Applied Energy 306 (2022) 118023

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Role of banking sector performance in renewable energy consumption

Franklin Amuakwa-Mensah [a,b,*], Elin Násström [c]

[a] Environment for Development Initiative (EfD), University of Gothenburg, Box 645, SE 405 30, Gothenburg, Sweden
[b] Department of Business Administration, Technology and Social Sciences, Luleå University of Technology, 971 87 Luleå, Sweden
[c] Swedish Transport Administration, Solna Strandväg 98,171 54 Solna, Sweden

HIGHLIGHTS

- Examines the effect of banking performance on renewable energy consumption (REC).
- Improved banking performance enhances renewable energy consumption globally.
- Heterogenous effect of the relationship between banking performance and REC across income groups.
- Market capitalization, asset quality and managerial inefficiency explain REC in HI countries.
- Return on asset, market capitalization, asset quality and z-score explain REC in MI and LC countries.
- Heterogenous effect of the relationship between banking performance and REC types is observed.

ARTICLE INFO

Keywords:
Banking performance
CO2 emissions
Energy investments
Renewable energy
Panel data

ABSTRACT

To secure future universal access to modern energy, large investments in renewable energy technology are required. This paper estimates the impact of five banking sector performance indicators (return on asset, market capitalisation, asset quality, managerial efficiency and financial stability) on renewable energy consumption for a global panel consisting of 124 countries. The study used two-step system-GMM panel model to handle potential endogeneity and serial correlation. The paper considers three homogenous subpanels which are constructed based on the income group classification (high-, middle-, and low-income countries). Generally, our results show that improved banking sector performance enhances renewable energy consumption, with heterogenous effect across income group classification. For high -income (HI) countries, an increase in bank size together with improved asset quality and managerial efficiency have positive effects on renewable energy consumption. For middle-income (MI) and low-income (LI) countries, a high return on asset, an increase in bank size and financial stability are positive determinants of renewable energy consumption. We also find heterogenous effect of banking performance indicators across various renewable energy consumption types. The results highlight the importance of a well-functioning bank sector to achieve the investment in renewable energy needed to meet future energy demand and simultaneous decrease CO_2 emissions.

1. Introduction

Electricity generation from renewable sources has grown rapidly over the recent years [1]. One example is the year 2000, where Solar Photovoltaics[1] accounted for 1 TWh of the world's electricity generation, a number that had grown to 435 TWh by 2017. Nevertheless, in the year 2017, the share of modern renewable energy in total final energy consumption was less than 10.3 percent [2]. In order to reach the 2 °C goal set out in the Paris agreement, continuous conversion in energy from fossil fuels to renewable energy sources is crucial. As a way of estimating the effects of global warming, the International Energy Agency has developed three different forward-looking scenarios, all of which predicts different effects that global warming has in the future. To attain what they call the sustainable development scenario, global CO_2 emissions will have to peak at around 2020 and be followed by a steep decline. By 2040, global CO_2 emissions will have to be at half of the levels they are at today [3].

Renewable energy is projected to be an avenue in addressing energy

* Corresponding author at: Environment for Development Initiative (EfD), University of Gothenburg, Box 645, SE 405 30, Gothenburg, Sweden.
E-mail addresses: franklin.amuakwa-mensah@efd.gu.se (F. Amuakwa-Mensah), elinnasstrom@gmail.com (E. Násström).

[1] Photovoltaics are a method for generating electric power by using solar cells to convert energy from the sun into a flow of electrons by the photovoltaic effect.

https://doi.org/10.1016/j.apenergy.2021.118023
Received 25 November 2020; Received in revised form 21 September 2021; Accepted 27 September 2021
Available online 23 October 2021
0306-2619/

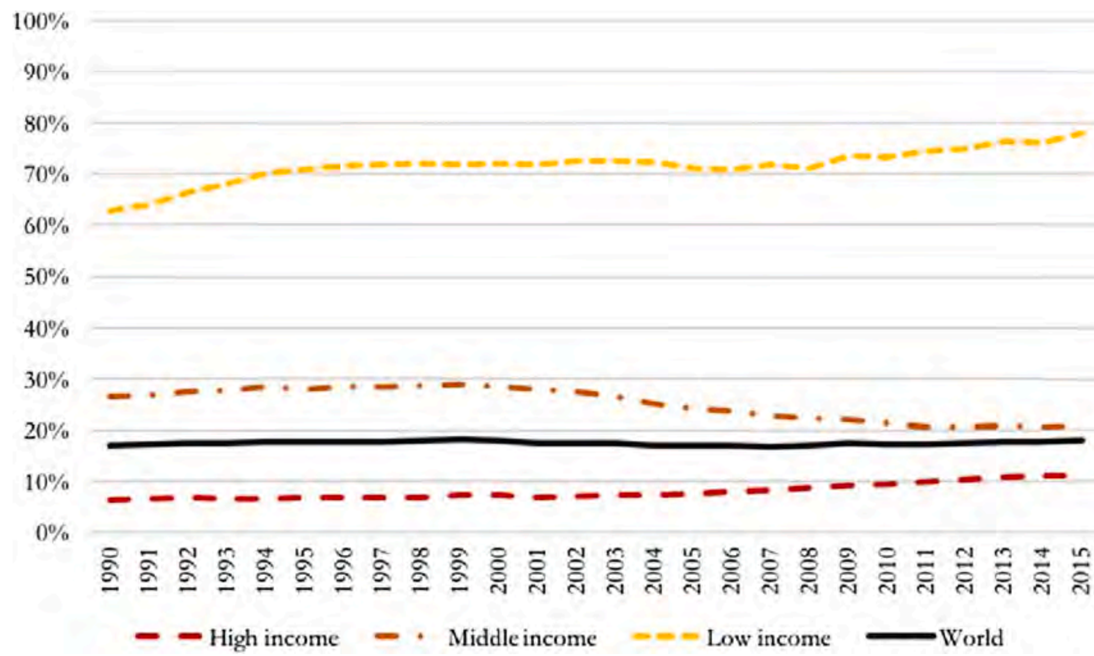

Fig. 1. Renewable energy consumption (hydro, biomass, wind, solar, liquid biofuels, biogas, geothermal, marine and renewable wastes) as a share of total final energy consumption over time.

insecurity since it can play an important role in reducing a country's dependence on imported energy products (like oil and gas). Through reduced emissions of greenhouse gases, renewable energy can also play an important role in helping to address climate change issues [4]. The response to this dual problem will however entail large investments in renewable energy technology, and this requires support from financial institutions. It is estimated that in order to reach the sustainable development scenario, global annual investments in renewable energy will have to increase by 97 percent compared with the investment levels of today [2].

The cost of renewable energy has decreased during recent years and continues to fall [5]. This is true also for the price of energy storage as battery prices have fallen steeply during the past decade [6]. A challenge related to renewable energy extraction has to do with securing a stable energy supply when relying on the nature for the generation of energy. According to a report published by BloombergNEF, battery prices has already fallen by 79 percent compared to prices in 2010, with a prediction of a continuous decrease of 67 percent from today's prices until 2030 [6]. At the same time as prices in both renewable energy and storage are fallen, oil prices peaked in 2018 compared to the past four years [7]. This trend together with reforms and subsidies to promote energy generation from renewable sources are important mechanisms for investments in renewable energy to increase. Policy and other support mechanisms still play an important role in sustaining the returns and limiting risks for project developers, indirectly supporting the availability of finance that is required for investments in renewable energy technology [5]. The rapid worldwide expansion of renewable energy has largely been driven by support policies from governments or multilateral institutions. These aim to address market failures in an effort to promote the uptake of renewable energy while achieving a number of other objectives, including energy diversification, the development of a local industry and job creation [8].

With the falling prices in renewable technology and storage, one can wonder why there is still a need of large government interventions for investments in renewable energy. A lower renewable energy price compared to the price of traditional energy sources should be expected to lead to a higher share of energy consumption coming from renewable sources. Fig. 1 shows that this increase is globally occurring at a very slow pace. Only for low-income countries, where we can see a noticeable increase in the average share of renewable energy consumption since 1990. These modest trends can be explained by the high growth in energy demand over the same period [7]. It brings perspective to the proportion of efforts needed to meet the increased demand while lowering CO_2 emissions. As can be seen in Fig. 1, low-income countries in general have substantially larger share of renewable energy consumption (mostly from hydro and traditional biomass) in relation to total energy consumption than high- and medium income countries. Since 2015, developing countries also exceeds the rest of the world regarding energy investments. Most of this is due to the wide expansion of solar power on the African continent [5].

Given the high financial budget required for investment in renewable energy, the role of the financial sector is paramount. According to Wu and Broadstock [9], the financial sector contributes to renewable energy consumption in two ways. They include i) promotion of capital accumulation and technological innovation and ii) allocation of funds to profitable projects. These imply that a well-functioning financial sector would be able to reduce liquidity risk and mobilize funds at a lower cost for investment in energy-efficient technologies, including renewable energy. In addition, through the activities of financial institutions, they are able to resolve the problem of asymmetric information based on the knowledge they have on their customers (both lenders and borrowers). This results in a reduction in cost of doing business and enhances efficiency, and potentially reduce risk associated with renewable energy projects. Moreover, based on the regulations of financial institutions, they are able to redistribute funds from less energy efficient appliances and non-renewable energy to environmentally friendly or renewable energy. For examples, most banks in developed countries (eg. Sweden, Germany, etc.) have introduced green mortgage and green car loans for houses, which use solar and vehicles which are eco-friendly, respectively. These loans provide interest rate discount to customers, thereby redistributing funds to cleaner energy. Finally, large scale infrastructure is required to support sustainable technological research and development in renewable energy, and this could be made possible with financial support [9]. As banks improve their performance by recording positive figures in their financial books, there is the likelihood for them to support such investments, hence increasing the consumption of renewable energy.

Due to the challenges faced by the world to both achieve universal energy access and to lower CO_2 emissions, it is important to investigate the relationship between banking sector performance and renewable energy consumption. The transition from generating energy through fossil fuels to renewable energy sources will demand a massive increase in investments directed towards production and storage of renewable energy. It is therefore likely that well-functioning capital markets and a high performing banking sector will stimulate renewable energy consumption. This paper aims to contribute to the existing literature on financial development and renewable energy by estimating the effect of banking sector performance on renewable energy consumption. For that purpose, the study used a bank-based dataset by Andrianova et al. [10]. The dataset contains data for 124 countries available for the years 1998–2012. Unfortunately, this is the most current dataset for the aggregated banking performance indicators. After considering the whole sample, a subgroup analysis is carried out based on income groupings. This recognises the heterogenous effects among different income-groups. Our study focuses on banking performance based on balance sheet and income statement financial indicators. These are return on asset, market capitalisation, asset quality, managerial inefficiency and Z-score. Z-score measures the level of financial stability. The five banking performance indicators considered in this study constitute the core indicators in the dataset by Andrianova et al. [10]. The study used the dynamic two-step sys-GMM technique to deal with problems of simultaneity bias/endogeneity and serial correlation problems.

This study is similar to the studies by Wu and Broadstock [9], Anto and Afloarei Nucu [11], Eren et al. [12] and Wang et al. [13] who investigated the effect of financial development on renewable energy in emerging economies, EU, India and China, respectively. Also, Amuakwa-Mensah et al. [14] examined the importance of the effect of a well-performing banking sector using the five banking performance indicators (that is, return on asset, market capitalisation, asset quality, managerial inefficiency and Z-score) on energy intensity for 43 sub-Saharan African countries. However, the current study makes two important contributions to the renewable energy finance literature: i) unlike other studies, our study considers a global sample of about 124 countries (that is, panel dataset) to investigate the effect of banking performance on renewable energy consumption. The increase in sample will provide a broader perspective about the relationship between banking performance and renewable energy consumption. In addition, given the heterogeneity across countries, we also construct three homogenous subpanels based on the income group classification (high-, middle-, and low-income countries) to examine the heterogeneity effect of the relationship between banking performance and renewable energy consumption. ii) We contribute by using balance sheet financial performance indicators (that is, return on asset, market capitalisation, asset quality, managerial inefficiency and Z-score) of banks based the unique dataset by Andrianova et al. [10]. This is based on data from five types of financial institutions; commercial banks, co-operative banks, Islamic banks, real estate and mortgage banks. Data is collected from 23 287 banks where commercial banks accounts for about two thirds of the banking frequency in all the 124 countries. The importance of using balance sheet and income statement financial performance indicators highlight the strength of banks in taking advantage of investment opportunities and the financial stability of the banking system.

Our findings suggest that interventions to improve the banking sector and strengthen credit markets will stimulate an increase in renewable energy consumption as a share of total energy consumption globally as well as for the three income categories. By using a large sample and dividing the countries into groups by income level, the paper is also able to point at interesting differences between the groups which can give important policy guidance when attempting to increase renewable energy consumption. Thus, for high -income countries, an increase in bank size together with improved asset quality and managerial efficiency have positive effects on renewable energy consumption. For middle- and low-income countries, a high return on asset, an increase in bank size and financial stability are positive determinants of renewable energy consumption. Surprisingly, an improved asset quality reduces renewable energy consumption in middle- and low-income countries.

The remainder of the study is organized as follows; section 2 provides an overview of the existing literature on the dynamics of renewable energy consumption and financial development. The methodology and data are presented in section 3 and in section 4, we present and discuss the empirical findings. Section 5 presents conclusions and suggestions for further studies within the research field.

2. Literature review

There are several studies to understand the determinants of energy consumption, with a recent increasing focus on the topics of renewable energy consumption and CO_2 emissions [4,15–20]. Most of these studies have been on the relationships between energy demand and growth or energy demand and financial development. Kraft and Kraft [21] found in a pioneering article that growth caused a growing energy demand in the United States between 1947 and 1974. Since then, the determinants of energy demand have been scrutinized, leading to a large pool of research both on economic growth and energy consumption nexus [22–27] and later on the nexus of financial development and energy consumption [28–32].

On the relationship of growth and energy consumption, the differentiated results within the field has led to the development of four hypotheses [33]. These are the growth-, conservation-, feedback- and neutrality hypotheses. The growth hypothesis indicates unidirectional causality from energy consumption to economic growth whereas the conservation hypothesis indicates the opposite causality that goes from economic growth to energy consumption. The feedback hypothesis is supported if there is bidirectional causality between energy consumption and economic growth and the neutrality hypothesis implies that there is no causal relationship between energy consumption and economic growth [34].

Karanfil [35] elaborates on the determinants of energy consumption stating that the causality between economic growth and energy consumption cannot be justified just by a simple bivariate model. Instead, the author suggests that one of the financial variables, domestic credit to private sector, stock market capitalisation or liquid liabilities should be put into the model as well as exchange rate and interest rate, which could have an effect on energy consumption through energy prices. This conclusion by Karanfil [35] has inspired researchers to study the link between financial development and energy consumption, something that has led to the formation of two separate hypotheses on what statutes the relationship.

The first of these two hypotheses is that financial development decreases energy consumption. This builds on the assumption that a well-established financial system increases the efficiency of the economy which leads to the usage of resources being more productive. It is therefore assumed that through efficiency gains, financial development can lead to a reduction in energy consumption [29,36–37]. The second hypothesis states the contrary, that is, financial development increases energy consumption. This is based on the notion that a well-functioning financial sector eases the financing process for consumers by lowering the borrowing cost [35,38]. Consumers will then borrow to invest in energy-intensive products.

Islam et al. [30] find that economic growth increases the demand for energy and that financial development leads to increased energy consumption in the long run. Similarly, Komal and Abbas [31] and Shahbaz and Lean [29] find long-run positive effects of financial development and economic growth on energy consumption.

From a policy standpoint, research has showed that the consumption of renewable energy is a rather complex topic. When distinguishing renewable energy consumption from energy consumption as a whole, the majority of studies have been investigating the relationship between economic growth and renewable energy consumption [16,39,19,40,27,41]. In an attempt to estimate the effect of renewable energy consumption on economic growth, Bhattacharya et al. [27] reach a heterogeneous result with substantial differences in effects across countries. Sadorsky [16] find that increases in real per capita income have a positive and statistically significant impact on per capita renewable energy consumption. Apergis and Payne [18] find indications for a bidirectional causality between renewable energy consumption and economic growth in both the short- and long-run. This conclusion is supported by Bhattacharya et al. [27] but dismissed by Menegaki [19] as the author do not find support for a statistically significant relationship between growth and renewable energy consumption when looking specifically at 27 European countries.

Attention has also been paid to other determinants of renewable and non-renewable energy consumption. Bartleet and Gounder [23] and Shahbaz and Lean [29] find a co-integration relationship between energy consumption, economic growth and variables such as employment, industrialisation and urbanisation. In the long run, Shahbaz and Lean [29] find that both industrialisation and urbanisation increase energy consumption. Sadorsky [4] looks at the effect of CO_2 emissions and finds it to be an important driver of renewable energy consumption. On the contrary, Mehrara [42] reaches the conclusion that CO_2 emission have a negative significant effect on renewable energy consumption for middle eastern countries part of the Economic Cooperation Organization. Aside from CO_2 emissions, Mehrara [42] finds that political instability and violence, government effectiveness, urban population (% of total) and human capital (school enrolment) are the most robust drivers of renewable energy consumption for the countries within the Economic Cooperation Organization.

In another study on the determinants of renewable energy, Omri and Nyugen [43] applies the same approach as we follow in this paper by dividing their sample into three income groups when investigating factors affecting renewable energy consumption. They considered variables, such as per capita GDP, oil prices, trade openness and CO_2 emissions. Conclusions from their study show that i) the impact of environmental degradation (CO_2 emissions) is statistically significant across all panels, ii) oil prices have a small and negative impact on renewable energy consumption, iii) changes in the per capita GDP significantly affect the renewable energy consumption only in the high- and low-income countries and iv) that changes in the trade openness variable have a statistically significant effect on the renewable energy consumption for all the panels with the exception of the high-income panel [37]. The finding that oil prices have a negative effect on renewable energy consumption would mean that crude oil and renewable energy have a complementary rather than a substitute relationship.

Very few studies have recognised the role of financial development related to renewable energy consumption. In one study, Paramati et al. [44] estimate the effect of foreign direct investment and stock market growth on clean energy and concludes that these variables are drivers of both generation and use of clean energy. In a similar article, Dogan and Seker [45] estimate that trade and financial development can help countries to adopt and use new environmentally-friendly technologies, which will in turn boost renewable energy consumption. Wu and Broadstock [9] , using panel data from 22 emerging economies and a dynamic system generalised method of moments (GMM) estimator, find a positive effect of financial development and institutional quality on renewable energy consumption. Similarly, Kutan et al. [46], considering four emerging economies (that is, China, India, Brazil and South Africa), find stock market development and FDI enhance renewable energy consumption. Anto and Afloarei Nucu [11] also find positive effect of financial development on the share of renewable energy consumption for a panel of 28 EU countries. The authors applied panel fixed effect model in the analysis.

In India, Eren et al. [12] applied a dynamic ordinary least squares (DOLS) estimation and found positive impacts of economic growth and financial development on renewable energy consumption. In addition, their results show a bidirectional causality between renewable energy consumption and financial development based on Granger causality analysis. Sweerts et al. [47], relying on the technology-rich energy-economy-environment model, TIAM-ECN, explore the effect of financial status on the electricity generation in 46 African countries, by considering renewable and fossil-based technologies. They find that lowering financing costs contribute to higher development of renewable energy in Africa. However, in the case of China, Wang et al. [13] find a negative long-run relationship between financial development and renewable energy consumption, albeit, a positive effect in the short-run. The authors applied Pooled Mean Group-Autoregressive Distributed Lag (PMG-ARDL) model and a panel dataset at the national and regional levels.

Even though there have not been extensive studies on how bank's balance sheet financial performance indicators affect renewable energy consumption, researchers have drawn conclusions which suggest that the commercial banks and the banking sector have a vital part to play in aiming at increasing renewable energy consumption. Omri and Nyugen [43], when discussing the policy implications of their study, suggests that a decreased cost of credit could help stimulate renewable energy consumption. This supports the hypothesis of this paper, that is, a well-performing banking sector can increase renewable energy consumption. Banking sector performance has previously been studied in relation to energy efficiency in the context of sub-Saharan Africa, where it has been proven to have a positive effect on energy efficiency [14]. If a well-functioning bank sector can foster more efficient energy use, it is likely that the same variables are also determinants when it comes to renewable energy consumption as a share of total final energy consumption.

Our paper adopts the neoclassical model used by Amuakwa-Mensah et al. [14] to further examine the nexus between renewable energy consumption and financial development, specifically focusing on the role of the banking sector performance based on balance sheet information. Unlike other studies, this our study considers a global sample of about 124 countries (that is, panel dataset) to investigate the effect of banking performance on renewable energy consumption. The increase in sample will provide a broader perspective about the relationship between banking performance and renewable energy consumption. In addition, given the heterogeneity across countries, we also construct three homogenous subpanels based on the income group classification (high-, middle-, and low-income countries) to examine the heterogeneity effect of the relationship between banking performance and renewable energy consumption. We also contribute by using balance sheet financial performance indicators (that is, return on asset, market capitalisation, asset quality, managerial inefficiency and Z-score) of banks from the unique dataset by Andrianova et al. [10]. The importance of using balance sheet and income statement financial performance indicators highlight the strength of banks in taking advantage of investment opportunities and the financial stability of the banking system. Three of our indicators, that is, return on asset, market capitalisation, and managerial inefficiency are similar to those used by Wu and Broadstock [9]. However, the inclusion of the Z-score is to measure the level of stability of the financial sector and its effect on the consumption of renewable energy. Also, asset quality investigates the implication of non-performing loans or credit risk in the financial sector on renewable energy consumption. These additional indicators considered in this study were not captured by Wu and Broadstock [9].

3. Method and data

The theoretical framework for our study assumes a neoclassical economic model where firms maximise their profits, following the work of Adom and Amuakwa-Mensah [48] and Amuakwa-Mensah et al. [14].

3.1. Theoretical framework

Each firm is assumed to maximise profit by choosing the optimal

Table 1
Description of variables and statistics.

VARIABLES	Definition	N	mean	Sd	min	max	skewness	kurtosis
MarketCap	Market capitalisation: $\frac{Equity}{TotalAsset}$	1,656	9.799	6.304	−41.58	85.37	2.143	29.04
Assetquality	Asset quality: $\frac{Impairedloans}{GrossLoan}$	1,394	7.628	8.540	0.0300	103.3	3.508	25.24
ManIneff	Ratio of cost to revenue: $\frac{Cost}{Revenue}$	1,641	61.14	21.36	3.810	382.2	4.213	48.20
RoA	Return on Asset: $\frac{NetIncome}{TotalAsset}$	1,653	1.382	2.443	−47.43	21.79	−5.028	110.3
Z-score	Financial stability, $Z_{it} = \frac{ROAA_{it} + \frac{equity_{it}}{assets_{it}}}{\sigma ROAA_i}$	1,653	15.09	11.17	−14.33	94.16	1.361	6.817
FDI	Foreign direct investment, net inflows (% of GDP)	1,684	4.724	7.477	−15.99	89.48	5.293	44.53
Trade	Trade volume (% of GDP)	1,685	79.300	49.13	16.44	531.74	3.440	21.972
dTrade	Growth in trade volume	1,572	0.861	12.29	−132.2	218.6	0.828	90.76
Urbanization	Urban population (% of total)	1,694	55.32	22.71	7.830	100	−0.113	1.968
lnREC	Natural log of renewable energy consumption(% of total final energy consumption)	1,693	−1.514	1.295	−6.335	−0.0167	−0.996	3.440
lnGDPPC	Natural log of real GDP per capita	1,693	8.292	1.600	5.390	11.43	0.125	1.898
lnCO2	CO_2 emissions (metric ton per capita)	1,694	0.412	1.706	−4.058	3.005	−0.614	2.332
lnCOP	Crude oil price	1,695	4.041	0.561	2.951	4.798	−0.292	1.916
Institution	Proxied by polity2. The polity score is computed by subtracting the p_autocracy score from the p_democracy score	1,695	0.701	0.315	0	1	−0.818	2.168
lnIVA	Industry, value added	1,663	3.252	0.377	1.176	4.475	−0.433	6.036
dlnIVA	Growth in industry, value added	1,549	0.000384	0.109	−2.064	0.808	−6.419	129.0

NB: $\sigma ROAA_i$ is a country specific deviation of the national average value of ROA $(ROAA_{jt})$ over time.

Table 2
Cross-section dependence test.

Variable	CD-test	p-value	mean ρ	mean abs(ρ)
lnREC	0.384	0.701	0.00	0.56
lnCOP	308.091	0.000	1.00	1.00
lnGDPPC	205.768	0.000	0.67	0.77
lnCO2	17.078	0.000	0.06	0.51
FDI	24.178	0.000	0.08	0.28
Trade	70.819	0.000	0.23	0.50
lnIVA	17.838	0.000	0.06	0.44
Institution	11.796	0.000	0.04	0.15
Urbanization	177.341	0.000	0.58	0.91
Return on asset	10.47	0.000	0.03	0.30
Market capitalisation	4.501	0.000	0.01	0.37
Asset quality	19.87	0.000	0.06	0.39
Managerial inefficiency	9.176	0.000	0.03	0.35
Z-score	1.886	0.059	0.00	0.35

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.

level of inputs, which in this case includes energy input. The model assumes a Cobb-Douglas technology such that each firm maximises profit (that is, equation (1)) subject to a Cobb-Douglas production technology in equation (2).

$$Max_{E,Z} \rightarrow \pi = PY - P_e E - Z \tag{1}$$

$$\text{Subjectto}: Y = AE^{\alpha} Z^{\beta} \tag{2}$$

The variables π, P, Y, P_e, E, A and Z are firm's profit, output price, output, price of energy input, energy input, total factor productivity and composite input (with a price normalised to one) respectively. α and β indicate respective share of energy input and composite input in total production. The Lagrangian equation used in solving this optimisation problem is given as:

$$\mathscr{L} = PY - P_e E - Z + \lambda(Y - AE^{\alpha} Z^{\beta}) \tag{3}$$

The Lagrangian is differentiated with respect to energy (E) , composite input (Z) and the Lagrangian multiplier (λ). This gives the following first-order conditions for the maximisation problem;

$$\frac{dL}{dE} = -P_e - \lambda \alpha A E^{\alpha-1} Z^{\beta} = 0 \tag{4}$$

$$\frac{dL}{dZ} = -1 - \lambda \beta A E^{\alpha} Z^{\beta-1} = 0 \tag{5}$$

$$\frac{dL}{d\lambda} = Y - AE^{\alpha} Z^{\beta} = 0 \tag{6}$$

By solving the first-order conditions in equations (4) to (6), for a given level of technology, the optimal demand for energy input required for the firm to achieve optimal profit is derived as equation (7). As this paper focuses on the effects of banking performance on renewable energy, we will solely focus on the optimal energy input demand.

$$E = \left(\frac{\alpha}{\beta}\right)^{\frac{\alpha\beta}{\alpha\beta+1}} \left(\frac{1}{P_e}\right)^{\frac{\alpha\beta}{\alpha\beta+1}} \left(\frac{1}{A}\right)^{\frac{\alpha}{\alpha\beta+1}} Y^{\frac{\alpha}{\alpha\beta+1}} \tag{7}$$

This equation shows that the firm's optimal demand for energy is inversely proportional to price and technology and increases with output. To include banking performance in the model, total factor productivity can be described as a positive exponential function of financial performance (FP) [14]. Studies have shown that financial development enhances firm level total factor productivity [49–50]. Thus, with improved financial system, there is an enhancement in overall economic productivity through an efficient resource reallocation among firms.

$$A = e^{f(\beta_2 FP)} \tag{8}$$

In the expression for energy demand (equation (7)), A can then be replaced by equation (8), yielding the following expression for energy demand:

$$E = \left(\frac{\alpha}{\beta}\right)^{\frac{\alpha\beta}{\alpha\beta+1}} \left(\frac{1}{P_e}\right)^{\frac{\alpha\beta}{\alpha\beta+1}} \left(\frac{1}{e^{\beta_2 FP}}\right)^{\frac{\alpha}{\alpha\beta+1}} Y^{\frac{\alpha}{\alpha\beta+1}} \tag{9}$$

By taking the natural logaritm on both sides we get:

$$\ln E = \frac{\alpha\beta}{\alpha\beta+1} \ln\left(\frac{\alpha}{\beta}\right) - \frac{\alpha\beta}{\alpha\beta+1} \ln P_e - \frac{\alpha}{\alpha\beta+1}(\beta_2 FP) + \frac{\alpha}{\alpha\beta+1} \ln Y \tag{10}$$

Equation (10) can then, for simplicity, be written as:

$$\ln E = \gamma_0 - \gamma_1 \ln P_e - \gamma_2 FP + \gamma_3 \ln Y \tag{11}$$

Here γ_0 is the constant term on the right hand side of the equation and $\gamma_1, \gamma_2,$ and γ_3 are the respective coefficients of energy price, financial performance, and income.

Table 3
Unit root test.

Variable	ADF		Phillips-Perron		CIPS
	Inverse logit	Modified inv. chi-squared	Inverse logit	Modified inv. chi-squared	Z(t-bar)
lnREC	−8.8962***	11.6473***	5.9897	−2.7508	0.738
dlnREC	−37.2144***	56.9901***	−36.7966***	57.2459***	−19.296***
lnCOP	−14.8219***	17.0474***	0.2470	−3.4833	42.130
dlnCOP	−40.2433***	62.31***	−38.444***	59.0533***	42.130
lnGDPPC	−8.0770***	12.3727***	5.1805	0.2737	−1.740**
dlnGDPPC	−30.0631***	44.1264***	−22.9214***	33.0288***	−19.296***
lnCO2	−11.9277***	14.5638***	3.3703	−0.7528	−0.571
dlnCO2	−38.4663***	59.1563***	−39.2523***	61.1308***	−14.768***
FDI	−26.2773***	37.9160***	−17.5285***	24.7171***	−10.204***
Trade	−14.8706***	18.3123***	−0.0550	0.9979	0.895
dTrade	−38.4552***	59.1139***	−38.0060***	58.5882***	−12.467***
lnIVA	−15.9765***	20.4693***	−2.3885***	3.8938***	0.058
dlnIVA	−37.3082***	57.0964***	−36.7717***	56.7535***	−15.231***
Institution	−12.7708***	16.5904***	−4.7606***	1.5162*	19.324[a]
Urbanization	1.9489	44.8516***	−42.8652***	63.4408***	−4.369***
RoA	−25.9225***	37.1670***	−17.5202***	25.7558***	−6.613***
MarketCap	−18.9597***	25.3933***	−5.6819***	8.8041***	0.418
dMarketCap	−39.7510***	61.4858***	−43.3004***	68.3139***	−16.162***
Assetquality	−15.2923***	20.4459***	−6.5199***	12.8114***	.
ManagIneff	−23.8477***	33.6336***	−13.68***	19.8562***	−8.087***
Z-score	−20.7087 ***	28.2326***	−7.7036***	10.7307***	−0.213

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. a indicates that test wasn't stationary at level nor at first difference.

Table 4
Cross-section dependence test per income group.

Variable	High Income Countries		Middle Income Countries		Low Income countries	
	CD-test	p-value	CD-test	p-value	CD-test	p-value
lnREC	35.144	0.000	12.398	0.000	19.354	0.000
lnCOP	86.255	0.000	154.726	0.000	64.343	0.000
lnGDPPC	72.708	0.000	125.907	0.000	20.972	0.000
lnCO2	11.643	0.000	34.642	0.000	8.339	0.000
FDI	12.576	0.000	17.411	0.000	11.788	0.000
Trade	36.716	0.000	29.77	0.000	11.679	0.000
lnIVA	28.207	0.000	11.135	0.000	0.403	0.687
Institution	-0.076	0.939	10.44	0.000	3.158	0.002
Urbanization	35.838	0.000	84.78	0.000	56.233	0.000
Return on asset	21.426	0.000	7.142	0.000	−0.782	0.434
Market capitalisation	4.295	0.000	0.669	0.504	−1.076	0.282
Asset quality	12.92	0.000	17.055	0.000	3.468	0.001
Managerial inefficiency	4.096	0.000	16.774	0.000	−0.142	0.887
Z-score	3.927	0.000	0.927	0.354	−1.228	0.220

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.

3.2. Empirical model

Since we are interested in the effect of banking performance on renewable energy consumption, renewable energy will henceforth be used as the source of energy input. This follows by the assumption that energy demand is determined by equation (11), regardless of the source of energy input. Renewable energy is measured as the share of total final energy consumption that comes from renewable sources. This includes renewable energy consumption of all technologies: hydro, biomass, wind, solar, liquid biofuels, biogas, geothermal, marine and renewable wastes. Following Wu and Broadstock [9], we assume that renewable energy consumption exhibits persistence, as the level of renewable energy consumed in previous periods are believed to be carried on to the current period. Thus, in the long-term, countries will conditionally converge to the same energy use state. Therefore, we include a lagged value of renewable energy consumption in the empirical model as expressed in equation (12):

$$\ln RE_{it} = \gamma_0 + \lambda \ln RE_{it-1} - \gamma_1 \ln P_{et} - \gamma_2 FP_{it} + \gamma_3 \ln Y_{it} + \boldsymbol{\gamma X_{it}} + \eta_i + v_t + \varepsilon_{it} \quad (12)$$

Each γ takes on the previously described definitions whereas λ is the coefficient of the lagged dependent variable. $\boldsymbol{\gamma X_{it}}$ symbolises the coefficient and vector of other control variables that can be of interest to the analysis. These controls are included in the model to address potential omitted variable bias. Equation (12) includes the control variables such as foreign direct investment, trade openness, institutional quality, urbanisation, industry (value added) and carbon dioxide (CO_2) emissions. These are taken from the literature studying determinants of both energy consumption as well as renewable energy consumption [4,29,51]. When estimating country level data, it can be difficult to avoid endogeneity problems by only including control variables related to the economic state of a country. As mentioned, it has been proven that governance and institutional indicators show significant effect on a country's environmental condition [42]. In an attempt to avoid endogeneity and control for these country characteristics, control variables such as institutional quality and urbanisation (% of total population) are included in the estimations. According to Claessens and Feyen [52], through improved institutional quality, financial sector development can spur greater energy structure change. Countries with improved institutional quality are likely to implement strong policies to regulate energy innovation.

Crude oil price is used as a proxy for alternative energy prices. In the literature, it has been either used as an indicator of general prices due to the pass-through effect on other sectors of the economy, or to show the cross-price effect of non-renewable energy on demand for renewable energy [4,9]. The relationship between crude oil price and renewable energy consumption has been mixed in the literature. Economic openness which is captured either in the form of foreign direct investment (FDI) or trade openness, has been showed to have significant effect on energy (and renewable energy) consumption [37,44–46,53]. FDI promotes the inflow of foreign capital, technological transfers, introduction of new processes and access to markets, which enhances renewable energy. Trade openness, which is the sum of annual imports and exports as a percentage of GDP, has a scale, technical, and composition effects, and these effects work in opposite direction in relation with renewable energy consumption.

The η_i and v_t respectively captures the country and time fixed effects

Table 5
Impact of banking sector performance on renewable energy consumption.

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Return on Asset	Market Capitalisation	Asset quality	Managerial Inefficiency	Z-score
RoA	0.00185** (0.000933)				
dMarketCap		0.000763*** (0.000244)			
Assetquality			−0.000588*** (0.000228)		
ManIneff				−0.000311*** (0.000119)	
Z-score					0.000671* (0.000351)
L.lnREC	0.991*** (0.00927)	0.992*** (0.00882)	0.948*** (0.0105)	0.988*** (0.00939)	0.991*** (0.00907)
dlnCOP	0.000979 (0.00641)	−0.000868 (0.00644)	0.000456 (0.00686)	0.00141 (0.00643)	−0.000469 (0.00641)
dlnGDPPC	−0.144*** (0.0492)	−0.142*** (0.0470)	−0.173*** (0.0496)	−0.137*** (0.0508)	−0.136*** (0.0481)
dlnCO2	−0.150*** (0.0243)	−0.147*** (0.0251)	−0.162*** (0.0263)	−0.148*** (0.0250)	−0.151*** (0.0249)
FDI	0.000818** (0.000389)	0.000880** (0.000390)	0.00125*** (0.000454)	0.000909** (0.000390)	0.000917** (0.000394)
Trade	−0.000244 (0.000172)	−0.000261 (0.000170)	−0.000400** (0.000175)	−0.000276 (0.000174)	−0.000259 (0.000172)
dlnIVA	0.0107 (0.0127)	0.0100 (0.0125)	0.0161 (0.0155)	0.0101 (0.0115)	0.00792 (0.0122)
Institution	0.0479 (0.0304)	0.0445 (0.0302)	0.0421 (0.0326)	0.0453 (0.0322)	0.0438 (0.0308)
Urbanisation	0.00109** (0.000541)	0.00116** (0.000549)	−0.000438 (0.000571)	0.000825 (0.000557)	0.00103* (0.000555)
Constant	−0.102*** (0.0211)	−0.0994*** (0.0214)	−0.0697*** (0.0258)	−0.0689*** (0.0218)	−0.104*** (0.0220)
Observations	1,501	1,495	1,305	1,492	1,501
Nr. of ContrID	113	113	111	113	113
Wald test	26954.50***	25746.75***	19290.88***	25021.86***	27987.94***
Sargan's test	41.6 (0.02)	42.5 (0.016)	40.9 (0.02)	42.9 (0.015)	41.4 (0.02)
1st order auto	−4.45***	−4.42***	−4.16***	−4.44***	−4.45***
2nd order auto	1.07	1.02	0.605	1.09	1.03
CD test	0.626	0.315	0.235	0.492	0.336
CIPS test	0.000	0.000	0.000[a]	0.000	0.000

Standard errors in parentheses. The chi-square values are presented for the Sargan's test, and the associated p-values are in parentheses. Z-values for the autocorrelation test are presented as well as the chi-square. P-values for the CD and CIPS tests are reported. a indicates instances where the CIPS test could not work in Stata and instead the ADF-test is used.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6
Number of countries and observation per category.

	Average GDP per capita	Number of countries	Number of observations
High Income Countries	$ 27,742	32	397–427
Middle Income Countries	$ 4086	57 (56 for Asset quality)	681–772
Low Income Countries	$ 510	24 (23 for Asset quality)	227–306

and the error term is denoted as ε_{it} . Bank performance is based on balance sheet information of banks, and it includes return on asset, asset quality, bank capitalisation and managerial inefficiency. The Z-score is used to measure the stability of the financial system [10]. The variables used in the econometric estimations are further defined and described in the data section.

3.3. Econometric method

For our econometric estimations, equation (12) is estimated by the two-stage system general method of moments (system-GMM) technique. The system-GMM is useful because, it allows for the lagged level of the renewable energy consumption as an independent variable as equation (12) exhibits. The lagged version of the dependent variable (renewable energy consumption) is included to capture the persistence of renewable energy consumption. It is highly reasonable to expect that if a country had a high level of renewable energy consumption in one year, it would probably remain at a high level also the following year. Ignoring the lagged dependent variable would probably lead to a high correlation between the dependent variable and the error term, causing biased estimations. However, if the estimation is done using an ordinary least squares estimation, the included lagged dependent variable could lead to inconsistent estimates. That is due to the problems of autocorrelation of the residuals and endogeneity of the regressors. The system-GMM method uses a set of internal instrumental variables (that is, lagged variables of the endogenous variables) to solve the endogeneity problem of the regressors.

There are two types of GMM estimators (difference and system) and they could both be alternatively considered, that is, one-step and two-step versions. Arellano and Bond [54] initially suggested the one-step difference-GMM, which introduced the set of internal instruments to solve the described inconsistencies of the ordinary least squares estimation. The set of instruments of the difference-GMM estimator include all the available lags in difference of the endogenous variables and the strictly exogenous regressors. This method was, however, later pointed out to be suffering from bias, showing imprecise estimates [55]. Blundell

Table 7
Impact of banking sector performance on renewable energy consumption for high income countries.

VARIABLES	Return on Asset	Market Capitalisation	Asset quality	Managerial Inefficiency	Z-score
RoA	−0.00209				
	(0.00316)				
dMarketCap		0.000266**			
		(0.000113)			
Assetquality			−0.00101***		
			(0.000130)		
ManIneff				−0.000829***	
				(0.000158)	
dZ-score					0.000210
					(0.000416)
L.lnREC	1.015***	1.010***	0.979***	1.017***	1.013***
	(0.0122)	(0.00675)	(0.00941)	(0.0119)	(0.0103)
dlnCOP	−0.0152**	−0.0178**	−0.0141**	−0.0161**	−0.0135*
	(0.00763)	(0.00798)	(0.00701)	(0.00691)	(0.00734)
lnGDPPC	0.119**	0.150***	0.0780**	0.131***	0.144***
	(0.0598)	(0.0396)	(0.0385)	(0.0358)	(0.0359)
dlnCO2	−0.284***	−0.283***	−0.251***	−0.289***	−0.291***
	(0.0447)	(0.0434)	(0.0396)	(0.0441)	(0.0439)
FDI	0.00232***	0.00234***	0.00167***	0.00160***	0.00199***
	(0.000332)	(0.000337)	(0.000393)	(0.000367)	(0.000306)
dTrade	−0.000442***	−0.000350**	−0.000378***	−0.000324**	−0.000488***
	(9.28e-05)	(0.000142)	(0.000125)	(0.000126)	(0.000134)
dlnIVA	−0.0482	−0.0459	0.0576	0.0367	−0.0232
	(0.0732)	(0.0724)	(0.0861)	(0.0980)	(0.0837)
Institution	−0.148*	−0.190***	−0.0669	−0.0916	−0.164**
	(0.0759)	(0.0661)	(0.0701)	(0.0908)	(0.0664)
Urbanisation	−0.00234	−0.00365**	−0.00249*	−0.00220*	−0.00226*
	(0.00163)	(0.00164)	(0.00129)	(0.00119)	(0.00120)
Constant	−0.837*	−1.030***	−0.556*	−0.972***	−1.093***
	(0.495)	(0.315)	(0.309)	(0.318)	(0.307)
Observations	427	427	397	425	427
Nr. of ContrID	32	32	32	32	32
Wald test	167584.73***	215694.09***	293953.06***	48725.37***	62623.88***
Sargan's test	21.07 (0.69)	20.66 (0.71)	21.5 (0.66)	22.16 (0.63)	21.76 (0.65)
1st order auto	−2.95***	−2.93***	−2.94***	−2.83***	−2.86***
2nd order auto	0.18	0.11	−0.41	0.32	0.25
CD test	0.000	0.000	0.000	0.000	0.000
CIPS test	0.000	0.000	0.000[a]	0.000	0.000

Standard errors in parentheses. The chi-square values are presented for the Sargan's test, and the associated p-values are in parentheses. Z-values for the autocorrelation test are presented as well as the chi-square. P-values for the CD and CIPS tests are reported. a indicates instances where the CIPS test could not work in Stata and instead the ADF-test is used.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

and Bond [55] instead introduced the system-GMM estimator. The system-GMM estimator, which is used in this study, includes not only the previous instruments of the difference-GMM but also the lagged values of the dependent variable. This solves the bias and imprecision by first assuming independent and homoscedastic error terms and then using the first-step residuals to construct consistent variance and covariance matrices in the second stage. This method can, however, in finite sample cases, lead to a downward bias for the standard errors [14].

The system-GMM is advantageous in that it helps solve the endogeneity problem arising from the potential correlation between the independent variable and the error term in dynamic panel data models. It is also favourable to use over the difference-GMM when working with unbalanced panel data, such as in this paper [56].

To avoid the problem of a downward bias in standard errors, this paper minimises the number of lags and then use the Sargan test to check instrumental validity. To test for serial correlation, serial correlation is hypothesised at first-order but no serial-correlation at second order. We carried out cross-sectional dependence and stationary test of the residual term in each model. When the residual term from the model is stationary, it provides an evidence of the model goodness of fit [57]. In an event that the cross-sectional dependence test for the residual term in each model is insignificant, it implies that our model is robust to cross-sectional dependence. However, if the test is significant then our result would be interpreted with caution. We are not able to correct the problem of cross-sectional dependence in the residual, if any, because of the relatively short time series in our panel dataset. The pooled mean group (PMG) and common correlated effects mean group (CCEMG) estimators are recommended to be efficient in the presence of cross-sectional dependence [58–59]. These methods nonetheless are dependent on long-run restrictions, which requires long time series for the panel dataset. Given our data limitation, we stick to our earlier proposed estimation technique (that is, two-step system-GMM estimator) whether or not cross-sectional dependence is present in the residual.

3.4. Data and tests

This study uses panel data covering 124 countries over the period 1998–2012. Data on banking performance are sourced from the International Database on Financial Fragility created by Andrianova et al. [10]. In this paper, we use the five variables related to banks performance from the dataset by Andrianova et al. [10] to estimate the relationship between the performance of the banks and consumption of renewable energy. These are return on asset, market capitalisation (bank size), Z-score (financial stability), asset quality (non-performing loans) and managerial inefficiency (cost to revenue ratio). The data on crude oil price is sourced from the BP Statistical Review of World Energy. Data on renewable energy and other macroeconomic variables are collected from the World Bank's World Development Indicator (WDI), whereas the institutional variable proxy is sourced from Polity IV Project. The Polity IV Project is developed to monitor regime change and studying the effects of regime authority [60]. Some variables in the data, especially asset quality, institution and industry, contain missing values

Table 8
Impact of banking sector performance on renewable energy consumption for middle income countries.

VARIABLES	Return on Asset	Market Capitalisation	Asset quality	Managerial Inefficiency	Z-score
RoA	0.00309***				
	(0.000951)				
MarketCap		0.00178***			
		(0.000512)			
Assetquality			0.000807**		
			(0.000381)		
ManIneff				1.39e-05	
				(0.000222)	
Z-score					0.00138***
					(0.000498)
L.lnREC	0.953***	0.956***	0.921***	0.956***	0.962***
	(0.0160)	(0.0160)	(0.0195)	(0.0156)	(0.0145)
dlnCOP	−0.0152**	−0.0160**	−0.00596	−0.0153*	−0.0187***
	(0.00759)	(0.00719)	(0.00641)	(0.00786)	(0.00686)
dlnGDPPC	−0.0746	−0.0690	−0.108*	−0.0667	−0.0701
	(0.0719)	(0.0747)	(0.0579)	(0.0744)	(0.0743)
lnCO2	−0.0702**	−0.0541**	−0.0822***	−0.0700**	−0.0593**
	(0.0290)	(0.0246)	(0.0256)	(0.0277)	(0.0276)
FDI	−0.000296	−0.000505	0.000466	−0.000236	−0.000309
	(0.000784)	(0.000814)	(0.000782)	(0.000831)	(0.000747)
dTrade	−0.000556**	−0.000443*	−0.00105***	−0.000525**	−0.000420*
	(0.000231)	(0.000229)	(0.000207)	(0.000238)	(0.000247)
dlnIVA	0.0532***	0.0467***	0.0304*	0.0382**	0.0515***
	(0.0158)	(0.0149)	(0.0181)	(0.0157)	(0.0162)
Institution	0.0286	0.0200	0.0871*	0.0311	0.0214
	(0.0429)	(0.0426)	(0.0522)	(0.0419)	(0.0431)
dUrbanisation	−0.145***	−0.131***	−0.126***	−0.133***	−0.138***
	(0.0316)	(0.0303)	(0.0250)	(0.0345)	(0.0328)
Constant	−0.000767	−0.0170	−0.0889**	3.42e-05	−0.00547
	(0.0331)	(0.0344)	(0.0442)	(0.0371)	(0.0309)
Observations	770	771	681	767	770
Nr. of ContrID	57	57	56	57	57
Wald test	16267.64***	14505.88***	11841.54***	14047.11***	24749.64***
Sargan's test	28.51 (0.29)	28.52 (0.28)	31.36 (0.18)	27.42 (0.34)	26.75 (0.37)
1st order auto	−3.39***	−3.4***	−3.21***	−3.4***	−3.45***
2nd order auto	1.01	1.002	0.69	0.98	1.005
CD test	0.000	0.000	0.000	0.000	0.000
CIPS test	0.000	0.000	0.000[a]	0.000	0.000

Standard errors in parentheses. The chi-square values are presented for the Sargan's test, and the associated p-values are in parentheses. Z-values for the autocorrelation test are presented as well as the chi-square. P-values for the CD and CIPS tests are reported. a indicates instances where the CIPS test could not work in Stata and instead the ADF-test is used.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

making the panel unbalanced. For countries with missing observations on these variables, we dropped them from the sample.[2] Because of the large number of observations, this is not expected to have an impact on the estimated results.

Renewable energy consumption is defined as the share of renewable energy in total final energy consumption. Total final energy consumption is in turn derived from energy balances statistics and is equivalent to total final end use consumption excluding non-energy use (World Bank, 2018). Although we acknowledge the possible heterogenous effect of banking performance on the disaggregated renewable energy sources (such as solar, wind, hydro and biomass), our study focuses on the total renewable energy consumption as a share of total energy consumption due to data limitation for the countries and the time period considered in this study[3]. Regarding control variables used, Omri and Nyugen [43] have studied the determinants of renewable energy consumption. They find CO_2 emissions to be a significant determinant of renewable energy consumption both when estimating global effects as well as for high, middle- and low-income groups. Crude oil price, per capita GDP and trade openness have also shown to have effects on renewable energy consumption but show heterogeneous results across the different income groups. In this paper, CO_2 emissions is expressed as CO_2 emissions per capita (metric tons). GDP serves as a measure of output and GDP figures are in 2011 US dollars. We use GDP per capita in our study. Urbanisation and industrialisation is included as control variables as both have been proved to have a significant effect on energy use and CO_2 emissions [57,61].

Table 1 defines and presents the descriptive statistics for each variable. The top rows show the five variables that are used to describe banking sector performance. Market capitalisation is defined as the ratio between equity and total asset. The average market capitalisation for banks in the sample is 9.8, with a standard deviation of 6.3. Asset quality is the ratio between impaired loans and gross loans and can also be expressed as share of non-performing loans. It has a mean of 7.63 and a standard deviation of 8.54. Managerial inefficiency is the cost to revenue ratio and it is on average 61.14, with a standard deviation of 21.36. This high value shows that banks in the sample generally are inefficiently managed. A management which deploys its resources efficiently will look to maximise its income and reduce its operating costs. Therefore, a larger ratio implies a lower level of efficiency. Return on asset has a mean of 1.382 and a standard deviation of 2.443. Both asset quality and return on asset suggest a high variability for countries across years since the standard deviation is larger than the mean. The average Z-score, which measures financial stability, is 15.09 with a standard deviation of 11.17. The higher the Z-score, the more financially sound a country is [10].

[2] Seychelles, Russian Federation, Cote d'Ivoire, Hong Kong, Sao Tome and Principe, Djibouti, Angola, Cape Verde, Ethiopia and Guinea Bissau.

[3] We however provide some estimation in section 4.4 for disaggregated renewable energy consumption sources based on data from few countries we have information on.

Table 9
Impact of banking sector performance on renewable energy consumption for low income countries.

VARIABLES	Return on Asset	Market Capitalisation	Asset quality	Managerial Inefficiency	Z-score
RoA	0.000968***				
	(0.000217)				
MarketCap		0.00125***			
		(0.000115)			
Assetquality			0.000232**		
			(9.99e-05)		
ManIneff				−8.08e-05	
				(5.01e-05)	
Z-score					0.000865***
					(0.000145)
L.lnREC	1.003***	1.027***	1.051***	1.026***	1.060***
	(0.0211)	(0.0201)	(0.0178)	(0.0152)	(0.0303)
dlnCOP	0.0186***	0.0186***	0.0169***	0.0210***	0.0209***
	(0.00315)	(0.00287)	(0.00401)	(0.00355)	(0.00235)
dlnGDPPC	0.00616	0.00679	−0.0223	0.00556	0.00738
	(0.00975)	(0.0115)	(0.0446)	(0.0103)	(0.0102)
dlnCO2	−0.105***	−0.103***	−0.122***	−0.112***	−0.108***
	(0.00854)	(0.00756)	(0.00667)	(0.00834)	(0.00834)
FDI	−0.000204*	−0.000231*	0.000224	−0.000245**	−0.000231
	(0.000113)	(0.000132)	(0.000183)	(0.000124)	(0.000148)
dTrade	2.02e-05	3.92e-05	0.000131	4.06e-05	3.96e-05
	(6.81e-05)	(6.05e-05)	(9.10e-05)	(7.32e-05)	(6.50e-05)
lnIVA	−0.00861*	−0.00842	−0.00919*	−0.0101*	−0.0106**
	(0.00510)	(0.00525)	(0.00472)	(0.00537)	(0.00456)
Institution	−0.0110***	−0.0106**	−0.00938**	−0.0102**	−0.0107*
	(0.00394)	(0.00473)	(0.00431)	(0.00500)	(0.00550)
Urbanisation	−0.00158**	−0.00110**	−0.000261	−0.000910*	−0.000340
	(0.000643)	(0.000554)	(0.000618)	(0.000540)	(0.000625)
Constant	0.0666***	0.0464**	0.0399*	0.0637***	0.0415**
	(0.0193)	(0.0230)	(0.0208)	(0.0205)	(0.0186)
Observations	305	307	228	301	305
Nr. of ContrID	24	24	23	24	24
Wald test	42326.26***	16483.48***	1.75e + 06***	24146.29***	9568.79***
Sargan's test	16.32 (0.91)	16.1 (0.91)	12.33 (0.98)	17.98 (0.84)	17.02 (0.88)
1st order auto	−2.71***	−2.65***	−2.29**	−2.68***	−2.7***
2nd order auto	−0.58	−0.33	−0.87	−0.39	−0.39
CD test	0.000	0.000	0.000	0.000	0.000
CIPS test	0.000	0.000	0.000[a]	0.000	0.000

Standard errors in parentheses. The chi-square values are presented for the Sargan's test, and the associated p-values are in parentheses. Z-values for the autocorrelation test are presented. P-values for the CD and CIPS tests are reported. a indicates instances where the CIPS test could not work in Stata and instead the ADF-test is used.
*** $p < 0.01$ s, ** $p < 0.05$, * $p < 0.1$.

Table 10
Short- and long elasticities.

VARIABLES	Return on Asset	Market Capitalisation	Asset quality	Managerial Inefficiency	Z-score
	Short run Elasticities				
Global	0.0023	0.000075	−0.00288	−0.01833	0.00897
High Income	———	0.00002	−0.00263	−0.0502	———
Middle Income	0.0045	0.0182	0.0047	———	0.0196
Low Income	0.002	0.0127	0.0018	———	0.0073
	Long run Elasticities				
Global	0.2473	0.0096	−0.0551	−1.548	0.9892
High Income	———	−0.00196	−0.1281	3.013	———
Middle Income	0.097	0.4128	0.0596	———	0.523
Low Income	−0.793	−0.476	−0.036	———	−0.121

For the whole sample, the log of the renewable energy consumption variable has a mean of −1.514, with a standard deviation of 1.295. This translates to a sample mean of 22 percent share of renewable energy consumption to total final energy consumption.[4]

3.5. *Cross-sectional dependence, unit root test and correlation matrix*

3.5.1. *Testing for the entire sample*

To determine if the variables are correlated across countries, the Pesaran's [62] cross-section dependence test is used. Researchers have pointed out that empirical variables are more likely to show cross-sectional dependence than to live up to the assumption of cross-sectional independence [63–64]. De Hoyos Sarafidis [65] highlights the need of testing for cross-section dependence if T is small and N is large. That description fits the data used in this paper, where T = 15 and N = 113 after excluding countries exhibiting large counts of missing values. Pesaran's [62] cross-sectional dependence test is used because, it is valid under a wide class of panel data models [66].

In Table 2, the result from the cross-section dependence test over the entire sample is displayed. In line with the projection by Banerjee et al. [63] and Pesaran [64] above, all variables except the dependent variable of renewable energy consumption show results rejecting the null hypothesis of cross-sectional independence. The Z-score variable shows a weak tendency of cross-sectional independence, where the null hypothesis is only rejected at a 10 percent significance level. The dependent variable of renewable energy consumption is the only variable

[4] Taking the log transformation of the figure −1.514 in Table 1.

Table 11a
Effect of return on asset on renewable energy consumption.

	Pooled					OECD countries				
VARIABLES	(1) lnbiofuels	(2) lnbiogeo	(3) lnhydro	(4) lnsolar	(5) lnwind	(6) lnbiofuels	(7) lnbiogeo[A]	(8) lnhydro	(9) lnsolar	(10) lnwind
RoA	0.090***	−0.004	0.013***	0.010	−0.023**	0.042**	0.002	0.027***	0.001	0.015***
	(0.029)	(0.008)	(0.005)	(0.010)	(0.011)	(0.021)	(0.008)	(0.007)	(0.011)	(0.004)
Observations	470	639	814	449	610	324	432	450	307	422
No. of countries	56	53	59	52	54	33	33	33	32	33
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sargan's test	30.35 (0.21)	24.9(0.5)	35.2(0.08)	28.54(0.28)	29.29(0.3)	17.79(0.85)	19.68(0.76)	27.76(0.3)	22.14(0.62)	25.88(0.4)
1st order auto	−3.029***	−2.24**	−3.44***	−1.78*	−3.34***	−2.26**	−2.51**	−4.03***	−0.86	−3.26***
2nd order auto	−0.668	−1.72*	0.29	−0.53	−1.71*	−1.63	−1.94*	−0.83	0.43	−1.31

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The chi-square values are presented for the Sargan's test, and the associated p-values are in parentheses. Z-values for the autocorrelation test are presented. Control variables: GDP per capita, crude oil prices, foreign direct investment, trade openness, institutional quality, urbanisation, industry (value added) and carbon dioxide (CO2) emissions. Estimation for all models is based on system-GMM technique. "A" includes geothermal, biomass and other sources.

Table 11b
Effect of market capitalization on renewable energy consumption.

	Pooled					OECD countries				
VARIABLES	(1) lnbiofuels	(2) lnbiogeo	(3) lnhydro	(4) lnsolar	(5) lnwind	(6) lnbiofuels	(7) lnbiogeo[A]	(8) lnhydro	(9) lnsolar	(10) lnwind
MarketCap	0.064***	−0.003	−0.001*	0.001	−0.002	0.071***	0.001*	0.001	0.001	−0.004***
	(0.019)	(0.002)	(0.001)	(0.001)	(0.001)	(0.007)	(0.000)	(0.001)	(0.001)	(0.001)
Observations	470	639	814	449	610	324	432	450	307	422
No. of countries	56	53	59	52	54	33	33	33	32	33
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sargan's test	31.49 (0.17)	26.36(0.39)	35.2(0.08)	26.2(0.39)	30.4(0.2)	17.31 (0.87)	22.23(0.62)	27.4(0.33)	21.7(0.66)	26.8(0.4)
1st order auto	−3.06***	−2.25**	−3.46***	−1.77*	−3.33***	−2.02**	−2.53**	−3.96***	−0.87	−3.26***
2nd order auto	−0.52	−1.72*	0.28	−0.54	−1.69*	−1.63	−1.96*	−0.92	0.41	−1.41

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The chi-square values are presented for the Sargan's test, and the associated p-values are in parentheses. Z-values for the autocorrelation test are presented. Control variables: GDP per capita, crude oil prices, foreign direct investment, trade openness, institutional quality, urbanisation, industry (value added) and carbon dioxide (CO2) emissions. Estimation for all models is based on system-GMM technique. "A" includes geothermal, biomass and other sources.

Table 11c
Effect of asset quality on renewable energy consumption.

	Pooled					OECD countries				
VARIABLES	(1) lnbiofuels	(2) lnbiogeo	(3) lnhydro	(4) lnsolar	(5) lnwind	(6) lnbiofuels	(7) lnbiogeo[A]	(8) lnhydro	(9) lnsolar	(10) lnwind
Assetquality	−0.094***	−0.002	−0.005***	0.012***	0.002	−0.005	0.014***	−0.004**	−0.027***	0.002
	(0.021)	(0.002)	(0.001)	(0.005)	(0.003)	(0.025)	(0.002)	(0.002)	(0.010)	(0.003)
Observations	450	611	759	425	576	308	406	422	289	394
No. of countries	55	53	59	52	54	33	33	33	32	33
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sargan's test	25.01(0.46)	24.96(0.46)	36.2(0.07)	28.63(0.28)	29.8(0.23)	18.01(0.84)	19.98(0.75)	28.79(0.27)	22.12(0.63)	25.1(0.46)
1st order auto	−3.28***	−2.098**	−4.77***	−1.76*	−3.28***	−1.94*	−2.54**	−3.89***	−0.66	−3.26***
2nd order auto	−0.143	−1.74*	−1.02	−0.62	−1.53	−1.11	−1.93*	−0.91	0.29	−1.15

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The chi-square values are presented for the Sargan's test, and the associated p-values are in parentheses. Z-values for the autocorrelation test are presented. Control variables: GDP per capita, crude oil prices, foreign direct investment, trade openness, institutional quality, urbanisation, industry (value added) and carbon dioxide (CO2) emissions. Estimation for all models is based on system-GMM technique. "A" includes geothermal, biomass and other sources.

being cross-sectional independent.

For the cross-sectional independent variables, the panel augmented Dick Fuller and Phillip-Perron tests are used to perform the unit root test. These tests are widely used because, they account for individual unit root process and as such deals with heterogeneity. Both tests are used because, even if the augmented Dick Fuller test shows that variables are stationary, the Phillip-Perron test (which has more power) show that some variables only become stationary after first difference. For variables that are cross-sectional dependent, neither of these tests can be relied upon, as they assume cross-sectional independence. Therefore, for the variables showing cross-sectional dependence, the Pesaran [62] cross-sectional augmented panel unit root test (CIPS) is used, which accounts for cross-sectional dependence.

The three columns in Table 3 present the augmented Dick Fuller and Phillip-Perron as well as the Pesaran [62] cross-sectional augmented panel unit root test (CIPS). Renewable energy consumption and the Z-score were the variables that, according to the above cross-section dependence test, showed cross-sectional independence. For these two variables, we regard the augmented Dick Fuller and Phillip-Perron as the indicator of unit root. From Table 3, we see that Z-score is stationary at level, while renewable energy consumption is stationary at first difference. The rest of the variables are evaluated based on the CIPS-test. It shows that foreign direct investment, urbanisation, return on asset and managerial inefficiency are stationary at level. Crude oil price, per

Table 11d
Effect of managerial inefficiency on renewable energy consumption.

	Pooled					OECD countries				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	lnbiofuels	lnbiogeo	lnhydro	lnsolar	lnwind	lnbiofuels	lnbiogeo[A]	lnhydro	lnsolar	lnwind
ManIneff	−0.002	0.000	−0.001***	0.000	−0.001*	0.004	−0.000	−0.001***	0.000	−0.001
	(0.003)	(0.000)	(0.000)	(0.001)	(0.001)	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	470	639	814	449	610	324	432	450	307	422
No. of countries	56	53	59	52	54	33	33	33	32	33
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sargan's test	31.31(0.18)	25.97(0.41)	35.57(0.08)	26.25(0.39)	30.49(0.21)	17.55(0.86)	22.34(0.62)	26.97(0.36)	22.66(0.59)	27.31(0.34)
1st order auto	−3.02***	−2.25**	−3.39***	−1.79*	−3.34***	−2.01**	−2.52**	−3.99***	−1.01	−3.25***
2nd order auto	−0.62	−1.73*	0.298	−0.52	−1.68*	−1.59	−1.95*	−0.82	0.45	−1.38

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The chi-square values are presented for the Sargan's test, and the associated p-values are in parentheses. Z-values for the autocorrelation test are presented. Control variables: GDP per capita, crude oil prices, foreign direct investment, trade openness, institutional quality, urbanisation, industry (value added) and carbon dioxide (CO2) emissions. Estimation for all models is based on system-GMM technique. "A" includes geothermal, biomass and other sources.

Table 11e
Effect of z-score on renewable energy consumption.

	Pooled					OECD countries				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	lnbiofuels	lnbiogeo	lnhydro	lnsolar	lnwind	lnbiofuels	lnbiogeo[A]	lnhydro	lnsolar	lnwind
Z-score	0.002	−0.002	0.000	−0.002	−0.005**	0.054***	−0.000	−0.001	−0.006	−0.004***
	(0.030)	(0.001)	(0.001)	(0.004)	(0.002)	(0.011)	(0.001)	(0.001)	(0.004)	(0.001)
Observations	470	639	814	449	610	324	432	450	307	422
No. of countries	56	53	59	52	54	33	33	33	32	33
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sargan's test	31.43(0.18)	26.34(0.39)	35.33(0.08)	26.43(0.38)	30.12(0.22)	19.04(0.80)	22.21(0.62)	27.46(0.33)	23.84(0.53)	26.99(0.36)
1st order auto	−3.04***	−2.25**	−3.44***	−1.78*	−3.34***	−2.14**	−2.52**	−3.97***	−0.91	−3.27***
2nd order auto	−0.598	−1.72*	0.26	−0.52	−1.70*	−1.46	−1.96*	−0.89	0.45	−1.40

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The chi-square values are presented for the Sargan's test, and the associated p-values are in parentheses. Z-values for the autocorrelation test are presented. Control variables: GDP per capita, crude oil prices, foreign direct investment, trade openness, institutional quality, urbanisation, industry (value added) and carbon dioxide (CO2) emissions. Estimation for all models is based on system-GMM technique. "A" includes geothermal, biomass and other sources.

Table 12
Summary of the results for all the four panels.

Variable	Global	HIC	MIC	LIC
Return on Asset	✓ (+)	(−)	✓(+)	✓(+)
Market Capital	✓(+)	✓(+)	✓(+)	✓(+)
Asset quality	✓(−)	✓(−)	✓(+)	✓(+)
Managerial inefficiency	✓(−)	✓(−)	(+)	(−)
Financial stability (Z-score)	✓(+)	(+)	✓(+)	✓(+)

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

Table 13
Summary of the results for renewable energy types for OECD countries.

Variable	biofuel	Geothermal, Biomass & others	Hydro	Solar	Wind
Return on Asset	✓(+)	(+)	✓(+)	(+)	✓(+)
Market Capital	✓(+)	✓(+)	(+)	(+)	✓(−)
Asset quality	(−)	✓(+)	✓(−)	✓ (−)	(+)
Managerial inefficiency	(+)	(−)	✓(−)	(+)	(−)
Financial stability (Z-score)	✓(+)	(−)	(−)	(−)	✓(−)

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

capita GDP, CO_2 emissions, trade, industry value added and market capitalisation are not stationary at level and need to be transformed into growth form before being put into the estimation model.[5]

For the variables used in the econometric estimation, a correlation matrix is presented in Table A2 in the appendix. It shows no high correlation between the pair of variables, indicating that the presence of multicollinearity in the econometric estimations is low.

3.5.2. Testing data for each income group.

As part of the analysis is to estimate the different effects for the three income categories, Table 4 presents the results from Pesaran's [62] cross-sectional independence test for the different income groups. This shows some interesting findings, in terms of which variables are cross-sectional independent in each income group. For high income countries, all variables except the institution variable are cross-sectional dependent. The column for middle income countries shows that market capitalisation and Z-score are cross-sectional independent whilst the test for the other variables are rejecting the null hypothesis. For the low-income countries, all banking performance variables (except asset quality) are cross-sectional independent along with the industry variable. This result is consistent with previous work focusing on sub-Saharan Africa, being a region that mainly consists of countries that, in this dataset, is defined as low income countries [14].

Tables A3, A5 and A7 in the appendix present the results from the unit root tests for each income group. They provide us with some differences regarding which variables are stationary for which income groups. Table A3 indicates that for high income countries, the growth

[5] The CIPS(Z(t-bar)) unit root test could not estimate for asset quality since data on the variable didn't consist of sufficiently long time series.

form should be used for the variables crude oil price, CO_2 emissions, per capita GDP, industry value added, trade, market capitalisation and Z-score. For estimations covering middle income countries, Table A5 suggests that the growth form be used on variables crude oil price, per capita GDP, industry value added, trade and urbanisation, in the case of middle-income countries. Table A7 indicates that for low-income countries, the variables should be transformed into growth form before added into the estimations be crude oil price, CO_2 emissions, per capita GDP, industry value added and trade.

For each income group, a correlation matrix is presented in the appendix. Tables A4, A6 and A8 describe the correlation coefficients between pairs of variables for high-, middle- and low-income countries respectively. The correlation tests show no high correlation among the independent variables of interest for any panel. By this, it can be assumed that the presence of multicollinearity in the econometric estimations is low.

4. Empirical findings and discussion

In order to analyse how banking sector performance effects renewable energy consumption, estimations were based on pooled sample (global panel) and sub-samples for the three income groups.

4.1. Impacts of banking sector performance based on the global panel

The columns (1) to (5) in Table 5 show the impact of each banking sector variable on renewable energy consumption. Each estimation is based on system-GMM and the banking performance variables were included step-wise and estimated separately in each column. For the global panel, Table 5 shows that all banking performance have a significant effect on the share of renewable energy consumption. Return on asset and market capitalisation can be seen to increase renewable energy consumption. Asset quality, which is defined as the share of non-performing loans, has a significant negative effect on renewable energy consumption. This implies that a higher share of non-performing loans decreases renewable energy consumption. The same can be seen for managerial inefficiency which exhibits significant negative effect on the dependent variable. A mismanaged banking sector can thus be said to negatively affect renewable energy consumption. Z-score is viewed to have a positive effect on renewable energy consumption implying that a more stable financial environment enhances renewable energy consumption.

The coefficients presented in Table 5 suggest that return on asset has the largest separate impact on the share of energy consumed from renewable sources. An increase by one unit in return on asset will significantly increase the renewable energy consumption as a share of total energy consumption by 0.19 percentage points. Since market capitalisation was stationary at first difference for the global panel, the growth form of the variable is used in the estimations. The estimation suggests that a one-unit increase in the growth of market capitalisation increases renewable energy consumption by about 0.08 percentage points. Asset quality (indicating the share of total loans that is non-performing) and managerial inefficiency (cost to revenue ratio) are respectively decreasing the share of renewable energy consumption by about 0.06 and 0.03 percentage points each.[6] A marginal increase in Z-score increases energy consumed from renewable sources by about 0.007 percentage points. That would suggest that financial stability has an increasing effect on renewable energy consumption in relation to energy consumption from other sources.

The lagged variable for renewable energy consumption shows a large positive effect on the dependent variable across all models in the table. This result is expected because of the persistence of energy consumption. Thus, the level of renewable energy consumed in previous periods are believed to be carried on to the current period.

Table 5 includes a range of tests to determine how reliable the estimated results are. These are the Wald chi-squared test for variable significance, Sargan's test for testing over-identification and an autocorrelation test. The p-values for the cross-sectional dependence and the CIPS tests over the model residuals are also shown in the table. The large coefficients of the Wald chi-squared test tell us that the variables contribute to the model fit and should not be moved from the model [67]. According to the autocorrelation test, our model satisfies the autocorrelation assumptions for all the models. However, in Table 5, the p-values for the Sargan's test imply rejecting the null at a 5 percent significance level across all models. That indicates that the over-identifying restrictions are not valid, implying that the instrument might not be valid. This implies that some caution should be taken when building on these results. Additionally, the CD test shows that the residuals from all the models are cross-sectional independent. Thus, our results for the global analysis are robust to cross-sectional dependence. The CIPS test tells us that the residuals for all the models are stationary which indicates a good model fit.

4.2. Impacts of banking sector performance by income group

Income differences across countries could play a part in how the banking sectors' performance affects renewable energy consumption. Here on, the sample is divided into three categories of high-, middle- and low-income countries. Based on the World Bank's World Development Indicator, the data is divided into five income categories. For this paper, these categories have been regrouped into three. Upper middle- income countries and lower middle-income countries are compressed into middle income countries. The data also consisted of two income categories for high income countries, one for OECD countries and one for non-OECD. Also, these have been merged together. Table 6 gives a basic overview of the three income categories and presents the number of countries and observations plus the average per capita GDP for each income group.

Looking closer at the results from the econometric estimations for our different income groups, they do exhibit some differences. Table 7 presents the results for the high-income panel. To get stationary variables both market capitalisation and Z-score for financial stability are used in their growth form. When conducting the econometric estimations for the high-income panel, only the variables market capitalisation, asset quality, and managerial inefficiency are significant. Return on asset and financial stability (Z-score) are insignificant. Looking at the significant coefficients, an increase in the growth of market capitalisation by one unit is estimated to increase renewable energy consumption as a share of total energy consumption by about 0.03 percentage points. Asset quality and managerial inefficiency both have a significant negative effect on the share of renewable energy consumption with a one-unit increase leading to a decrease in the dependent variable by 0.1 and 0.08 percentage points respectively. Because, asset quality is defined as the share of total loans which is non-performing, the results imply that the share of energy consumed from renewable sources decreases with a rise in non-performing loans. On the other hand, an improvement in asset quality implies a decrease in the share of non-performing loans, and this is associated with an increase in the share of renewable energy consumption. In the same way, improvement in the management of banks will increase renewable energy consumption as a share of total energy consumption.

Table 8 presents the results for middle-income countries. For the middle-income panel, all banking performance variables except managerial inefficiency significantly increase the share of energy consumption coming from renewable sources. A one-unit increase in return on asset is suggested to increase the share of renewable energy consumption by 0.3 percentage points. A similar increase in market capitalisation and Z-score is associated with an increase in renewable energy

[6] The percentage point change in renewable energy consumption is calculated as: $\%\Delta y = 100^*(e^{\beta_1} - 1)$.

consumption as a share of total energy consumption by 0.18 and 0.14 percentage points respectively. Asset quality is estimated to have a significant positive effect on the share of renewable energy consumption with a one-unit rise leading to an increase by 0.08 percentage points. This result is interesting because, it implies that an increase in non-performing loans would lead to an increase in the share of renewable energy consumption, which is in contrast to what we observed earlier for the global and the high-income panel, where the coefficients for asset quality were negative.

Table 9 presents the results for the low-income panel. The results are similar to that of middle-income panel for all banking performance variables in terms of significance and sign. In Table 9, return on asset increases the share of energy consumption that stems from renewable sources by about 0.1 percentage points when increased by one unit. A marginal increase in market capitalisation is associated with a 0.13 percentage point increase in the share of renewable energy consumption. For asset quality, a marginal rise is estimated to increase the dependent variable by 0.02 percentage points. An increase in Z-score by one unit is predicted to increase renewable energy consumption as a share of total energy consumption by 0.09 percentage points.

The various tests performed on the whole sample in the previous sub-section show some concern regarding the validity of the instruments. However, the subsample analysis based on the three income categories show no such problems. The Sargan's test show that the null hypothesis, which states that the over-identifying restrictions are valid, do hold for all the models across all three panels of high, middle- and low-income counties. Together with the autocorrelation tests, the tests show that the models satisfy the over-identification and autocorrelation assumptions characterising the system General Method of Moments estimation technique. The CD test shows that the residuals across all models in Tables 7, 8 and 9 are cross-sectional dependent. As stated earlier, we are unable to correct the problem of cross-dependence in the residual because of the relatively short time series in our panel dataset. The pooled mean group (PMG) and common correlated effects mean group (CCEMG) estimators which are appropriate in addressing cross-sectional dependence, are dependent on long-run restrictions, requiring long time series for the panel dataset [58–59]. According to the CIPS test, all residuals are stationary and can thus be seen as having a good model of fitness.

4.3. Short- and long run elasticities

Based on the results from Tables 6 to 9, one could easily calculate the short- and long-run elasticities of renewable energy consumption as a response to the banking performance indicators. From equation (12), the relationship between renewable energy consumption and banking performance follows a log-linear function. This implies that the short-run elasticity of renewable energy consumption in response to banking performance is given as;

$$\varepsilon_{RE\_FP} = \gamma_2 {}^{*} FP_{median} \tag{13a}$$

Where ε_{RE_FP} is the short-run elasticity of renewable energy consumption, γ_2 is the coefficient of each banking performance indicator based on results in Tables 6 to 9, and FP_{median} is the median value of each banking performance indicator. The median relative to the mean value is considered to control for possible outliers within the sample. Based on the coefficient of the lagged dependent variable (that is, $\ln RE_{it-1}$) in equation (12) (that is, λ) and the short-run elasticity (that is, ε_{RE_FP}), we calculate the long-run elasticities based on the expression in equation (13b);

$$L\varepsilon_{RE\_FP} = \frac{\varepsilon_{RE\_FP}}{1-\lambda} \tag{13b}$$

The long-run elasticities have important policy implications. The elasticities are calculated based on the banking performance indicators which portrayed statistically significant result in Tables 6 to 9. The resultant short- and long-run elasticities are shown in Table 10. In absolute terms the long-run elasticities are higher than the short-run elasticities. The signs of the short-run elasticities take on the sign of the results from Tables 6-9. One noticeable observation is that, the long-run elasticities for low-income countries are negative. This is also true for high-income countries in the case of market capitalization which was positive in the short-run. This is because the coefficients of the lagged dependent variable (that is, $\ln RE_{it-1}$) is greater than one. This implies that the renewable energy consumption for low-income countries will diverge from the steady state values in the long-run.

4.4. Renewable consumption types[7]

This sub-section explores the association between banking performance and various renewable energy consumption categories (types). The renewable energy consumption categories considered include; (i) hydroelectricity, (ii) solar, (iii) wind, (iv) biofuel, and (v) geothermal, biomass and other sources. The unit of measurement of these renewable energy consumption sources is exajoules (EJ). Each of the renewable energy consumption type is natural log transformed to deal with outliers. The data on the various renewable energy consumption categories is sourced from BP Statistical Review of World Energy. Out of the 113 countries considered in the earlier part of this study, we obtained data for only 60 countries for the renewable energy category estimation. These countries comprise of 33 OECD and 27 non-OECD countries[8].

The main reason for the disaggregated renewable energy consumption is due to the fact that different renewable energy consumption types may require different financing source. For example, traditional biomass (eg. woods for home cooking) usually does not need loans or investments while the hydro power building may rely on public/government investments and multinational development banks. There are instances where the banking sector provides debt financing to government to undertake hydro power investment. In the case of solar and wind power, funding options are likely to come from the private sector in the form of venture capital, private equity, crowd-funding, and the banking sector in some cases.

In Tables 11a, 11b, 11c., 11d, 11e, we present the results for the pooled sample and restricted sample for OECD countries. All the estimations are based on the system-GMM technique. Our results in Table 11A show that return on asset is positively associated with an increase in biofuel and hydroelectricity consumption for both pooled and OECD samples. In the case of wind energy, whereas return on assets is positively correlated with wind energy consumption for the OECD countries, a negative correlation is observed for the pooled sample. From Table 11B we find a positive association between market capitalization and biofuel consumption for both pooled and OECD samples, and in the case of geothermal, biomass and other sources for only OECD sample. However, we find a negative correlation between market capitalization and hydroelectricity and wind power consumption for the pooled and OECD samples, respectively.

Also, asset quality (that is, share of non-performing loans in total

[7] As stated earlier, there is potential heterogenous effects of banking sector performance across different renewable energy consumption categories. Despite data limitations for most of the countries considered in this study for the time period under consideration, we carried out this sub-section based on the recommendation of one reviewer, which we believe have added value to this paper.

[8] These countries are: Algeria, Argentina, Australia, Austria, Azerbaijan, Bangladesh, Belarus, Belgium, Brazil, Bulgaria, Canada, Chile, China, Colombia, Czech Republic, Denmark, Ecuador, Egypt, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Kazakhstan, Korea, Latvia, Lithuania, Malaysia, Mexico, Morocco, Netherlands, New Zealand, Norway, Pakistan, Peru, Philippines, Poland, Portugal, Romania, Russian, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Thailand, Turkey, Ukraine, United Kingdom, United States, Uzbekistan, Venezuela, Vietnam

loans) has significant negative relationship with hydroelectricity consumption for the pooled and OECD samples. This implies that a higher share of non-performing loans decreases hydroelectricity consumption. Similar relationship is observed for biofuel and solar energy in the case of pooled and OECD samples, respectively (see Table 11C). Nevertheless, we find a positive association between asset quality and solar and geothermal, biomass and other sources in the pooled and OECD samples, respectively. In the case of managerial inefficiency, we find a negative correlation with hydroelectricity consumption for both the pooled and OECD samples (see Table 11D). Similar result is observed for the relationship between managerial inefficiency and wind power consumption for the pooled sample. From Table 11E, our results show that financial stability which is measured by z-score, is positively correlated with biofuel consumption in our OECD sample. However, a negative association between wind power consumption and financial stability is observed for both the pooled and OECD samples.

4.5. Implications

Based on our results, renewable energy consumption, globally and for the three income groups, is significantly affected by majority of the banking performance variables. We have summarised our results from Tables 6 to 9 in Table 12 to ease comparative discussion on the effects of banking performance indicators on renewable energy consumption.

In middle- and low-income counties, return on asset is predicted to have a significant positive effect on the share of renewable energy consumption. The same is true for the global panel but not for high income countries. The positive association between return on asset and renewable energy consumption corroborate the finding by Wu and Broadstock [9]. Return on asset defines the banking sectors profit on its investments. With higher profitability, firms are encouraged to invest in technology-intensive energy like renewable energy. Higher return on asset can also imply a scaling up effect for the banks credit business, stimulating investments in renewable energy. These results are supporting arguments that for consumers, especially in lower income counties, a functioning credit market is essential when securing energy supply. Given the high risk in most middle- and low-income countries, return on investment is mostly higher relative to high-income countries. Coupled with the low access to electrification in middle- and low-income countries compared to high-income countries, the high return on investment is likely to be channelled into the energy sector with higher investment going into renewable energy. In high-income countries, gaining access to energy is associated with investments, which are not proportionate to income for households [68]. This could explain why the effect is insignificant for countries with a higher per capita GDP. The findings support the suggestion that consumers with higher income are not as dependent on access to credit when making decisions regarding energy consumption.

The positive association between market capitalisation and renewable energy consumption insinuates that large banks can enjoy scale advantages that make them more willing to invest in renewable energy technology. Such findings are consistent with Amuakwa-Mensah et al. [14)], where they state that large banks are able to provide leverage for the state when the state is acquiring energy technologies that are the most capital-intensive. They also suggest that actions that promotes incentives for small banks to grow or encourage mergers could be in line with the goals of achieving universal access to modern energy. Also, our result is consistent with the findings of Wu and Broadstock [9].

Asset quality has significant effect on renewable energy consumption across all panels. The coefficients, however, provide opposite signs for high income countries compared to middle- and low-income counties. For the global and the high-income panels, an increase in non-performing loans decreases the share of energy stemming from renewable sources. A poor asset quality reduces growth of the individual bank which constraints the bank from lending. For a non-profitable bank, all else equal, a large part of non-performing loans means that the bank's equity decreases, which in turn makes it more difficult to issue new loans [69]. For the panels of middle- and low-income countries, an increase in non-performing loans does not exhibit the same effect. The sign is instead positive, meaning that an increase in the asset quality variable increases renewable energy consumption. That is, a rise in non-performing loans would increase renewable energy consumption, which is contradictory to the argument of this paper, that is, well-functioning banks are essential for access to credit which in turn is important for the share of renewable energy consumption to grow.

An explanation to this conflicting result could be that the assumptions of perfectly competitive markets and complete information do not hold for middle- and low-income markets, relative to high-income countries. If there is, for example, a lag in the information flow, banks might continue to issue loans in a pace as if the loan performance rate were unchanged. If markets were to develop towards perfect competition, this could imply that the sign of the coefficients for asset quality in the middle- and low-income panels could shift from positive to negative. Another factor, for which renewable energy consumption is not effected negatively by an increase in non-performing loans, could be how cooperation, through bilateral and multilateral relationships had played a crucial role in delivering financial support towards renewable energy projects in e.g. Africa [70] . Our estimations controlled for investments in businesses by investors from other countries through foreign direct investment. But, because much of the multilateral financing is grant funding, this would not be captured in the model, indicating that the estimates could suffer from bias.

In their study on energy efficiency in sub-Saharan Africa, Amuakwa-Mensah et al. [14] argue that poor asset quality reduces the possibility to invest in energy efficient technology and thereby effects energy efficiency negatively. Also, this conclusion contradicts the results found for medium- and low-income counties in this paper, if we assume that renewable energy technology is more energy efficient. Because little is known in the literature, except Amuakwa-Mensah et al. [14], on the specific role for these five variables in relation to energy use, it is difficult to find an explanation to the result for asset quality in middle- and low income countries in the existing literature. This is subject to further research.

Managerial inefficiency, that describes the cost to income ratio, has a significant negative effect on renewable energy consumption for the global and the high-income panels while not being significant for the other two. When banks do not optimise their financial results, it will thus have a negative effect on renewable energy consumption in high income countries. Financial stability is, however, significant for the global-, middle- and low-income panels but not for the high-income panel. For the significant coefficients, financial stability has a positive effect on renewable energy consumption, which implies that more financially stable countries tend to have a larger share of energy consumption from renewable sources than financially non-stable ones. The results for these two variables (managerial inefficiency and financial stability) suggest that the performance of individual banks is important for stimulating renewable energy consumption in high income countries, while it is the general financial condition of the entire bank sector that has a determining role for the share of renewable energy consumption in middle- and low-income countries.

From our elasticity computation, managerial inefficient variable for high-income countries changes from negative in the short-run to positive in the long-run. This implies that, in high-income countries, an increase in banks' cost relative to revenue (that is, risk exposure) will adversely affect long–run support for renewable energy investment following the argument by Wu and Broadstock [9]. In the case of low-income countries, the positive short-run elasticities (especially, return on asset, market capitalization and z-score) turn to negative in the long-run. According to Wu and Broadstock [9], this could be attributed to the fact that, in the long-run, total elimination of constraints such as capital and technical limitations associated with renewable energy development is not possible. As a result, any income-induced energy demand may be biased to an increase in non-renewable (fossil-based) energy sources, hence a relative decrease in renewable energy consumption in future periods.

Given the limitation of data for the renewable energy consumption types, we only summarise the results from the OECD countries sub-sample based on results from Tables 11a, 11b, 11c, 11d, 11e. This is because our data for this part of the analysis includes 33 out of the total of the 38 OECD countries. From Table 13, our results implies that an improvement in banking performance as the potential of enhancing biofuel, hydroelectricity and solar energy consumption among OECD countries. We however find a mixed results for wind power and “geothermal, biomass & others” depending the banking performance indicator.

5. Conclusions

The aim of this paper has been to investigate the association between banking performance and renewable energy consumption, focusing on balance sheet financial performance indicators (that is, return on asset, market capitalisation, asset quality, managerial inefficiency and z-score (financial stability)). We focused on a global panel data of 124 countries and also considered heterogenous effect of the relationship between banking performance and renewable energy consumption based on income-group classification of countries. We applied the two-step system-GMM technique to account for potential serial correlation and endogeneity associated with our dynamic panel model.

We conclude that an improvement in banking performance based on our five banking performance indicators is associated with an increase renewable energy consumption for our global sample. By dividing the data set into three income categories, we detected some differences between the categories in the role that the banking sector has for increasing renewable energy consumption. The results for the middle- and low-income panels largely follow the same pattern while the results for the high-income panel stand out in this study. According to our results, the share of renewable energy consumption in high income countries is significantly and positively affected by an increase in bank size, a low level of non-performing loans and well-managed banks. The share of energy consumption coming from renewable sources in middle- and low-income countries is increased by high return on asset, an increase in bank size and financial stability. However, the study shows that low levels of non-performing loans seem to decrease renewable energy consumption as a share of total energy consumption for middle- and low- income countries.

The heterogenous effect of banking performance on renewable energy consumption across income groups, points to important targeted policy direction based on countries income class with the intention of stimulating growth in renewable energy consumption. Notwithstanding the caution about the interpretation of our results from the global sample as pointed out earlier due to instrumental validity, our result supports the argument that the banking sector plays an important role for renewable energy consumption. As more data become available in the future, research could be extended to re-examine the effect of banking performance on the various types of renewable energy such as solar, wind, hydro and biomass with focus on several countries, especially non-OECD countries. This is because the different sources require varying investment size and have different associated risk level. In addition, the problem of cross-sectional dependence which was observed in the subsample (that is, income group) analysis can be addressed if long time series within a panel data becomes available.

CRediT authorship contribution statement

Franklin Amuakwa-Mensah: Conceptualization, Methodology, Data curation, Writing – original draft, Writing – review & editing, Supervision. **Elin Näsström:** Conceptualization, Methodology, Data curation, Writing – original draft.

Table A1
Countries included in each income group.

High Income Countries	Middle Income Countries	Low Income Countries
Australia	Albania	Bangladesh
Austria	Algeria	Benin
Belgium	Angola*	Burkina Faso
Canada	Argentina	Burundi
Chile	Azerbaijan	Central African Republic
Czech Republic	Belarus	Chad
Denmark	Bolivia	Congo, Dem. Rep.
Equatorial Guinea	Botswana	Eritrea
Estonia	Brazil	Ethiopia*
Finland	Bulgaria	Gambia, The
France	Cabo Verde*	Guinea
Germany	Cameroon	Guinea-Bissau*
Greece	China	Kenya
Hong Kong SAR, China*	Colombia	Liberia
Ireland	Congo, Rep.	Madagascar
Israel	Costa Rica	Malawi
Italy	Cote d’Ivoire*	Mali
Japan	Djibouti*	Mozambique
Korea, Rep.	Dominican Republic	Nepal
Latvia	Ecuador	Niger
Lithuania	Egypt, Arab Rep.	Rwanda
Netherlands	El Salvador	Sierra Leone
New Zealand	Gabon	Tanzania
Norway	Georgia	Togo
Poland	Ghana	Uganda
Portugal	Guatemala	Zimbabwe
Russian Federation*	Hungary	
Singapore	India	
Spain	Indonesia	
Sweden	Jamaica	
Switzerland	Jordan	
United Kingdom	Kazakhstan	
United States	Kyrgyz Republic	
Uruguay	Lesotho	
	Libya	
	Malaysia	
	Mauritania	
	Mauritius	
	Mexico	
	Morocco	
	Namibia	
	Nicaragua	
	Nigeria	
	Pakistan	
	Paraguay	
	Peru	
	Philippines	
	Romania	
	Sao Tome and Principe*	
	Senegal	
	Seychelles*	
	South Africa	
	Sri Lanka	
	Sudan	
	Swaziland	
	Thailand	
	Tunisia	
	Turkey	
	Ukraine	
	Uzbekistan	
	Venezuela, RB	
	Vietnam	
	Zambia	

* Country is excluded due to missing values

Table A2
Correlation matrix.

	lnREC	dlnCOP	dlnGDPPC	dlnCO2	FDI	dTrade	dlnIVA	Institution	Urbanisation	RoA	dMarket Cap	Asset quality	ManIneff	Z-score
lnREC	1.0000													
dlnCOP	−0.0029	1.0000												
dlnGDPPC	−0.0730***	0.1435***	1.0000											
dlnCO2	0.0745***	0.0558**	0.3199***	1.0000										
FDI	−0.1119***	0.0307	0.1243***	0.1251***	1.0000									
dTrade	−0.0229	0.2381***	0.0353	0.0431*	0.0647**	1.0000								
dlnIVA	0.0209	0.1631***	0.0656***	0.0791***	0.1375***	0.2253***	1.0000							
Institution	−0.0657***	−0.0081	−0.0803***	−0.0732***	−0.0490**	0.0428*	−0.0338	1.0000						
Urbanisation	−0.5915***	−0.0130	−0.0569**	−0.1017***	0.0875***	0.0362	−0.0240	0.4186***	1.0000					
RoA	0.1792***	0.0507**	0.0930***	0.0843***	−0.0057	0.0092	−0.0371	−0.1115***	−0.2130***	1.0000				
dMarketCap	0.0009	−0.0136	−0.0200	−0.0232	−0.0130	−0.0127	−0.0210	0.0024	−0.0035	0.1104***	1.0000			
Assetquality	0.0440	0.0089	−0.0750***	−0.0048	−0.0285	0.0163	0.0522*	−0.2681***	−0.2129***	−0.1913***	−0.0024	1.0000		
ManIneff	0.0844***	0.0047	−0.0349	0.0187	−0.0360	0.0384	0.0433*	0.1436***	0.0190	−0.2821***	−0.0478*	0.1640***	1.0000	
Z-score	−0.1170***	0.0035	−0.0389	−0.0242	−0.0351	−0.0072	−0.0033	0.0189	0.1054***	0.0916***	0.1678***	−0.1283***	−0.1833***	1.0000

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A3
Unit root test High Income Countries.

Variable	ADF		Phillips-Perron		CIPS-test
	Inverse logit	Modified inv. chi-squared	Inverse logit	Modified inv. chi-squared	Z(t-bar)
lnREC	−2.9339***	3.9919***	5.3447	−2.4873	−4.542***
lnCOP	−7.9049***	9.0718***	0.1317	−1.8537	22.472
dlnCOP	−21.4626***	33.1584***	−20.5030***	31.4253***	22.472
lnGDPPC	−10.3157***	14.0281***	−3.1438***	4.9933***	−0.786
dlnGDPPC	−13.869***	19.6006***	−7.8516***	9.8631***	−5.767***
lnCO2	−5.3791***	6.4353***	3.1751	−1.2933	−2.100
dlnCO2	−21.6906***	33.5902***	−23.0799***	36.2713***	−10.599***
FDI	−16.2343***	23.8540***	−11.9314***	16.9911***	−7.911***
Trade	−7.1889***	8.4802***	0.9877	−0.7232	0.058
dTrade	−20.7281***	31.8400***	−19.7525***	30.1494***	−5.373***
lnIVA	−6.7197***	8.5667***	0.4190	0.0514	0.860
dlnIVA	−19.2365***	29.1787***	−17.9693***	27.1127***	−8.164***
Institution	−4.499***	6.0511***	−2.7569***	−2.9199[a]	.
Urbanization	−9.7375***	25.2683***	−17.4122***	30.5621***	2.656[a]
RoA	−12.9382***	18.4411***	−6.8065***	9.3312***	−4.539***
MarketCap	−9.5579***	12.2578***	−2.1974**	2.6741***	0.423
dMarketCap	−21.1791***	32.6627***	−22.2453***	34.7125***	−7.990***
Assetquality	−5.0876***	6.6771***	2.0867	−0.4328	.
ManIneff	−13.3428***	19.2964***	−7.5423***	11.0168***	−3.827***
Z-score	−11.0492***	14.7122***	−4.0416***	4.5372***	−1.014
dZ-score	−22.7288***	35.4518***	−24.9997***	39.5799***	−10.946***

*** p < 0.01, ** p < 0.05, * p < 0.1. a indicates that test wasn't stationary at level nor at first difference.

Table A4
Correlation matrix for High Income Countries.

	lnREC	dlnCOP	dlnGDPPC	dlnCO2	FDI	dTrade	dlnIVA	Institution	Urbanisation	RoA	dMarket Cap	Asset quality	ManIneff	dZ-score
lnREC	1.0000													
dlnCOP	−0.0236	1.0000												
dlnGDPPC	−0.1443***	−0.0216	1.0000											
dlnCO2	0.0688	0.0217	−0.1685***	1.0000										
FDI	−0.1607***	0.0449	−0.0519	0.2436***	1.0000									
dTrade	−0.0758	0.2448***	0.1126**	−0.0798*	0.0077	1.0000								
dlnIVA	0.0737	0.3047***	−0.0184	0.1781***	0.0371	0.2238***	1.0000							
Institution	0.2753***	−0.0000	0.2306***	−0.1894***	−0.3604***	0.2875***	0.0426	1.0000						
Urbanisation	−0.2041***	−0.0126	0.3155***	−0.1587***	−0.0603	0.2125***	−0.0082	0.2065***	1.0000					
RoA	0.0221	0.1173**	−0.0649	0.0818*	0.0453	−0.0147	0.0791	−0.0870*	−0.0420	1.0000				
dMarketCap	0.0055	−0.0504	−0.0064	0.0009	−0.0035	−0.0093	−0.0044	0.0024	−0.0027	0.0264	1.0000			
Assetquality	−0.1200**	−0.0499	−0.2478***	−0.0671	−0.0223	0.0015	−0.0109	−0.3195***	−0.0743	−0.2507***	0.0212	1.0000		
ManIneff	0.0252	−0.0299	−0.0469	0.0805*	−0.0726	0.0788*	0.0721	0.2014***	−0.0198	−0.3497***	−0.0877*	0.0771	1.0000	
dZ-score	0.0099	−0.0853*	−0.0131	0.0205	−0.0233	−0.0326	0.0468	0.0065	−0.0027	0.0428	0.8921***	0.1340***	−0.0750	1.0000

*** p < 0.01, ** p < 0.05, * p < 0.1

Table A5
Unit root test Middle Income Countries.

	ADF		Phillips-Perron		CIPS-test
Variable	Inverse logit	Modified inv. chi-squared	Inverse logit	Modified inv. chi-squared	Z(t-bar)
lnREC	−9.0766**	11.0043***	1.7801	−0.3338	−2.729***
lnCOP	−10.5360***	12.1076***	0.1756	−2.4740	29.719
dlnCOP	−28.6065***	44.2543***	−27.3275***	41.9413***	29.719
lnGDPPC	−1.5507*	3.9906***	7.6543	−2.4702	−1.375*
dlnGDPPC	−21.5225***	31.6228***	−16.6592***	24.1594***	−8.825***
lnCO2	−9.3299***	11.9133***	1.1319	1.1819	−2.819***
FDI	−17.7817***	24.9778***	−10.1066***	13.565***	−6.843***
Trade	−11.1476***	13.8172***	0.7498	1.1042	0.428
dTrade	−26.2843***	40.0972***	−24.8415***	37.7766***	−8.510***
lnIVA	−11.4075***	14.2654***	−1.3667*	2.3856**	0.315
dlnIVA	−25.9844***	39.6005***	−24.7755***	37.9865***	−9.861***
Institution	−9.9605***	13.174***	−4.4688***	4.0503***	10.747[a]
Urbanization	−12.1957***	44.4293***	−39.6645***	64.4086***	6.206
dUrbanisation	−10.9844***	22.8344***	−12.6711***	21.1495***	−2.496***
RoA	−19.6589***	28.5346***	−15.8663***	24.61***	−6.191***
MarketCap	−13.4703***	18.3538***	−3.9406***	6.9922***	.
Assetquality	−13.4549***	18.3992***	−9.9157***	17.2705***	.
ManIneff	−16.7562***	23.4064***	−10.0759***	14.9897***	−6.801***
Z-score	−14.7813***	20.4208***	−5.3465***	8.2387***	.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. a indicates that test wasn't stationary at level nor at first difference.

Table A6
Correlation matrix for Middle Income Countries.

	lnREC	dlnCOP	dlnGDPPC	lnCO2	FDI	dTrade	dlnIVA	Institution	dUrbanisation	RoA	Market Cap	Asset quality	ManIneff	Z-score
lnREC	1.0000													
dlnCOP	0.0061	1.0000												
dlnGDPPC	−0.0774**	0.1209***	1.0000											
lnCO2	−0.7437***	−0.0093	0.0624*	1.0000										
FDI	−0.1209***	0.0291	0.1632***	0.0653*	1.0000									
dTrade	−0.0372	0.3864***	0.0982***	0.0196	0.1323***	1.0000								
dlnIVA	−0.0252	0.2324***	0.0511	0.0111	0.0686*	0.1982***	1.0000							
Institution	0.2369***	−0.0133	−0.0891**	0.0060	−0.0782**	−0.0158	−0.0355	1.0000						
dUrbanisation	0.1597***	−0.0123	0.0042	−0.0340	0.0018	−0.0264	0.0088	0.1148***	1.0000					
RoA	0.0527	0.0395	0.1128***	−0.0250	0.0657*	0.0186	−0.0642*	0.0740**	−0.0290	1.0000				
MarketCap	−0.0353	0.0099	−0.0178	0.0384	0.0485	0.0222	−0.0341	−0.0056	−0.1311***	0.4499***	1.0000			
Assetquality	−0.1075***	0.0211	−0.0997***	0.0067	0.0329	0.0441	0.0378	−0.1968***	−0.0122	−0.3349***	−0.1513***	1.0000		
ManIneff	0.1922***	0.0510	−0.0601*	−0.2085***	−0.0826**	0.0142	0.0460	0.1140***	−0.0501	−0.2388***	−0.0916***	0.1857***	1.0000	
Z-score	0.0029	0.0113	−0.0859**	−0.0388	−0.0363	0.0018	−0.0082	−0.0446	0.0132	0.1548***	0.2999***	−0.0853**	−0.2201***	1.0000

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A7
Unit root test Low Income Countries.

Variable	ADF		Phillips-Perron		CIPS-test
	Inverse logit	Modified inv. chi-squared	Inverse logit	Modified inv. chi-squared	Z(t-bar)
lnREC	−1.9536**	3.7050***	4.1817	−2.5823	0.904
dlnREC	−14.0965***	20.8108***	−11.2593***	16.8349***	−5.756***
lnCOP	−6.8527***	7.8564***	0.1142	−1.6053	19.284
dlnCOP	−18.6059***	28.716***	−17.774***	27.2151***	19.284
lnGDPPC	−3.2632***	4.499***	3.3289	−1.3649	1.246
dlnGDPPC	−16.1653***	24.3818***	−15.0868***	23.0471***	−7.817***
lnCO2	−5.3350***	5.8111***	1.9181	−1.9614	1.825
dlnCO2	−15.7728***	23.6604***	−14.0559***	21.0652***	−7.237***
FDI	−10.9688***	16.2351***	−8.7702***	13.1081***	−3.490***
Trade	−6.8413***	8.6495***	−0.1032	1.2988*	−0.567
dTrade	−19.1497***	29.7100***	−21.5281***	34.0976***	−9.794***
lnIVA	−9.3896***	12.5393***	−3.5418***	4.7133***	.
Institution	−6.7676***	8.2822***	−0.9882	0.4195	3.720[a]
Urbanization	35.6307	−0.2974	−8.9529***	3.1079***	3.331[a]
RoA	−11.1066***	15.3789***	−5.7620***	7.1854***	.
MarketCap	−9.4166***	12.6608***	−3.7416***	5.2403***	.
Assetquality	−6.7612***	8.4497***	−1.3383*	1.7586**	.
ManIneff	−10.6064***	14.6273 ***	−5.4966***	7.2635***	.
Z-score	−9.4749***	12.8024***	−3.8390***	5.3485***	.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. a indicates that test wasn't stationary at level nor at first difference.

Table A8
Correlation matrix for Low Income Countries.

	lnREC	dlnCOP	dlnGDPPC	dlnCO2	FDI	dTrade	lnIVA	Institution	Urbanisation	RoA	Market Cap	Asset quality	ManIneff	Z-score
lnREC	1.0000													
dlnCOP	0.0243	1.0000												
dlnGDPPC	0.0300	−0.0174	1.0000											
dlnCO2	−0.0810	0.0518	0.2623***	1.0000										
FDI	0.1041*	0.0202	−0.0577	0.1053*	1.0000									
dTrade	0.0160	0.1033*	0.0636	0.1218*	0.0770	1.0000								
lnIVA	−0.1592***	0.0373	0.0537	0.0318	−0.3281***	0.0092	1.0000							
Institution	0.0048	−0.0063	0.1380**	0.0538	0.0336	0.0085	−0.0435	1.0000						
Urbanisation	−0.3962***	−0.0309	−0.0592	0.0429	0.2933***	0.0339	−0.1285**	0.0088	1.0000					
RoA	0.0585	0.0333	−0.0968*	0.0001	−0.0771	0.0462	−0.0311	−0.1665***	−0.0180	1.0000				
MarketCap	0.1565***	0.0124	−0.0527	−0.1031*	0.0236	−0.0410	−0.0816	−0.0069	0.1248**	0.1530***	1.0000			
Assetquality	−0.1134*	0.0702	−0.0915	−0.0372	−0.0583	0.0252	−0.2392***	−0.0326	0.1052	−0.1030	−0.2248***	1.0000		
ManIneff	−0.0224	−0.0308	0.1197**	0.0112	0.0854	0.0089	0.0848	0.2568***	0.2141***	−0.4196***	−0.0068	0.2205***	1.0000	
Z-score	0.1379**	−0.0027	−0.0297	−0.0198	−0.0908*	−0.0154	−0.0780	0.2409***	−0.4101***	0.1595	0.4322***	−0.2967***	−0.2446***	1.0000

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors sincerely thank the Editor-in-Chief and the three anonymous reviewers for their valuable comments and suggestions.

Appendix

See Table A1-A8.

References

[1] Moomaw W, Yamba F, Kamimoto M, Maurice L, Nyboer J, Urama K, et al. Renewable Energy and Climate Change. Renewable Energy and Climate Change. 2011;48.
[2] International Energy Agency. Renewables 2018 [Internet]. International Energy Agency; 2018. Available from: https://www.oecd-ilibrary.org/content/publication/re_mar-2018-en.
[3] Sustainable Development Scenario [Internet]. International Energy Agency. 2019 [cited 2019 Apr 29]. Available from: https://www.iea.org/weo/weomodel/sds/.
[4] Sadorsky P. Renewable energy consumption, CO2 emissions and oil prices in the G7 countries. Energy Econ 2009 May;31(3):456–62.
[5] McCrone A, Moslener U, Estais F, Grüning C. Global Trends in Renewable Energy Investment Report 2018 [Internet]. UN Environment's Economy Division, Frankfurt School-UNEP Collaborating Centre for Climate & Sustainable Energy Finance, and Bloomberg New Energy. Finance 2018 [cited 2019 May 10]. Available from: http://www.greengrowthknowledge.org/sites/default/files/downloads/resource/Global_Trends_in_Renewable_Energy_Investment_Report_2018.pdf.
[6] Henbest S, Giannakopoulou E, Kimmel M. New Energy Outlook 2018 [Internet]. BloombergNEF 2018 [cited 2019 May 10]. Available from: https://bnef.turtl.co/story/neo2018.
[7] International Energy agency. World Energy Outlook 2018. 2018;661.
[8] Lucas H, Ferroukhi R, Hawila D. Renewable Energy Auctions in Developing Countries. 2013:52.
[9] Wu L, Broadstock DC. Does economic, financial and institutional development matter for renewable energy consumption? Evidence from emerging economies. IJEPEE [Internet]. 2015 [cited 2021 May 26];8(1):20. Available from: http://www.inderscience.com/link.php?id=68246.
[10] Andrianova S, Baltagi B, Beck T, Demetriades P, Fielding D, Hall S, et al. A new international database on financial fragility [Internet]. Leicester, UK: Department of Economics, University of Leicester; 2015. Report No.: 15/18. Available from: http://www.le.ac.uk/economics/research/RePEc/lec/leecon/dp15-18.pdf?uol_r=d307e306.
[11] Anton SG, Afloarei Nucu AE. The effect of financial development on renewable energy consumption. A panel data approach. Renewable Energy [Internet]. 2020 Mar 1 [cited 2021 May 26];147:330–8. Available from: https://www.sciencedirect.com/science/article/pii/S0960148119313357.
[12] Eren BM, Taspinar N, Gokmenoglu KK. The impact of financial development and economic growth on renewable energy consumption: Empirical analysis of India. Science of The Total Environment [Internet]. 2019 May 1 [cited 2021 May 26]; 663:189–97. Available from: https://www.sciencedirect.com/science/article/pii/S0048969719303729.
[13] Wang J, Zhang S, Zhang Q. The relationship of renewable energy consumption to financial development and economic growth in China. Renewable Energy [Internet]. 2021 Jun 1 [cited 2021 May 26];170:897–904. Available from: https://www.sciencedirect.com/science/article/pii/S0960148121002068.
[14] Amuakwa-Mensah F, Klege RA, Adom PK, Amoah A, Hagan E. Unveiling the energy saving role of banking performance in Sub-Sahara Africa. Energy Econ 2018;1(74): 828–42.
[15] Tamazian A, Chousa JP, Vadlamannati KC. Does higher economic and financial development lead to environmental degradation: Evidence from BRIC countries. Available from Energy Policy [Internet]. 2009;37(1):246–53. http://www.sciencedirect.com/science/article/pii/S0301421508005065.
[16] Sadorsky P. Renewable energy consumption and income in emerging economies. Energy Policy. 2009;37(10):4021–8.
[17] Menyah K, Wolde-Rufael Y. CO 2 emissions, nuclear energy, renewable energy and economic growth in the US. Energy Policy. 2010;38(6):2911–5.
[18] Apergis N, Payne JE. Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. Energy Policy. 2010 01;38(1):656–60.
[19] Menegaki AN. Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis. Energy Econ 2011;33(2):257–63.
[20] Destek MA, Aslan A. Renewable and non-renewable energy consumption and economic growth in emerging economies: Evidence from bootstrap panel causality. Renewable Energy 2017;10(111):757–63.
[21] Kraft J, Kraft A. On the Relationship Between Energy and GNP. The Journal of Energy and Development. 1978;3(2):401–3.
[22] Akinlo AE. Energy consumption and economic growth: Evidence from 11 Sub-Sahara African countries. Energy Economics. 2008 09;30(5):2391–400.
[23] Bartleet M, Gounder R. Energy consumption and economic growth in New Zealand: Results of trivariate and multivariate models. Energy Policy. 2010;38(7):3508–17.
[24] Ozturk I, Aslan A, Kalyoncu H. Energy consumption and economic growth relationship: Evidence from panel data for low and middle income countries. Energy Policy. 2010 08;38(8):4422–8.
[25] Arouri MEH, Ben Youssef A, M'Henni H, Rault C. Energy consumption, economic growth and CO2 emissions in Middle East and North African countries. Energy Policy. 2012;45(C):342–9.
[26] Karanfil F, Li Y. Electricity consumption and economic growth: Exploring panel-specific differences. Energy Policy. 2015;07(82):264–77.
[27] Bhattacharya M, Paramati SR, Ozturk I, Bhattacharya S. The effect of renewable energy consumption on economic growth: Evidence from top 38 countries. Appl Energy 2016;162:733–41.
[28] Sadorsky P. The impact of financial development on energy consumption in emerging economies. Energy Policy. 2010;38(5):2528–35.
[29] Shahbaz M, Lean HH. Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia. Available from Energy Policy [Internet]. 2012 Jan;1(40):473–9. http://www.sciencedirect.com/science/article/pii/S0301421511008652.
[30] Islam F, Shahbaz M, Ahmed AU, Alam MM. Financial development and energy consumption nexus in Malaysia: A multivariate time series analysis. Available from: Economic Modelling [Internet]. 2013 Jan;1(30):435–41. http://www.sciencedirect.com/science/article/pii/S0264999312003082.
[31] Komal R, Abbas F. Linking financial development, economic growth and energy consumption in Pakistan. Available from Renewable and Sustainable Energy Reviews [Internet]. 2015;1(44):211–20. http://www.sciencedirect.com/science/article/pii/S1364032114010673.
[32] Kakar ZK. Financial development and energy consumption: Evidence from Pakistan and Malaysia. Energy Sources, Part B: Economics, Planning, and Policy [Internet]. 2016 Sep 1;11(9):868–73. Available from: https://doi.org/10.1080/15567249.2011.603020.
[33] Payne JE. Survey of the international evidence on the causal relationship between energy consumption and growth. Journal of Economic Studies. 2010;37(1):53–95.
[34] Destek MA, Aslan A. Renewable and non-renewable energy consumption and economic growth in emerging economies: Evidence from bootstrap panel causality. Renewable Energy 2017;111:757–63.
[35] Karanfil F. How many times again will we examine the energy-income nexus using a limited range of traditional econometric tools?. Available from Energy Policy [Internet]. 2009;37(4):1191–4. http://www.sciencedirect.com/science/article/pii/S0301421508007192.
[36] Islam F, Shahbaz M, Ahmed AU, Alam MM. Financial development and energy consumption nexus in Malaysia: A multivariate time series analysis. Econ Model 2013;30:435–41.
[37] Kakar ZK. Financial development and energy consumption: Evidence from Pakistan and Malaysia. Energy Sources Part B 2016;11(9):868–73.
[38] Sadorsky P. Financial development and energy consumption in Central and Eastern European frontier economies. Energy Policy. 2011;39(2):999–1006.
[39] Apergis N, Payne JE. Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. Energy Policy. 2010;38(1):656–60.
[40] Bölük G, Mert M. The renewable energy, growth and environmental Kuznets curve in Turkey: An ARDL approach. Renew Sustain Energy Rev 2015;52:587–95.
[41] Adewuyi AO, Awodumi OB. Renewable and non-renewable energy-growth-emissions linkages: Review of emerging trends with policy implications. Renew Sustain Energy Rev 2017;69:275–91.
[42] Mehrara M, Rezaei S, Razi DH. Determinants of Renewable Energy Consumption among ECO Countries; Based on Bayesian Model Averaging and Weighted-Average Least Square. International Letters of Social and Humanistic Sciences. 2015;06(54): 96–109.
[43] Omri A, Nguyen DK. On the determinants of renewable energy consumption: International evidence. Energy. 2014;72:554–60.
[44] Paramati SR, Ummalla M, Apergis N. The effect of foreign direct investment and stock market growth on clean energy use across a panel of emerging market economies. Energy Economics [Internet]. 2016 [cited 2016 May 13];56:29–41. Available from: http://www.sciencedirect.com/science/article/pii/S0140988316300214.
[45] Dogan E, Seker F. The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. Renew Sustain Energy Rev 2016;07(60):1074–85.
[46] Kutan AM, Paramati SR, Ummalla M, Zakari A. Financing Renewable Energy Projects in Major Emerging Market Economies: Evidence in the Perspective of Sustainable Economic Development. Emerging Markets Finance and Trade [Internet]. 2018 Jun 21 [cited 2021 May 30];54(8):1761–77. Available from: https://doi.org/10.1080/1540496X.2017.1363036.
[47] Sweerts B, Longa FD, van der Zwaan B. Financial de-risking to unlock Africa's renewable energy potential. Renewable and Sustainable Energy Reviews [Internet]. 2019 Mar 1 [cited 2021 May 30];102:75–82. Available from: https://www.sciencedirect.com/science/article/pii/S1364032118307925.
[48] Adom PK, Amuakwa-Mensah F. What drives the energy saving role of FDI and industrialization in East Africa?. Available from Renewable and Sustainable Energy Reviews [Internet]. 2016;1(65):925–42. http://www.sciencedirect.com/science/article/pii/S136403211630363X.
[49] Kumbhakar SC, Mavrotas G. Financial Sector Development and Total Factor Productivity Growth. In: Guha-Khasnobis B, Mavrotas G, editors. Financial Development, Institutions, Growth and Poverty Reduction [Internet]. London:

Palgrave Macmillan UK; 2008 [cited 2021 Jun 3]. p. 231–59. (Studies in Development Economics and Policy). Available from: https://doi.org/10.1057/9780230594029_11.

[50] Han J, Shen Y. Financial Development and Total Factor Productivity Growth: Evidence from China. Emerging Markets Finance and Trade [Internet]. 2015 Jan 30 [cited 2021 Jun 3];51(sup1):S261–74. Available from: https://doi.org/10.1080/1540496X.2014.998928.

[51] Aguirre M, Ibikunle G. Determinants of renewable energy growth: A global sample analysis. Energy Policy. 2014;69:374–84.

[52] Claessens S, Feyen E. Financial Sector Development and the Millennium Development Goals [Internet]. Rochester, NY: Social Science Research Network; 2007 Jan [cited 2021 May 30]. Report No.: ID 950269. Available from: https://papers.ssrn.com/abstract=950269.

[53] Omri A, Kahouli B. Causal relationships between energy consumption, foreign direct investment and economic growth: Fresh evidence from dynamic simultaneous-equations models. Available from Energy Policy [Internet]. 2014;1(67):913–22. http://www.sciencedirect.com/science/article/pii/S030142151301197X.

[54] Arellano M, Bond S. Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. Review of Economic Studies [Internet]. 1991 Jan 4 [cited 2016 Oct 1];58(2):277–97. Available from: http://restud.oxfordjournals.org/content/58/2/277.

[55] Blundell R, Bond S. Initial conditions and moment restrictions in dynamic panel data models. J Econ 1998;29.

[56] Çoban S, Topcu M. The nexus between financial development and energy consumption in the EU: A dynamic panel data analysis. Energy Econ 2013;39:81–8.

[57] Sadorsky P. Do urbanization and industrialization affect energy intensity in developing countries? Energy Econ 2013;37:52–9.

[58] Pesaran MH. Estimation and Inference in Large Heterogeneous Panels with a Multifactor Error Structure. Econometrica [Internet]. 2006 [cited 2021 Jun 1];74(4):967–1012. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1468-0262.2006.00692.x.

[59] Pesaran MH, Shin Y, Smith RP. Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. Journal of the American Statistical Association [Internet]. 1999 [cited 2021 Jun 1];94(446):621–34. Available from: https://www.jstor.org/stable/2670182.

[60] Marshall MG. POLITY IV PROJECT: Dataset Users' Manual. 2018 Oct;24:86.

[61] Li K, Lin B. Impacts of urbanization and industrialization on energy consumption/CO2 emissions: Does the level of development matter? Renew Sustain Energy Rev 2015;52:1107–22.

[62] Pesaran MH. A simple panel unit root test in the presence of cross-section dependence. J Appl Econ 2007;22(2):265–312.

[63] Banerjee A, Marcellino M, Osbat C. Some cautions on the use of panel methods for integrated series of macroeconomic data. Econ J 2004;7(2):322–40.

[64] Pesaran MH. Time Series and Panel Data Econometrics [Internet]. Oxford University Press; 2015 [cited 2019 May 9]. Available from: http://www.oxfordscholarship.com/view/10.1093/acprof:oso/9780198736912.001.0001/acprof-9780198736912.

[65] De Hoyos RE, Sarafidis V. Testing for Cross-Sectional Dependence in Panel-Data Models. The Stata Journal: Promoting communications on statistics and Stata. 2006 11;6(4):482–96.

[66] Sarafidis V, Wansbeek T. Cross-Sectional Dependence in Panel Data Analysis. Econ Rev 2012;31(5):483–531.

[67] Agresti A. Categorical Data Analysis [Internet]. Somerset, UNITED STATES: John Wiley & Sons, Incorporated; 2012 [cited 2019 Apr 26]. Available from: http://ebookcentral.proquest.com/lib/uu/detail.action?docID=1168529.

[68] Fowlie M, Khaitan Y, Wolfram C, Wolfson D. Solar Microgrids and Remote Energy Access: How Weak Incentives Can Undermine Smart Technology. Economics of Energy & Environmental Policy [Internet]. 2019 Jan 1 [cited 2019 May 15];8(1). Available from: http://www.iaee.org/en/publications/eeeparticle.aspx?id=254.

[69] Fredriksson O, Frykström N. "Bad loans" and their effects on banks and financial stability [Internet]. Sveriges riksbank; 2019 03-14 p. 15. (Economic Commentary). Available from: https://www.riksbank.se/globalassets/media/rapporter/ekonomiska-kommentarer/engelska/2019/bad-loans-and-their-effects-on-banks-and-financial-stability.pdf.

[70] Kaluba DC. Financing Renewable Energy in Africa in the SDG Era [Internet]. Geneva, Switzerland: International Centre for Trade and Sustainable Development; 2018 Apr [cited 2019 Jun 5]. (BRIDGES AFRICA -Trade and Sustainable Development News and Analysis on Africa). Report No.: Volume 7-No 3. Available from: https://www.ictsd.org/bridges-news/bridges-africa/news/financing-renewable-energy-in-africa-in-the-sdg-era.