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Assessing the public funding's impact on renewable energy: Evidence from developing countries

Ahmed Jabbar Ghazi *

Department of Construction and Projects, University of Kufa.

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Abstract

In this study, the authors examine the impact of public funding of renewable energy technologies in 36 developing countries between 2000 and 2020. Using panel cointegration approach, research explains the long-term relationship between the relevant variables. This study applies a pooled mean group-panel autoregressive distributive lag (PMG-ARDL) method and confirms a significant link between uses of renewable energy per capita, public flow and income per capita. It highlights the impact of public financial flows on renewable energy in developing countries. The study nevertheless urges a comprehensive approach, especially emphasis on the availability of effective measures in the financial instrument development and in the process of creating public-private partnerships in the energy renewables market. Governments are encouraged to focus on efficiency, transparency and responsiveness and to adapt their strategies to the specific situation in each country to ensure effective implementation.

Keywords: Financial Incentives; Renewable Energy Consumption; Government Effectiveness; Behavioral Economics; PMG-ARDL; Developing Countries

1. Introduction

The growing worries about the degradation of the environment have made it more and more important for the adoption of renewable energy (RE) technologies. Certain groups are more vulnerable and suffer more from increased impacts of climate change. This situation is exacerbated by the rapid needs for energy increase and the economic activities that drive both this demand and significant rise in the global average temperature by 1°C since 1900s (Oluc et al., 2023). Combined with economic growth and population expansion, GHG emissions have become skyrocketing in this century, creating challenges of immense proportions for the world. To address this, countries have introduced new financing tools and provided new adaptation support funds to help developing countries adapt to the consequences of climate change losses (Hasni et al., 2023).

The focus of COP talks is shifting towards access to renewable energy (RE) and funding allocation, especially in developing countries with limited financial capacity and underdeveloped financial markets (Oluc et al., 2022). Financial mobilisation, technology, and growth opportunities to truly reduce CO2 emissions emerged as a strong focus point in COP28. During the COP26, it was pointed out that RE plays a central role on the global agenda for sustainability, in this case, by reducing CO2 emissions by introducing more Renewable Energy Certificates. Furthermore, COP27 focused on financing for renewable energy projects and the critical importance of green finance in expediting their implementation. The financial sector is a transformative influence whose growth is subject of a vast and comprehensive study on CO2 control governance, and it is crucial for the attainment of the COP27 aims (Hasni et al., 2023).

* Corresponding author: Ahmed Jabbar Ghazi

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Just over USD 5 trillion in annual investments is necessary to get on track with the 1.5C temperature target, a massive increase from the existing level, according to a report from IRENA released in March 2023. As we approach COPs and other forums where commitments have been made, we have a pressing question: How do we bring these commitments from the ideals into the realities of green finance, and make them effective strategies for scaling up renewable energy?

Sustainable development is defined by the UN Brundtland Commission, who state that it is defined as meeting the needs of the present generation without preventing future generations from meeting their needs. One of the key stepping stones to this delicate balance is the escalating shift toward a renewable energy source. By increasing priority and investment in renewable energy activities, nations can hasten their deployment, achieve sustainable economic growth, and reach a more environmentally sustainable energy system. It is noted that unless there is monetary funding environmental improvement is impossible, in the event that anything unusual occurs (Curley, 2014).

Antonio et al. (2017) assert that climate funding serves as a potent political tool for addressing global warming and fostering green growth in developing nations. Environmental finance, particularly in energy efficiency and renewable energy, is positioned to serve as a bridge to other sub-sectors within the financial domain, such as microfinance, housing finance, or agricultural finance (Doris, 2012).

Green finance is therefore a key area that has enabled the deployment of renewable energy (Lowitzsch, 2019; Santosh and Seabron, 2020) and, ultimately, helped to tackle GHG emissions (Bourcet and Bovari, 2020; Jinlan and Wang, 2023; Mingxiang and Xing, 2022; Polzin and Sanders, 2020). Although much research has been conducted on factors affecting renewable energy, little work has been done on the influence of green finance in renewable energy. The amount of money being poured into renewable generation efforts to support developing economies in their efforts to reduce carbon emissions has turned toward mitigation projects, and data is readily available. It is expected that this trend will lead to an increased study and understanding of the linkage between green finance and renewable energy in the developing economies.

The scholarship of green finance includes a variety of topics in the field of sustainable finance and investment. Different components of green finance are pointed out as tools fostering sustainable development, especially by investing in clean energy. An illustration of this is that some of the objectives of environmentally friendly projects have been raised using green bonds and, as a result of these projects, the economic landscape has been improved, including CO2 emissions reduction, efficiency of resource usage (Xinkuo and Jingsi, 2023; Rasoulinezhad and Taghizadeh-Hesary, 2022; Chen and Chen, 2021; Ye and Ehsan, 2023). Green banking, including the aspects of environment and social issues, depends on practices such as green lending and environmental risk management and plays a role in the sustainable economy, in terms of evolution and trends (OECD, 2018). Financial institutions have been key to advancing green recovery, especially in emerging markets, and have helped realise Sustainable Development Goals (SDGs) (Chen and Chen, 2021, Chen et al., 2022). Governments are encouraged to enable the re-direction of financial flows to environmentally sustainable activities, thus supporting the transition towards a low carbon economy and building a regulatory environment that 'supports environmental sustainability.' But the effectiveness of the government intervention in this field is still subject of questions when it comes to green financing to promote the use of renewable energy.

The role of incentives in inducing sustainable and environmentally friendly behaviour is key, as outlined by the Behavioural Economics Theory (BET). It emphasizes the psychological effect on attractiveness and what drives adoption - how financial incentives shape preference for cleaner energy options. Although the use of renewable energy finance as a solution to environmental problems has grown very recently, there is still a lack of literature on the implications of green finance projects on renewable energy in developing nations. In this context, this study plays a role in understanding how well public flows can encourage the adoption of renewable energy in developing economies. The objectives of this current research are to analyze the effect of public funding on the utilization of renewable energy in developing countries. It aims to explore (ii) the effect of financial support and investment on green activities on the consumption of renewable energy, and (iii) the effect of income and effectiveness of government governance in the relationship between green finance and renewable energy consumption; to see if there are other control variables that would affect the examined relationship.

These objectives contribute to the existing literature on the renewable energy finance approach and provide valuable insights for policymakers in promoting sustainable energy practices.

The rest of this study is organized as follows. Section 2 includes the review of related research, including theoretical framework and hypothesis. Section 3 discusses the results as well as various econometric tools. Section 4 provides policy recommendations, addresses limitations, outlines future research, and concludes the study.

2. Literature Review

2.1. Empirical Literature

The recent literature regarding the green transition has highlighted the importance of green finance to achieve the SDGs. However, various methods have been employed to examine the relationship between GF and RE, leading to meaningful findings. Table 1 summarizes the main studies conducted to date. The relative importance of these findings varies depending on the context, country, and sample being studied. The relevant studies have significant implications.

Table 1 Summary of empirical studies

Study	Sample	Period	Methods	Findings
Buhari et al. (2023)	US	2014M8-2021M2	Granger causality test Cross antigram Quantile coherency	Findings emphasize the significance of green bonds as a haven asset in times of uncertainty.
Buhai et al. (2020)	32 European countries	1995–2014	Panel quantile Regression	The findings demonstrate that economic complexity, REC, trade openness, FDI, and institutional quality promote economic growth. Furthermore, REC promotes economic growth more effectively than the adoption of non-renewable energy.
Chen and Chen (2021)	30 Chinese provinces	2005-2018	Spatial dynamic model (OLS, GMM, Static SDM and dynamic SDM)	The development of green finance decreased carbon emissions by reducing financing constraints and boosting green technology innovation.
Chen et al. (2022)	67 to 93 banks of six members of the GCC	2011-2021	Fixed effect regressions	The impact of green financing is more profound for smaller banks indicating that responsible lending provides them with new earning avenues while mitigating the risk.
Chu et al. (2023)	E7 countries	1995-2018	PMG-ARDL	The results showed a long-term connection between economic complexity, Economic Policy Uncertainty, geopolitical risk, energy use, and two environmental quality measures, carbon dioxide emissions and ecological footprint.
James et al. (2023)	25 top energy use countries	1990-2015	Panel quantile regression approach	The findings show that a rise in economic complexity improves energy efficiency by reducing energy intensity and carbon intensity.
Jinlan and Chunyu (2023)	China	2000-2020	Wavelet power spectrum	There is a unidirectional causal link from GDP to Investment in RE and Investment in RE to GF as well as a bidirectional substantial correlation between Investment in RE and Renewable Electric Output.
Hasni et al., (2023)	18 APEC economies	2000-2019	PMG-ARDL Granger causality test	Long-term analysis reveals that economic growth and renewable energy increase carbon emissions, while financial development, ZS, and CC mitigate them; however, a

				bidirectional causality exists between REC and financial development.
Khan et al. (2022)	63 countries (5 regions)	2007-2021	Dumutriscu_Hurlin test causality and panel EGLS	The findings show that increasing renewable energy production, R&D, and the evolution of public-private partnership investment in renewable energy reduce CO2 emissions.
Mingxiang and Xing (2022)	China	1986-2019	ARDL approach	Green finance and renewable energy sources have a positive impact on sustainable development and a negative impact on carbon emissions
Rasoulinezhad, and Taghizadeh-Hesary (2022)	Top 10 economies using green finance	2002-2018	GMM, Granger test causality, FMOLS and CEMG	The findings indicated that green bonds promoted green energy projects and significantly reduced CO2 emissions.
Sreenu (2022)	28 states and 8 union territories in India	2010-2020	Semi-parametric difference-in-differences	Results show that in general India's green policies and related green finance have significantly reduced industrial CO2 emissions.
Ye and Ehsan (2023)	15 selected Asia-Pacific countries	2012-2021	FMOLS	Green bonds have a positive and statistically significant impact on the efficiency of renewable natural resource use in the short and long term.

Given the empirical literature's interest in testing financial instruments on CO2 emissions and financing projects to contribute to climate change, there is a shortage of studies on the impacts of green finance on renewable energy as a main strategy and tool to reduce CO2 emissions. According to Chen and Chen (2021), in the Chinese case, the development of green finance has reduced carbon emissions by reducing financing constraints and boosting green technology innovation. Mingxiang and Xing (2022) found that green finance and renewable energy sources have a positive impact on sustainable development but a negative impact on carbon emissions. It has been suggested that green finance for renewable energy sources is required to achieve environmental sustainability (Khan et al., 2022). Jinlan and Chunyu (2023) investigated the causal relationship between the investment in renewable energy (IRE) and green finance and discovered that it is unidirectional from IRE to GF in both the short and long term. The finding implies that real factors such as energy demand, technology, and infrastructure drive financial factors to develop the renewable energy sector. Otherwise, IRE attracts green finance by creating financing opportunities and developing new financial products and instruments. Accordingly, the scale of demand for energy transition has encouraged financial markets to develop products and services to channel investment (Ian, 2021). Yet another financial instrument that has been the subject of empirical research is green bonds, which promote green resource consumption efficiency (Ye and Ihsan, 2023). Furthermore, Xu and Li (2023) investigated the role of green innovation in the carbon mitigation effect and discovered that environmental regulation strengthens green bonds' inhibitory effect on city carbon emissions. Hasni et al., (2023) show that financial development is critical which leads to a decrease in carbon emissions, and find a bidirectional causality between financial development and CO2 emissions.

The recent literature has emphasized the importance of green finance promoting the green transition (Bourcet & Bovari, 2020; Polzin & Sanders, 2020; Jinlan & Chunyu, 2023; Mingxiang and Xing, 2022; Rasoulinezhad and Taghizadeh-Hesary, 2022; Sreenu, 2022; Ye and Ehsan, 2023). It has provided evidence regarding its finance instruments such as green bonds (Xinkuo and Jingsi, 2023; Buhari et al., 2023), green loans, and green investments (Chen &Chen, 2021; Chen et al.,2022, Khan et al., 2022). Additionally, recent studies have concentrated on economic complexity to gain deeper insights into the Sustainable Development Goals (SDGs) and their interconnected mechanisms (Buhai et al., 2020; Chu et al., 2023; James et al., 2023). The ability to diversify their industrial bases and drive sustainable development is a benefit of economic complexity for countries looking to use RE sources. The reliance on China's sample in the reviewed studies limits the generalizability of the findings to other countries and regions. Exploring the role of green finance in these contexts can shed light on effective strategies for supporting renewable energy deployment and green transition in developing countries.

There is a large literature on renewable energy; covering various aspects such as its drivers, consequences, and policy implications (Chen et al., 2020; Hu et al., 2022; Lv et al., 2022; Sidney et al., 2021, etc). Several factors influencing the consumption of renewable energy have already been studied and evaluated in the literature providing valuable insights into the drivers, barriers, and policy options for promoting renewable energy consumption (Akar, 2016; Han et al., 2022; Ilechukwu and Lahiri, 2022). Other factors, such as income per capita and Government effectiveness, have been examined in previous research as potential variables influencing renewable energy (Sadorsky, 2009; Sidney et al., 2021; Yahia and Rafik, 2019). These variables are taken into account to assess the relationship between green finance and renewable energy, which is the focus of this study.

The present research investigates the relationship between green finance initiatives and the use of renewable power, shedding light on the mechanisms underlying renewable energy finance and guiding the design of policies that better target SDGs. Before delving into the empirical investigation, this study undoubtedly examined the related theories and approaches that aid in understanding renewable energy finance relationships.

2.2. Theoretical Approaches and Research Hypotheses

The Environmental Kuznets Curve (EKC) theory has been the focus of the majority of academic studies in the field of environmental economics which state that there is a threshold after which environmental degradation decreases as the economy grows (Burcu and Ilhan, 2019; Bhattacharya, 2019; Recep et al., 2019, etc.). Environmental concerns may be less important than growth and development in nations that are developing economically. The relationship between the EKC theory and renewable energy (RE) uptake is complex, and financing the green transition is difficult for a nation seeking sustainability goals. As a result, the idea of renewable energy financing has been gaining momentum as a means of understanding the dynamics of renewable energy deployment (Lowitzsch, 2019). Money's role extends beyond its conventional functions, serving as a financing instrument through appropriate mechanisms aligned with Sustainable Development Goals (SDGs).

Curley (2014) defined environmental finance as "creating the greatest environmental benefit (good) for the greatest number of people at the lowest possible cost". Moreover, the literature has raised the role of financial development (FD) in understanding renewable energy finance (Doris, 2012; Antonio et al., 2017 and Holstenkamp, 2019). As per Hasni et al. (2023), FD's environmental effects are twofold: It funds emission tech but may boost pollution via manufacturing. Indirectly, it affects energy, income, industry, tech, investment, and usage future. While FD's importance lies in reflecting a country's financial capacity for advancing the RE sector, its effects are primarily indirect. Utilizing green finance tools and initiatives could enhance the understanding of the relationship between green finance and RE. The financial approaches refer to financial principles, instruments, and mechanisms that promote investment in environmentally friendly and sustainable projects including renewable sources (Lowitzsch, 2019; Lowitzsch and Hanke, 2019; Holstenkamp 2019; Santosh and Seabron, 2019; Curley, 2014).

Lopes et al., (2020) and Mundaca et al., (2020) examine CO2 reduction in developed nations, exploring diverse energy demand methods, and analyzing it through various perspectives like individual involvement and system adaptation. They highlight the sociotechnical complexity but point out the limited focus on incentives, stressing the potential to influence energy behavior at both individual and societal levels. In contrast, Camara et al., (2017) introduce behavioral economics as a means to designing effective energy conservation strategies that can be implemented with incentives and design, and to addressing how better understanding of behavioral economics could greatly impact on energy savings and improve energy conservation public policy outcomes. The BET is a tax on behavior: Financial incentives affect human behavior. Rewards of money or savings usually lead to positive responses (Hobman et al., 2016). Financial rewards for RE can encourage behaviour change as some RE options become economically viable, thereby improving uptake and acceptance of low carbon sources of energy. Frederiks et al., (2015) highlight people's susceptibility to social norms and the influence of others' attitudes, stressing the importance of sustainability-focused interventions by individuals/organizations for energy conservation.

Therefore, green knowledge, attitudes and values are not always associated with pro-environmental behaviour. Incentives have proven to be an ineffective change management tool if it comes to changing consumer behavior in favor of sustainability. This idea has been extended in recent research with a focus on consumer ownership as an eco-conscious consumer and producer (Yildiz and Sagebiel, 2019). To change consumer behavior, Lowitzsch (2019) argues for empowering consumers as RE installation owners and for promoting the use of the installation in an energy-efficient manner. Furthermore, Curry (2014) suggested a mixture of policy and economic options for promoting change. An alternate case occurs in low-resource countries where monetary support can help to transition towards cleaner energy systems. Financial instruments can have a significant effect in inducing personal, corporate or governmental investment and adoption of RE and the development of green infrastructure to increase consumption, sustainability and decrease

emissions, particularly in countries with limited economic resources. Given this, the current study offers adequate breadth to examine the following hypotheses:

- H1: It is expected that as the use of public flows increases due to civil war or disaster, the REC per capita would show a positive significance.
- H2: Expected positive relationship with income per capita.
- H3: The effects of the effectiveness of government are likely to be high.

The green transition remains a challenge for developing countries pursuing sustainability. The relationship between renewable energy and green finance initiatives requires empirical exploration.

Frederiks et al. (2015) recommend empirical research, impact assessment, scalable interventions, and investigating lasting behavioral changes. This aids in refining renewable energy finance strategies and facilitating the shift toward a cleaner and more sustainable energy future.

3. Data, Methodology and Results

3.1. Data and descriptives statistics

The studied sample includes 36 countries (DC) that faced energy transitions and developed renewables between 2000 and 2020. The sample selection takes into account geographical representation, data availability and specific research goals. Sustainable development requires support for the growth of renewable energy technologies; based on the data available from IRENA, public flows were extended to the following countries to help the progression of the renewable energy technologies. The choice of these countries made a comparative analysis possible, which enabled the identification of common trends, barriers and opportunities in the transition processes for sustainable energy. The study aimed to assess the impact of public flows on renewable energy consumption in developing countries. It sought valuable insights into the relationship between renewable energy and Green Finance initiatives in developing countries.

Table 2 Variables' specifications and data sources

Variable Name	Acronym	Definition	Source
RE Consumption per capita	REC capita	Renewable energy comes from naturally replenishing sources (measured in Btu and converted to MWh) and is expressed per capita using population data from WDI.	EIA
Public Flows % GDP	GFI%GDP	Public Flows, measured in millions of USD at 2020 prices and exchange rates, refer to green financial incentives provided by the public sector categorized by country/area, technologies, and year. This variable is expressed in terms of GDP.	IRENA
Income per capita	GNI capita	Gross National Income per Capita	WDI
Government Effectiveness	Gov	It measures public service quality, civil service effectiveness, policy implementation, and a government's commitment to improving these aspects.	GDI

The public flows (GFI) represent government support for various RE technologies, including financial investments, subsidies, and incentives. These initiatives aim to promote the development and adoption of RE technologies, accelerating the transition from fossil fuels to renewables to achieve sustainable development goals. The data is presented as a percentage of GDP to allow for a better comparison between countries of a vastly different economic size. A transitional variable is studied: income per capita and how the performance of development affects the relationship of RE finance. It can be useful to discuss the impact of economic development on the funding, investment and uptake of RE resources. Previous research (Killing-Ata and Dolmatov, 2022; Sadorsky, 2019; Sidney et al., 2021) shows that income per capita is an important determinant of RE consumption.

The government effectiveness category allows the researcher to see how quality of government incentives and policies affects the relationship of RE financing, shedding further light on the role of government in sustainable energy investments. Comparing national regulatory boxes is one of the most crucial determinants for success or failure of RE

projects and, cooperatives (Leitsch and Hanke, 2019). The role of the public sector can be strengthened by putting framework conditions for environmental finance into effect (Wolfgang, 2012).

The descriptive statistics on relevant variables among the countries selected are shown in Table 3. It also shows that Bhutan had the highest REC per capita (22.555 MWh (79.2 Giga Joule) in 2019, and Cambodia the lowest (0.00767 MWh (0.027612 Giga Joule) in 2002). Public flows per GDP (GFI) are approximately 0.28%, which suggests a more modest share of financial flows dedicated to RE technologies. These developing countries still exhibit lower REC and allocate fewer financial resources to it.

Table 3 Descriptive statistics

Variable	OBS	Mean	Std. Dev.	Min	Max
REC (per capita)	756,00	1.772893	3.206340	0.007677	22.55539
GFI (%GDP)	756,00	0.281915	0.845982	5.49E-07	8.557348
GNI (per capita)	756,00	3150.304	3099.441	130.0000	15230.00
GOV	756,00	41.30201	17.00265	1.081081	84.36019

3.2. Methodology and results

This study applies the BE Theory, which suggests that financial incentives for renewable energy make clean options appealing, encouraging their adoption and use. It evaluates the effects of financial incentives from both finance institutions and the government on the RE use per capita. This research uses various econometric tests to analyze the relationships among these variables. The step-wise approach includes the following steps: First, checking for cross-sectional dependence in the residuals using Pesaran (2004) test. Second, testing the integration order of the variables using either the first or the second-generation panel unit root tests (PURT), depending on the cross-sectional dependence results. Third, assessing if the variables are cointegrated using Pedroni (2001) and Westerlund (2007) tests. Finally, the PMG-ARDL model approach to determine the impact of public flows on REC per capita.

3.2.1. The specification model is presented as follows

$$RECcapitait = \alpha + \beta GFI*GFI\%GDPit + \beta GNI *.GNIcapitait + \beta gov*.GOVit + \varepsilon it \quad (1)$$

The dependent variable REC is regime dependent and the set (GFI, GNI and Gov) represents regime independent. The subscripts i=1, …, N represents the country and t=1,…,T is the time for each variable.

There are two generations of tests. The first generation of panel unit root tests assumes cross-sectional independence, whereas the second generation allows for CSD. Table 4 displays the outcomes of the CSD test using Pesaran (2004) for the relevant variables. The results show that the null hypothesis of cross-section independence is rejected at the 1% significance level for the variables, and the 5% for lnGov. This suggests that the underlying variables are cross-correlated within the sample, necessitating the use of the second-generation PURT test. The development of the second-generation panel test is crucial and frequently overlooked in the literature whereas it has recently piqued the interest of several empirical studies (Camach et al., 2022; Chen et al., 2020, and Chen and Chen 2021; Aqib and Zaman, 2023; Hasni et al.,2023; and Oluc et al., 2023).

Table 4 Pesaran's (2004) cross-sectional dependence test results

Variable	CD-test	p-value	corr	abs(corr)
Ln RE Cca pita	11.47	0.000	0.100	0.483
Ln GFI %GDP	10.44	0.000	0.091	0.230
Ln GNI capita	107.60	0.000	0.935	0.935
Ln Gov	1.99	0.047	0.017	0.360

Notes: Under the null hypothesis of cross-section independence CD ~ N(0,1)

Table 5 displays the results of the CIPS unit root test. It considers that the dependent variable (lnRECcapita), and ln GNI capita lack stationarity, whereas variables like lnGFI%GDP and lnGov exhibit stationnarity at level I(0). For the first differences, the variables show stationarity at a 1% significance level, and for lnGov at 5%.

Table 5 CIPS PURT Results

CIPS test		**Ln REC capita**	**lnGFI% GDP**	**lnGNIcapita**	**lnGov**
At Level	t-Statistic	-245.389	-2.5861*	-227.609	-2.6911**
At first difference	t-Statistic	-3.4895***	-2.9669***	-2.9973***	-2.7856**

Notes: "***", "**", and "*" indicates statistical significance at the 1%, 5%, and 10% level respectively. Pesaran panel unit root test (CIPS) with cross−sectional and first difference means included for each variable. The deterministic chosen is constant. Critical value is −2.57(10%), −2.65(5%), and −2.81 (1%)

The results of the stationarity tests suggest that all variables exhibit integrated of order 1 (I(1)). Consequently, it becomes imperative to investigate long-term cointegration using various cointegration methods, such as those proposed by Pedroni (2007) and Westerlund (2007). Westerlund (2007) has introduced four cointegration tests that account for the presence of CSD in residuals, ensuring more effective outcomes.

Table 6 Panel Cointegration Tests Results

Westerlund cointegration tests				
Statistic	Value		Z value	P-value
Gt	-2.759		-3.009	0.001***
Ga	-17.960		-5.468	0.000***
Pt	-9.840		-3.304	1.000
Pa	-9.326		-0,374	0.354
Pedroni cointegration tests				
Alternative hypothesis: common AR coifs. (within-dimension) Weighted				
	Statistic	Prob.	Statistic	Prob.
Panel v-Statistic	-1.708.924	0.9563	-2.490.673	0.9936
Panel rho-Statistic	3.023.786	0.9988	2.127.482	0.9833
Panel PP-Statistic	-1.450.537	0.0735*	-4.685.590	0.0000***
Panel ADF-Statistic	-2.410.339	0.0080***	-5.232.170	0.0000***
Alternative hypothesis: individual AR coefs. (between-dimension)				
	Statistic			Prob.
Group rho-Statistic	4.277.250			1.000
Group PP-Statistic	-5.270.320			0.0000***
Group ADF-Statistic	-4.994.685			0.0000***

Notes: "***," "**," and "*" indicate statistical signifcance at the 1%, 5%, and 10% levels, respectively

Table 6 illustrates that, among the four Westerlund cointegration tests, two statistical tests confirm the existence of a long-term relationship among the variables. Similarly, the Pedroni results indicate that, out of the seven statistics, four reject the null hypothesis of no cointegration. Consequently, these tests affirm the presence of long-term cointegration among the relevant variables.

The research analysis utilized the PMG-ARDL approach created by Pesaran et al. (1999) to explore the structural long-term relationships among REC per capita, public flows%GDP, income per capita, and governance effectiveness. This method enforces consistent long-term coefficients while permitting variations in short-term coefficients. Pesaran et al.'s

(2001) ARDL model excels by simultaneously estimating short- and long-term dynamics, accommodating different integration levels (I (0), I (1), or both), and adjusting to variable-specific lags.

Table 7 presents the results derived from the PMG-ARDL approach. Among the variables, both lnGFI%GDP and lnGNIcapita exhibit statistical significance at the 1% level, while the significance of the lnGov variable is not observed. Notably, a rise in GFI%GDP aligns with an increase in REC per capita, while a comparable increase in GNI per capita leads to an increase in REC per capita as well, indicating that more green spending as a percentage of GDP and a higher Income per capita is associated with increased REC per capita. The findings strongly support the notion that green finance initiatives, particularly through public funding, play a pivotal role in fostering the adoption of renewable energy in developing countries. This is evident in the establishment of green infrastructure, especially during its initial stages. As far as our understanding goes, this novel observation remains unexplored in the existing literature. This discovery lends partial support to the investigations carried out by Jinlan and Chunyu (2023). A positive and significant relationship is observed between income per capita and REC per capita. This suggests that higher income per capita encourages the utilization of REC even in developing countries, consistent with findings from earlier research (Kiling-Ata and Dolmatov, 2022; Sadorsky, 2019; Sidney et al., 2021). The variable related to government effectiveness (Gov) does not demonstrate significance within this estimated relationship for the selected sample. Furthermore, the error correction term holds significance and exhibits a negative value. This aspect indicates that REC per capita adjusts towards equilibrium at a rate of -0.619 per unit.

Table 7 PMG-ARDL Estimates (LRECC dependent variable)

Variable	Coefficient	Std. Error	t-Statistic	Prob
	Long Run Equation			
LNFI	0.009727	0.002328	4.177.823	0.0000***
LNGNI	0.067063	0.015695	4.272.988	0.0000***
LNGOV	-0.074299	0.047487	-1.564.606	0.1185
	Short Run Equation			
ECT	-0.619553	0.066171	-9.362.846	0.0000***
D (LNRECC (-1))	0.116987	0.050441	2.319.293	0.0209**
D(LNFI)	-0.008196	0.003645	-2.248.689	0.0251*
D (LNFI (-1))	-0.000775	0.003802	-0.203959	0.8385
D(LNGNI)	0.349557	0.200860	1.740.297	0.0826*
D (LNGNI (-1))	-0.762283	0.255222	-2.986.742	0.0030**
D(LNGOV)	-0.009708	0.121857	-0.079666	0.9365
D (LNGOV (-1))	-0.271841	0.218346	-1.245.002	0.2139
C	-0.363711	0.197612	-1.840.536	0.0664*
@TREND	0.014630	0.006270	2.333.318	0.0201**

Notes: unit root, Notes: "***", "**", and "*", indicate statistical significance at 1%, 5%, and 10%, respectively. ECT denotes the error correction term. D(.) indicates the first difference.

4. Discussion

Renewable energy technologies are a modern-day challenge to the environment and sustainable development. The global commitment to RE is present in both developed and less developed countries, with a wide range of energy demands being addressed. (Oluc et al., 2023) Incentives to encourage the use of renewable energy are complex in changing consumer behaviour (Frederiks et al., 2015). Research in recent years (Lowitzsch, 2019; Curley, 2014, etc.) have pointed to the multi-layered nature of sustainable consumer behaviour. The study highlights, however, the central role of financial incentives in the use of RE, encouraging the public's participation in RE technologies.

This view is in favor of green finance measures, here public flows, facilitating RE access in financially limited developing countries. Empirical studies support the importance of financial tools, including green loans, bonds, and investments, in advancing RE and challenge emissions reduction strategies, a fact highlighted, especially by studies in highly developed nations (Xinkuo & Jingsi, 2023; Buhari et al., 2023; Chen & Chen, 2021; Chen et al., 2022; Khan et al., 2022). Within the field of developing countries, the study makes a significant contribution to the production of existing literature, particularly by highlighting the important role played by financial assistance from the public sector in developing nations.

The data indicates that in developing countries, public funds for renewables, such as capital investment, subsidy, and incentive, are important in creating infrastructures and catalyzing technology adoption. It is recognised however that this may not be enough for vastly more complex RE technology development, especially in countries where financial markets are less sophisticated and resources less abundant. In these settings, additional funding and support is considered essential to help strengthen development of renewable energy technologies. Sondel et al. found that out, among their findings, that the impact of government effectiveness on the adoption of renewable energy (RE) is not significantly present in the sample they examined. Even though it is often believed that governments are key actors in promoting decarbonisation in energy systems, this research questioned such a view. It proposes that factors extending beyond government effectiveness may exert a more considerable influence on fostering RE deployment. These include political, institutional and technological aspects, as illustrated in earlier studies, including Chen et al. (2020) that explains the democracy effect. The realization invites a deeper inquiry into the complex dynamics driving the shift towards sustainable energy systems. The study findings reinforce the effectiveness of financial measures in substantially encouraging RE adoption and allow for a deeper understanding of these financial mechanisms that should be considered by policymakers.

5. Conclusion

This Paper highlights the importance of public flows as an efficient instrument for RE usage in developing countries. Specifically, it looks at the public flows effect on per capita REC for a sample of 36 developing countries between 2000 and 2020, within the context of the BE theory approach. Using the Westerlund and the Pedroni cointegration tests with PMG-ARDL approaches, the study concludes that series are cointegrated. The findings of the PMG-ARDL analysis confirms that public flows indeed influence clean energy adoption and utilization.

Therefore, green funding highlighted in recent COP agendas becomes an important policy move towards sustainable development. Resource constrained developing countries can leverage their resources to accelerate this shift. The role of the government is a major factor in advancing the RE sector by offering financial incentives and support. It also involves leveraging tax and subsidy measures to promote clean technologies (CTs), and especially in the competitive setting of transport decarbonization (TDC). Emission limits could be set by the government and the allowances sold for revenue; participation by the private sector may be expanded, creating financial incentives.

These include facilitating public-private partnerships to drive progress on RE projects, leveraging resources and expertise. The roles of government agencies should be strengthened in driving renewables: through improved public services, improved civil administration, a determined policy stance, and consistent implementation. With changing dynamics, policies need to be flexible and need to remain effective. There is a strong indication from the literature that the potential of national regulatory frameworks to have a decisive impact on RE projects is paramount. It is crucial that policy makers understand the importance of the RE sector, and it is imperative that funding is provided, support is given, and skills are transferred, using adaptation of information and communication technologies.

Policy recommendations

Thus, it is recommended to adapt the public flows to suit these countries' needs, evaluate and adapt regularly, involve public and private sector, educate, and provide transparent RE policy . Everything aside from financing consumption of renewable energy, in the developing world it is strongly recommended that government governments adopt a policy to make a place where these green solutions are created, and not consuming or importing. But governments need to cooperate internationally to enable financial assistance and technology transfer. Their findings would lead a subsequent research study into the impact of private finance (PPPs), if data are available to current studies. In addition, it would be interesting to analyse how green finance affects CO2 emissions and the carbon footprint in the sample of examined companies to provide firmer and clearer pieces of information.

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