}$$

where $lnco_2$ is the natural logarithm of CO_2 emissions per capita; *fi* denotes the natural logarithm of financial inclusion; *lnre* is the natural logarithm of renewable energy consumption (% of total final energy consumption); *lngdppc* stands for the natural logarithm of GDP per capita; *lnto* is the natural logarithm of trade openness (% of GDP); θ_1 is a constant parameter; and ε_{it} denotes the stochastic error term.

We estimate equation (1) using annual data from 2004 to 2019 for 11 MENA countries. The selection of the starting period was constrained by the availability of data. Since the earliest data of the explanatory variable (i.e., financial inclusion) was created in 2004, and the latest data of the major explained variable (CO_2 emissions per capita) was accumulated in 2019, the period of research samples employed in this study is from 2004 to 2019. Table 4 summarizes the variables and data sources.

This study considers the following four aspects in obtaining a composite Financial Inclusion Index (FI): (1) number of ATMs per 10,000 adults, (2) number of commercial bank branches per 10,000 adults, (3) outstanding deposits from commercial banks (% of GDP), and (4) outstanding loans from commercial banks (% of GDP). Since these aspects are measured in different units and scales, they need to be normalized before turning them into the composite index FI (Le et al., 2020). Thus, this study normalizes the variables using a z-score approach as described below.

Table 4. Definitions of Variables, Data Sources, and Statistical Descriptions.

Variable	Description	Source
ATM	Number of ATMs per 100,000 adults	FAS (IMF)
BB	Number of commercial bank branches per 100,000 adults	FAS (IMF)
ODCB	Outstanding deposits from commercial banks (% of GDP)	FAS (IMF)
OLCB	Outstanding loans from commercial banks (% of GDP)	FAS (IMF)
CO_2	CO_2 emissions (metric tons per capita)	WDI
RE	Renewable energy (% of total energy consumption)	WDI
GDPPC	GDP per capita (constant 2010 US$)	WDI
TO	Trade openness (% of GDP)	WDI

Note. Data Source: FAS: Financial Access Survey (International Monetary Fund); WDI: World Development Indicators.

Table 5. Principal Component Analysis for Financial Inclusion Index.

	PCA1	PCA2	PCA3	PCA4
Eigenvalues	2.289	1.051	.433	.228
% Of variance	.572	.263	.108	.057
Cumulative %	.572	.835	.943	1.000
Variable	Vector 1	Vector 2	Vector 3	Vector 4
ATM	.461	.552	−.643	.266
BB	.479	.481	.733	−.056
ODCB	.487	−.583	.113	.640
OLCB	.567	−.353	−.194	−.719

$$\mathrm{Z - score} = \frac{X_i - \overline{X}}{\alpha}$$

where X_i denotes the raw score, $\overline{X}$ is the group average, and α is the standard deviation. Then, conduct a principal component analysis (PCA) on the normalized indicators.[3] The advantage of this method over competing approaches is that it allows us to capture most of the information from the original dataset, which consists of four financial inclusion measures. At the same time, it reduces the risk of potential multi-collinearity that may arise when more than one proxy is included in a given equation.[4]

Table 5 shows the results of the principal component analysis for FI indicators. The eigenvalues reveal that the first principal component (PCA 1) explains about 57.2% of the standardized variance, the second principal component (PCA 2) explains another 26.3%, while the remaining 16.5% of the standardized variances are explained by the third and fourth principal components (PCA 3 and PCA 4). It is obvious that PCA 1 is the best principal component, and we only extract one principal component.

Estimation Techniques

Cross-Sectional Dependence. Before performing the analysis, it is necessary to check whether there is a cross-sectional dependence in our data. De Hoyos and Sarafidis (2006) propose that the presence of cross-sectional dependence in cross-country panels may be affected by disregarded common shocks that become part of the error terms. Therefore, if cross-sectional dependence appears in the data but is not taken into consideration in the analysis, it would bring about inconsistent standard errors in the estimated parameters (Driscoll & Kraay, 1998). As such, this study applies the Pesaran (2004) CD test.[5] The CD test's null hypothesis (H0) is that the residuals are cross-sectionally uncorrelated. The results in Table 6 show a rejection of the null hypothesis, which validates that the residuals are cross-sectionally correlated.

Panel Unit Root Tests. Since there is evidence of cross-sectional dependency in the data, the implementation of second-generation panel unit root tests is desirable. This study implements Pesaran's (2007) unit root test in Table 7. The results provide evidence that variables have a unit root in levels. Since the unit root hypothesis can be rejected for first differences, it has been concluded that all series are integrated of the same order one (I (1)). These results indicate that the variables used in this study are stationary.

Panel Cointegration Test. Provided that all our series are stationary and integrated of order 1, the following step is to check for the existence of cointegration between the variables. To avoid spurious long-term cointegration among the parameters, this study

Table 6. Pesaran's (2004) CD Test for Cross-Section Independence in Macro Panel Data.

Variable	CD test	*p*-Value
lnco2pc	3.80***	.000
fi	8.62***	.000
lnre	5.37***	.000
lngdppc	12.14***	.000
lnto	7.29***	.000

Notes: We use the xtcd command to implement Pesaran's (2004) CD test. Under the null hypothesis of cross-section independence, CD ~ N(0,1). *p*-Values close to zero indicate data are correlated across panel groups. ***Significant at 1% level.

Table 7. Pesaran's Simple Panel Unit Root Test in the Presence of Cross-Section Dependence.

	Level		First difference	
Variable	Z [t bar]	*p*-Value	Z [t bar]	*p*-Value
lnco2pc	−.120	.452	−1.862**	.031
fi	.690	.755	−3.418***	.000
lnre	−.864	.194	−5.873***	.000
lngdppc	.715	.763	−4.334***	.000
lnto	1.023	.847	−1.602*	.055

***Significant at 1% level. **Significant at 5% level. *Significant at 10% level.

Table 8. Cointegration Tests.

Estimates	Statistic	*p*-Value
Kao test		
Augmented Dickey–Fuller t	2.913***	.002
Pedroni test		
Modified Phillips–Perron t	3.730***	.000
Augmented Dickey–Fuller t	−3.348***	.000

***Significant at 1% level. **Significant at 5% level.

uses the Kao panel cointegration test (Kao, 1999) and the Pedroni panel cointegration test (Pedroni, 2004). These tests have a common null hypothesis of no cointegration. The alternative hypothesis of the Kao and Pedroni tests is that the variables are co-integrated in all panels. As shown in Table 8, all test statistics reject the null hypothesis of no cointegration in favor of the alternative hypothesis about the presence of a cointegrating link between the variables in equation (1).

Estimation of Long-Run Coefficients. The long-term estimates confirm the existence of a cointegration relationship between the series. This study employs four different estimators: FE-OLS, D-OLS, FM-OLS, and CCR. We first employ the FE-OLS estimator since our data has evidence of cross-sectional dependence. In the case of cross-sectional dependence, Driscoll and Kraay's (1998) standard errors are well-calibrated. Moreover, this statistical technique is robust to autocorrelation, heterogeneity, and cross-sectional dependence (see Le et al., 2020). We also use DOLS, a parametric estimator that addresses autocorrelation. Moreover, DOLS is also relevant to a small data series, allows for combining different variables in the analysis, and has several advantages in estimating cointegrated vectors (Liguo et al., 2022). Compared to OLS, the FMOLS estimator computes long-run coefficients by adjusting the conventional OLS. It addresses serial correlation and endogeneity issues generally occurring when utilizing the conventional OLS technique (Jiang et al., 2021; Yawen et al., 2021). Furthermore, FMOLS allows for possible association among error terms, constant terms, and the difference among regressors (Christiansen, 2015). In addition to DOLS and FMOLS, CCR uses a stationary conversion method to overcome a long-run interaction between stochastic regressor errors and the cointegration equation (Christiansen, 2015).

Empirical Results

This section discusses the empirical results in detail. Following an overview of data and variables (Table 9 and Table 10), the study presents the estimated results on the relationships between financial inclusion, renewable energy, and CO_2 emissions in Tables 11 and 12. Table 9 presents the data description of our included variables. One

Table 9. Summary Statistics, Obs = 171.

Variable	Mean	Std. dev	Min	Max
co2pc	8.14	9.91	1.36	49.21
atm	39.85	30.77	1.27	133.16
bb	15.80	7.83	3.80	32.31
odcb	82.58	54.56	26.97	251.26
olcb	58.23	24.16	16.13	140.91
re	5.79	5.52	.01	23.00
gdppc	14,413.53	17,711.08	2066.00	65,129.40
to	74.58	21.69	30.25	145.99

Table 10. Correlations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
co2pc (1)	1.00							
atm (2)	.34	1.00						
bb (3)	−.06	.32	1.00					
odcb (4)	−.20	.04	.35	1.00				
olcb (5)	.07	.26	.28	.62	1.00			
re (6)	−.50	−.10	.17	.01	.13	1.00		
gdppc (7)	.91	.56	−.02	−.09	.26	−.39	1.00	
to (8)	.23	−.11	.08	.27	.50	−.01	.21	1.00

Table 11. Panel Estimation Results.

	Model 1	Model 2	Model 3	Model 4
Variable	FEOLS	DOLS	FMOLS	CCR
Fi	−.050* (.027)	−.064* (.034)	−.065*** (.010)	−.065*** (.011)
re	−.074** (.027)	−.133*** (.016)	−.132*** (.005)	−.132*** (.005)
gdppc	.327** (.117)	.650*** (.034)	.653*** (.011)	.653*** (.011)
to	.121 (.078)	−.132 (.105)	−.092*** (.032)	−.092*** (.033)
constant	−1.837** (.778)	−3.602*** (.525)	−3.805*** (.164)	−3.805*** (.168)
Number of observations	171	168	170	170
Number of countries	11	11	11	11
R^2	.35	.95	.81	.81

***Significant at 1% level. **Significant at 5% level.

remarkable aspect of these descriptive statistics is the high standard deviation of some variables, such as CO_2 and GDPPC, compared to their mean values. Likewise, all the financial inclusion measures show a considerable standard deviation, illustrating the difference with respect to the level of financial inclusion across countries and over time. This makes it interesting to study the impact of financial inclusion and renewable energy on CO_2 emissions as a panel and across individual countries in the MENA region.

The correlations between the study variables of interest, namely, financial inclusion (ATM, BB, ODCB, and OLCB), renewable energy, economic growth, and trade openness, are reported in Table 10. The first observation is that there is a positive correlation between CO_2 emissions and the different variables (ATM, GDPPC, and TO). There is also a negative correlation between CO_2 emissions and renewable energy (−.50). Finally, a negative connection between GDPPC and renewable energy of −.39 has been shown.

Table 12. Country-Specific Estimates.[8]

Countries	fi	re	gdppc	to	constant
Algeria					
FMOLS	.006** (.002)	−.028*** (.006)	1.565*** (.173)	−.284*** (.036)	−10.606*** (1.549)
CCR	.005* (.003)	−.026*** (.007)	1.649*** (.068)	−.273*** (.030)	−11.342*** (.581)
Egypt					
FMOLS	−.025*** (.003)	.073 (.068)	.791*** (.069)	.025*** (.008)	−5.784*** (.656)
CCR	−.046 (.032)	.108 (.073)	.979*** (.293)	.032** (.016)	−7.398*** (2.535)
Israel					
FMOLS	−.037* (.020)	.018 (.037)	−.745** (.313)	.434** (.184)	8.037** (3.878)
CCR	−.038 (.023)	.019 (.047)	−.773*** (.291)	.427** (.205)	8.359** (3.752)
Lebanon					
FMOLS	.042** (.021)	−.190*** (.049)	.580*** (.099)	−.403*** (.146)	−1.709** (.732)
CCR	.034 (.052)	−.201 (.144)	.553** (.269)	−.336 (.502)	−1.750** (.775)
Morocco					
FMOLS	−.015 (.016)	−.070 (.135)	.638*** (.171)	.195** (.078)	−5.190*** (1.754)
CCR	−.010 (.021)	.001 (.195)	.727*** (.240)	.224* (.122)	−6.199** (2.532)
Qatar					
FMOLS	−.081*** (.010)	.018 (.026)	−1.507*** (.385)	.497*** (.180)	17.959*** (3.710)
CCR	−.084*** (.007)	.009 (.023)	−1.419*** (.356)	.440*** (.162)	17.225*** (3.598)
Saudi Arabia					
FMOLS	.067*** (.002)	.001 (.006)	1.148*** (.039)	.233*** (.017)	−9.602*** (.409)
CCR	.067*** (.004)	.001 (.007)	1.145*** (.036)	.230*** (.023)	−9.561*** (.354)
Tunisia					
FMOLS	−.115*** (.020)	−.352*** (.054)	1.859*** (.226)	−.194*** (.035)	−12.643*** (1.750)
CCR	−.129*** (.040)	−.388*** (.134)	2.014*** (.438)	−.192*** (.062)	−13.842*** (3.366)
Turkey					
FMOLS	−.003 (.013)	−.415*** (.107)	.473*** (.088)	−.069 (.134)	−1.537** (.641)
CCR	−.002 (.012)	−.493*** (.119)	.469*** (.088)	−.160 (.152)	−.945 (.810)

***Significant at 1% level. **Significant at 5% level.

It is interesting to mention that the results are quite robust under different specifications. Table 11 displays the panel estimations' results, including those of the FE-OLS, D-OLS, FM-OLS, and CCR. The results indicate that financial inclusion is negatively and significantly associated with CO_2 emissions in all specifications. Specifically, a 1% increase in financial inclusion decreases CO_2 emissions per capita within a range of .05%–.065%. These results are in line with the findings of Du et al. (2022); Liu et al. (2022); and Shahbaz et al. (2022), which indicate a significant negative relationship between financial inclusion and CO_2 emissions. However, our results do not agree with the findings of Amin et al. (2022); Dong et al. (2022); and Fareed et al. (2022), which argue that financial inclusion and CO_2 emissions are positively and significantly related. The results further indicate that renewable energy is negative and significant at a 1% significance level in all specifications. A 1% increase in renewable energy reduces CO_2 emissions per capita within a range of .074%–.133%. This finding aligns with previous literature, which indicates that renewable energy decreases CO_2 emissions (Abbasi et al., 2021; Jamil et al., 2022). As shown in all Models of Table 10, the coefficients of GDP per capita have significant positive effects on CO_2 emissions.

Table 12[6] exhibits the empirical results across countries using FM-OLS and CCR estimators.[7] As shown in Table 12, the relationship between financial inclusion, renewable energy, and CO_2 emissions differs across countries. The results show that the relationship between financial inclusion and CO_2 emissions is negative and significant for Egypt, Israel, Qatar, and Tunisia. This implies that a 1% increase in financial inclusion reduces CO_2 emissions within a range of .025% (Egypt), .037% (Israel), .081%–.084% (Qatar), and .115%–.129% (Tunisia). However, the results show that this relationship is positive and significant for Algeria, Lebanon, and Saudi Arabia. A 1% increase in financial inclusion increases CO_2 emissions within a range of .005%–.006% (Algeria), .042% (Lebanon), and .067% (Saudi Arabia). For the remaining countries, no significant link is found. In addition, renewable energy negatively impacts per capita

Table 13. Summary Table With the Key Country-Specific Results.

Country	Relationship between FI and CO_2 emissions	Relationship between RE and CO_2 emissions
Algeria	Positive	Negative
Egypt	Negative	Insignificant
Israel	Negative	Insignificant
Lebanon	Positive	Negative
Morocco	Insignificant	Insignificant
Qatar	Negative	Insignificant
Saudi Arabia	Positive	Insignificant
Tunisia	Negative	Negative
Turkey	Insignificant	Negative

CO_2 emissions for four (4) countries out of nine. Only for Algeria, Lebanon, Tunisia, and Turkey, renewable energy negatively affects CO_2 emissions. A 1% increase in renewable energy consumption leads to a decrease in CO_2 emissions within a range of .026%–.028% (Algeria), .190% (Lebanon), .352%–.388% (Tunisia), and .415%–.493% (Turkey). For the remaining countries, no significant relationship is found. In addition, the results indicate that GDP per capita has a significant positive effect on CO_2 emissions in all countries except for Israel and Qatar, which shows that the relationship between income and CO_2 emissions is negatively and significantly related. Lastly, the coefficient of trade openness is positive and significant in five countries out of nine. A 1% increase in trade openness increases CO_2 emissions within a range of .025%–.032% (Egypt), .427%–.434% (Israel), .195%–.244% (Morocco), .440%–.497% (Qatar), and .230%–.233% (Saudi Arabia). However, the results show that the relationship is negative and significant in three countries out of nine. A 1% increase in trade openness decreases CO_2 emissions within a range of .273%–.284% (Algeria), .403% (Lebanon), and .192%–.194% (Tunisia).

Conclusion and Policy Implications

This study is probably the first to empirically explore the association between financial inclusion, renewable energy, and CO_2 emissions for a panel dataset of 11 MENA countries from 2004 to 2019. It specifically answers the following questions: *(1) How does financial inclusion affect the environment in the MENA region? (2) Does the effect of financial inclusion on the environment vary across MENA countries? (3) Does renewable energy negatively impact the environment in the MENA region as a panel? (4) Does the relationship between renewable energy and CO_2 emissions vary across MENA countries?*

The empirical findings from the different estimation techniques, such as FEOLS, DOLS, FMOLS, and CCR, documented that financial inclusion is negatively and significantly associated with CO_2 emissions, implying that boosting financial inclusion supports environmental sustainability. More specifically, a 1% increase in financial inclusion can reduce CO_2 emissions within a range of .05%–.065%. However, the relationship between financial inclusion and CO_2 emissions differs across countries in the MENA region. This study finds that the relationship is negative and significant for Egypt, Israel, Qatar, and Tunisia; positive and significant for Algeria, Lebanon, and Saudi Arabia; and insignificant for Morocco and Turkey. Obtaining the unfavorable environmental impact of financial inclusion for some MENA countries such as Algeria, Lebanon, and Saudi Arabia certainly does not suggest reducing financial inclusion. Instead, it is in the interest of MENA countries to strengthen their financial inclusivity to accomplish improved environmental quality. In this regard, policymakers should design appropriate financially inclusive policies for economic and environmental welfare. Incentives should be offered to businesses and entrepreneurs for participating in green financial practices and products that may help develop cleaner energy technologies.

Furthermore, the results indicate that renewable energy has a significant negative impact on CO_2 emissions. Specifically, a 1% increase in renewable energy can reduce CO_2 emissions within a range of .074%–.133%. However, the relationship between CO_2 emissions and renewable energy varies across countries in the region. For instance, this study indicates that renewable energy has a significant negative effect in Algeria, Lebanon, Tunisia, and Turkey, while it has an insignificant effect for the remaining countries. Policymakers should use various incentives to promote the growth of the renewable energy sector, such as low-interest loans, grants, subsidies, and tax deductions for renewable energy investments to increase renewable energy penetration. Furthermore, enhancing energy efficiency through infrastructure investments in the energy sector by substituting obsolete technologies and facilities will diminish demand for fossil fuels (Akalin et al., 2021), reducing CO_2 emissions. Also, in line with Fahim et al.'s (2023b) recommendations, policymakers should integrate more renewables into economic load dispatch.

This research could be extended in several ways. First, prospective studies could explore the relationship between financial inclusion, renewable energy, and CO_2 emissions by focusing on individual countries in other regions. This would allow policymakers to consider each country's characteristics in the design of country-specific policy actions. Second, the broad definition of financial inclusion allows for measurement approaches beyond the proxy used in this study. Finally, future research could also explore whether financial inclusion indirectly affects CO_2 emissions via economic growth or whether an increase in economic growth accelerates the use of financial inclusion by population and companies.

Appendix

Table A1. Sample Composition.

Country name	Observation period
Algeria	[2004–2019]
Egypt	[2004–2019]
Iran	[2005–2019]
Israel	[2004–2019]
Jordan	[2007–2019]
Lebanon	[2004–2019]
Morocco	[2004–2019]
Qatar	[2004–2019]
Saudi Arabia	[2004–2019]
Tunisia	[2004–2019]
Turkey	[2004–2019]

Acknowledgments

The authors sincerely thank the Editor-in-Chief and the Associate Editors for their support. We are also grateful to the two anonymous reviewers for their valuable comments that helped improve this paper's quality. Nevertheless, the authors are responsible for all remaining errors.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Rabie Said https://orcid.org/0009-0004-6254-1109
Alex O. Acheampong https://orcid.org/0000-0002-5462-5466

Notes

1. Microcredit is a finance tool that helps individuals and entrepreneurs get small loans in poor countries. For more information on this, please see the following link: https://www.yearofmicrocredit.org/.
2. For more information, please visit the link https://www.worldbank.org/en/publication/globalfindex.
3. The study also derives the min–max approach to produce a financial inclusion index (FI1). However, we find that FI1 is equivalent to FI (z score-approach). For this reason, the study adopts one financial inclusion index (fi). Min–max normalization is derived as follows: mmx $= \frac{x_i - x_{min}}{x_{max} - x_{min}}$ where x_{min} = minimum data point and x_{max} = maximum data point.
4. Principal component analysis has traditionally been used to reduce a large set of correlated variables into a smaller set of uncorrelated variables, known as principal components (Ang & McKibbin, 2007; Stock & Watson, 2022).
5. The study chooses Pesaran's (2004) CD test because it is more suitable for unbalanced panels.
6. We have summarized the key findings from the country-specific analysis in Table 13.
7. Due to the short time periods, this study can't employ DOLS estimator across countries.
8. Iran and Jordan are not included in the analysis due to short time observations.

References

Abbasi, K. R., Adedoyin, F. F., Abbas, J., & Hussain, K. (2021). The impact of energy depletion and renewable energy on CO2 emissions in Thailand: Fresh evidence from the novel dynamic ARDL simulation. *Renewable Energy*, *180*, 1439–1450. https://doi.org/10.1016/j.renene.2021.08.078

Akalin, G., Erdogan, S., & Sarkodie, S. A. (2021). Do dependence on fossil fuels and corruption spur ecological footprint? *Environmental Impact Assessment Review*, *90*, 106641. https://doi.org/10.1016/j.eiar.2021.106641

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 International*, *29*(11), 16588–16596. https://doi.org/10.1007/s11356-021-16648-7

Ang, J. B., & McKibbin, W. J. (2007). Financial liberalization, financial sector development and growth: Evidence from Malaysia. *Journal of Development Economics*, *84*(1), 215–233. https://doi.org/10.1016/j.jdeveco.2006.11.006

Atsu, F., & Adams, S. (2021). Energy consumption, finance, and climate change: Does policy uncertainty matter? *Economic Analysis and Policy*, *70*, 490–501. https://doi.org/10.1016/j.eap.2021.03.013

Aydoğan, B., & Vardar, G. (2020). Evaluating the role of renewable energy, economic growth and agriculture on CO2 emission in E7 countries. *International Journal of Sustainable Energy*, *39*(4), 335–348. https://doi.org/10.1080/14786451.2019.1686380

Baloch, M. A., Ozturk, I., Bekun, F. V., & Khan, D. (2021). Modeling the dynamic linkage between financial development, energy innovation, and environmental quality: Does globalization matter? *Business Strategy and the Environment*, *30*(1), 176–184. https://doi.org/10.1002/bse.2615

Belaid, F., Boukrami, E., & Amine, R. (2021). Renewable energy in the MENA region: Key challenges and lessons learned. In *Advances in managing energy and climate risks* (pp. 1–22), Springer.

Boontome, P., Therdyothin, A., & Chontanawat, J. (2017). Investigating the causal relationship between non-renewable and renewable energy consumption, CO 2 emissions and economic growth in Thailand 1 1 This is a preliminary work. Please do not quote or cite without permission of the authors. *Energy Procedia*, *138*, 925–930. https://doi.org/10.1016/j.egypro.2017.10.141

Bulut, U. (2017). The impacts of non-renewable and renewable energy on CO2 emissions in Turkey. *Environmental Science and Pollution Research International*, *24*(18), 15416–15426. https://doi.org/10.1007/s11356-017-9175-2

Chaudhry, I. S., Yusop, Z, & Habibullah, MS (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

Christiansen, B. (2015). *Comparative political and economic perspectives on the MENA Region*, IGI Global.

De Hoyos, R. E., & Sarafidis, V. (2006). Testing for cross-sectional dependence in panel-data models. *STATA Journal: Promoting communications on statistics and Stata*, *6*(4), 482–496. https://doi.org/10.1177/1536867X0600600403

Didier, T., & Schmukler, S. L. (2013). *Emerging issues in financial development: Lessons from Latin America*. World Bank Publications.

Dong, J., Dou, Y., Jiang, Q., & Zhao, J. (2022). Can financial inclusion facilitate carbon neutrality in China? The role of energy efficiency. *Energy*, *251*, 123922. https://doi.org/10.1016/j.energy.2022.123922

Dong, K., Dong, X., & Jiang, Q. (2020). How renewable energy consumption lower global CO2 emissions? Evidence from countries with different income levels. *The World Economy*, *43*(6), 1665–1698. https://doi.org/10.1111/twec.12898

Driscoll, J. C., & Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *The Review of Economics and Statistics*, *80*(4), 549–560. https://doi.org/10.1162/003465398557825

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 International*, *29*(22), 33033–33045. https://doi.org/10.1007/s11356-021-17945-x

Fahim, K. E., De Silva, L. C., Hussain, F., Shezan, S. A., & Yassin, H. (2023). An evaluation of ASEAN renewable energy path to carbon neutrality. *Sustainability*, *15*(8), 6961. https://doi.org/10.3390/su15086961

Fahim, K. E., Silva, L. C. D., Hussain, F., & Yassin, H. (2023b). A state-of-the-art review on optimization methods and techniques for economic load dispatch with photovoltaic systems: Progress, challenges, and recommendations. *Sustainability*, *15*(15), 11837. https://doi.org/10.3390/su151511837

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*, 101961. https://doi.org/10.1016/j.techsoc.2022.101961

Gaies, B., Kaabia, O., Ayadi, R., Guesmi, K., & Abid, I. (2019). Financial development and energy consumption: Is the MENA region different? *Energy Policy*, *135*, 111000. https://doi.org/10.1016/j.enpol.2019.111000

Jamil, K., Liu, D., Gul, R. F., Hussain, Z., Mohsin, M., Qin, G., & Khan, F. U. (2022). Do remittance and renewable energy affect CO2 emissions? An empirical evidence from selected G-20 countries. *Energy and Environment*, *33*(5), 916–932. https://doi.org/10.1177/0958305X211029636

Jensen, A. (1996). Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. *Canadian Journal of Fisheries and Aquatic Sciences*, *53*(4), 820–822. https://doi.org/10.1139/f95-233

Jiang, Q., Khattak, S. I., Ahmad, M., & Lin, P. (2021). Mitigation pathways to sustainable production and consumption: Examining the impact of commercial policy on carbon dioxide emissions in Australia. *Sustainable Production and Consumption*, *25*, 390–403. https://doi.org/10.1016/j.spc.2020.11.016

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

Kar, M., Nazlıoğlu, Ş., & Ağır, H. (2011). Financial development and economic growth nexus in the MENA countries: Bootstrap panel granger causality analysis. *Economic Modelling*, *28*(1–2), 685–693. https://doi.org/10.1016/j.econmod.2010.05.015

Khan, H., Khan, I., & Binh, T. T. (2020). The heterogeneity of renewable energy consumption, carbon emission and financial development in the globe: A panel quantile regression approach. *Energy Reports*, *6*, 859–867. https://doi.org/10.1016/j.egyr.2020.04.002

Khan, M., & Ozturk, I. (2021). Examining the direct and indirect effects of financial development on CO2 emissions for 88 developing countries. *Journal of Environmental Management*, *293*, 112812. https://doi.org/10.1016/j.jenvman.2021.112812

Khan, S., Peng, Z., & Li, Y. (2019). Energy consumption, environmental degradation, economic growth and financial development in globe: Dynamic simultaneous equations panel analysis. *Energy Reports*, *5*, 1089–1102. https://doi.org/10.1016/j.egyr.2019.08.004

Kirikkaleli, D., Güngör, H., & Adebayo, T. S. (2022). Consumption-based carbon emissions, renewable energy consumption, financial development and economic growth in Chile. *Business Strategy and the Environment*, *31*(3), 1123–1137. https://doi.org/10.1002/bse.2945

Le, T.-H., Le, H.-C., & Taghizadeh-Hesary, F. (2020). Does financial inclusion impact CO2 emissions? Evidence from Asia. *Finance Research Letters*, *34*, 101451. https://doi.org/10.1016/j.frl.2020.101451

Liguo, X., Ahmad, M., & Khattak, S. I. (2022). Impact of innovation in marine energy generation, distribution, or transmission-related technologies on carbon dioxide emissions in the United States. *Renewable and Sustainable Energy Reviews*, *159*, 112225. https://doi.org/10.1016/j.rser.2022.112225

Liu, N., Hong, C., & Sohail, M. T. (2022). Does financial inclusion and education limit CO2 emissions in China? A new perspective. *Environmental Science and Pollution Research International*, *29*(13), 18452–18459. https://doi.org/10.1007/s11356-021-17032-1

Mehmood, U. (2022). Examining the role of financial inclusion towards CO2 emissions: Presenting the role of renewable energy and globalization in the context of EKC. *Environmental Science and Pollution Research International*, *29*(11), 15946–15954. https://doi.org/10.1007/s11356-021-16898-5

Mirziyoyeva, Z., & Salahodjaev, R. (2022). Renewable energy and CO2 emissions intensity in the top carbon intense countries. *Renewable Energy*, *192*, 507–512. https://doi.org/10.1016/j.renene.2022.04.137

Nasir, M. A., Duc Huynh, T. L., & Xuan Tram, H. T. (2019). Role of financial development, economic growth and foreign direct investment in driving climate change: A case of emerging ASEAN. *Journal of Environmental Management*, *242*, 131–141. https://doi.org/10.1016/j.jenvman.2019.03.112

Nathaniel, S. P., & Iheonu, C. O. (2019). Carbon dioxide abatement in Africa: The role of renewable and non-renewable energy consumption. *The Science of the total environment*, *679*, 337–345. https://doi.org/10.1016/j.scitotenv.2019.05.011

Nguyen, K. H., & Kakinaka, M. (2019). Renewable energy consumption, carbon emissions, and development stages: Some evidence from panel cointegration analysis. *Renewable Energy*, *132*, 1049–1057. https://doi.org/10.1016/j.renene.2018.08.069

Ozturk, I., & Ullah, S. (2022). Does digital financial inclusion matter for economic growth and environmental sustainability in OBRI economies? An empirical analysis. *Resources, Conservation and Recycling*, *185*, 106489. https://doi.org/10.1016/j.resconrec.2022.106489

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*(03), 597–625. https://doi.org/10.1017/s0266466604203073, https://www.jstor.org/stable/3533533

Pesaran, M. H. (2004). *General diagnostic tests for cross section dependence in panels*. https://ssrn.com/abstract=572504

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

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*(6), 1138–1154. https://doi.org/10.1002/sd.2208

Sahay, M. R., Cihak, M., N'Diaye, M. P., Barajas, M. A., Mitra, M. S., Kyobe, M. A., & Yousefi, M. R. (2015). *Financial inclusion: Can it meet multiple macroeconomic goals?* International Monetary Fund.

Saidi, K., & Omri, A. (2020). The impact of renewable energy on carbon emissions and economic growth in 15 major renewable energy-consuming countries. *Environmental Research*, *186*, 109567. https://doi.org/10.1016/j.envres.2020.109567

Salahodjaev, R., Sharipov, K., Rakhmanov, N., & Khabirov, D. (2022). *Tourism, renewable energy and CO2 emissions: Evidence from Europe and central Asia*. Environment, Development and Sustainability. (pp. 1–12). https://doi.org/10.1007/s10668-021-01993-x

Shahbaz, M., Li, J., Dong, X., & Dong, K. (2022). How financial inclusion affects the collaborative reduction of pollutant and carbon emissions: The case of China. *Energy Economics*, *107*, 105847. https://doi.org/10.1016/j.eneco.2022.105847

Shobande, O. A., & Ogbeifun, L. (2022). The criticality of financial development and energy consumption for environmental sustainability in OECD countries: Evidence from dynamic panel analysis. *The International Journal of Sustainable Development and World Ecology*, *29*(2), 153–163. https://doi.org/10.1080/13504509.2021.1934179

Singh, A. B., Tandon, P., & Jasuja, D. (2022). Does financial inclusion spur carbon emissions in India: An ARDL approach. *Management of Environmental Quality: An International Journal*, *34*(2), 511–534. https://doi.org/10.1108/MEQ-04-2022-0102

Stock, J. H., & Watson, M. W. (2002). Forecasting using principal components from a large number of predictors. *Journal of the American Statistical Association*, *97*(460), 1167–1179. https://doi.org/10.1198/016214502388618960

Tamazian, A., Chousa, J. P., & Vadlamannati, K. C. (2009). Does higher economic and financial development lead to environmental degradation: Evidence from BRIC countries. *Energy Policy*, *37*(1), 246–253. https://doi.org/10.1016/j.enpol.2008.08.025

Tian, Y., & Li, L. (2022). Impact of financial inclusion and globalization on environmental quality: Evidence from G20 economies. *Environmental Science and Pollution Research International*, *29*(40), 61265–61276. https://doi.org/10.1007/s11356-022-19618-9

Twumasi, Y. A. (2017). Relationship between CO2 emissions and renewable energy production in the United States of America. *Archives of Current Research International*, *7*(1), 1–12. https://doi.org/10.9734/acri/2017/30483

Umar, M., Ji, X., Kirikkaleli, D., & Xu, Q. (2020). COP21 Roadmap: Do innovation, financial development, and transportation infrastructure matter for environmental sustainability in China? *Journal of Environmental Management*, *271*, 111026. https://doi.org/10.1016/j.jenvman.2020.111026

Usman, M., Makhdum, M. S. A., & Kousar, R. (2021). Does financial inclusion, renewable and non-renewable energy utilization accelerate ecological footprints and economic growth? Fresh evidence from 15 highest emitting countries. *Sustainable Cities and Society*, *65*, 102590. https://doi.org/10.1016/j.scs.2020.102590

Wang, X., Wang, X., Ren, X., & Wen, F. (2022). Can digital financial inclusion affect CO2 emissions of China at the prefecture level? Evidence from a spatial econometric approach. *Energy Economics*, *109*, 105966. https://doi.org/10.1016/j.eneco.2022.105966

Wang, Z., Ben Jebli, M., Madaleno, M., Doğan, B., & Shahzad, U. (2021). Does export product quality and renewable energy induce carbon dioxide emissions: Evidence from leading complex and renewable energy economies. *Renewable Energy*, *171*, 360–370. https://doi.org/10.1016/j.renene.2021.02.066

World Bank. (2018). *Financial inclusion*. https://www.worldbank.org/en/topic/financialinclusion/overview#1

World Bank. (2022). World development indicators. In *EN.ATM*, CO2E.PC. https://data.worldbank.org/indicator/

Yawen, S., Jiang, Q., Khattak, S. I., Ahmad, M., & Li, H. (2021). *Do higher education research and development expenditures affect environmental sustainability?* New Evidence from Thirty-One Chinese Provinces. https://doi.org/10.21203/rs.3.rs-358931/v1

Zaidi, S. A. H., Hussain, M., & Uz Zaman, Q. (2021). Dynamic linkages between financial inclusion and carbon emissions: Evidence from selected OECD countries. *Resources, Environment and Sustainability*, *4*, 100022. https://doi.org/10.1016/j.resenv.2021.100022

Author Biographies

Dr Rabie Said is a part-time lecturer at La Trobe Business School. His main research interests include energy and environmental issues and carbon emission reduction.

Dr Alex O. Acheampong is an Assistant Professor of Economics at Bond Business School, Bond University, Australia. His research interest lies in applied econometrics, energy economics, environmental economics, macroeconomics, and development economics. His recent publications have been featured in leading international journals such as Energy Economics, Journal of Policy Modeling, Technological Forecasting and Social Change, Business Strategy and the Environment, Journal of Cleaner Production, Journal of Consumer Affairs and Utilities Policy. He is an Associate Editor for Energy Economics and the Journal of Public Affairs.