w w w . d e v b a n k n g . c o m

...Financing Sustainable Growth

WORKING PAPER SERIES

234, 2025

DOES PEAK TECHNOLOGY COMBAT ENERGY POVERTY IN DEVELOPING COUNTRIES?

Forthcoming: International Journal of Energy Sector Management

Prince P. Asaloko
Applied Economics and Development Research Laboratory (LAREAD), Faculty of Economics
and Management, University of Kisangani, Kisangani, The DRC
E-mail: princepiva.05asaloko@gmail.com

Simplice A. Asongu
(Corresponding author)
School of Economics, University of Johannesburg, Johannesburg, South Africa
E-mails: asonsusimplice@yahoo.com, asongus@afridev.org

Therese E. Zogo
Faculty of Economics and Management,
University of Yaoundé II, Soa, Cameroun &
The Association for Promoting Women in Research and Development in Africa (ASPROWORDA), P.O. Box 8413, Yaoundé, Cameroon
E-mail: zogoastrid@yahoo.fr
ORCID: 0000-0002-3123-8244

Abstract

Purpose – The results of this study highlight the importance of advanced technologies in combating energy poverty.

Design/methodology/approach – The study focses on a group of 99 developing countries spanning from 2000 to 2021. It applies different estimation methods such as OLS with fixed effects, Driscoll-Kraay with fixed effects and Gneralized Least Squares (GLF).

Findings – The main conclusion is that advanced technologies significantly reduce energy poverty in developing countries. Similarly, this effect remains robust by changing the estimation technique, including the GMM and Tobit models. Furthermore, we observed that the impact of advanced technologies on all alternative measures of energy poverty remains robust to the main result. By adding natural resources in the model, it is apparent that natural resources have an inverse impact on energy poverty. By taking into account the heterogeneity of income level of each country, the effect is more important in high-income developing countries. Followed by intermediary and middle-income countries. In the underdeveloped world, we discovered an inverse impact of technological readiness on the consumption of energy. Policy suggestions are provided.

Originality/value – The paper balances the existing literature by examining how peak technology influences energy poverty in emerging markets.

Keywords: technology; energy poverty; developing countries

1.Introduction

Energy poverty is a major global challenge, with profound implications for the well-being and development of the most vulnerable populations. Moreover, rural and remote areas are particularly affected due to their distance from centralized electricity networks. Furthermore, energy poverty is a powerful driver of poverty and inequality, hampering the economic and human sustainable development of the poorest populations. Its eradication is therefore a priority issue for attaining sustainable development. Thus, in a context marked by an advance in globalization for many decades, many authors see technological innovation as a possible solution in the resolution of energy poverty (Djeunankan et al., 2024). Advanced technologies, which include information and communication technologies, artificial intelligence, biotechnology, renewable energies and sophisticated manufacturing, are at the forefront of modern technological development. Their adoption and adaptation can completely change the game for developing countries, allowing them to advance more quickly than they could have done with more conventional development methods (Xie et al., 2024). By so doing, the hypothetical and pragmatic litetrature highlights that energy poverty responds to a number of factors, including advanced technologies.

The majority of the literature on energy poverty has focused on the following topics: the determinants of energy poverty as critically discussed in Section 2, the relationship between financial inclusion and energy poverty reduction (Boutabba et al. 2020; Asongu et al., 2024), entrepreneurship and energy poverty (Cheng et al., 2021; Asongu and Odhiambo, 2024), energy poverty and economic development (Djeunankan et al., 2024) and leveraging on technology to address concerns related to energy poverty (Varo et al., 2022). However, within the remit of studies on the nexus between technology and energy poverty, research is sparse on how peak technology is linked to energy poverty, especially as it pertains to employing Advanced Technology Readiness Index as a measure of advanced technologies for each country and for the world. Accordingly, the overall Advanced Technology Readiness Index as employed in this study is generated through a principal component analysis (PCA) and thus, provides a more comprehensive perspective on how technology affect energy poverty, in the light of policy and scholarly technology readiness literature (UNCTAD, 2021; Bakouan and Sawadogo, 2024). At the crossroads of the abundant studies on the causes of energy poverty and the ever-growing literature on the effects of advanced technologies, the objective of this article is to examine the impact of advanced technologies on energy poverty in emerging countries. Therefore, this study has more than one interest. First, this work is of definite interest because it fills the gap in knowledge of studies in the field by examining, perhaps for the first time, the impact of advanced technologies in the broad sense on energy poverty. Second, this research work has the particularity of taking into account alternative measures of advanced technologies on the one hand and energy poverty on the other hand. Taking into account these different dimensions make it possible to grasp the complexity of the variables studied and to arrive at better economic policy recommendations. Third, this work takes into account possible transmission channels through which advanced technologies contribute to effectively reducing energy poverty.

The rest of the study is ordered in the ensuing way. Section 2 encompasses the relevant stylized facts, and related empirical literature while the data and methodology are presented in Section 3. The empirical results are shown in Section 4. The study conclusively suggested in Section 5 with policy recommendations and directions for future research.

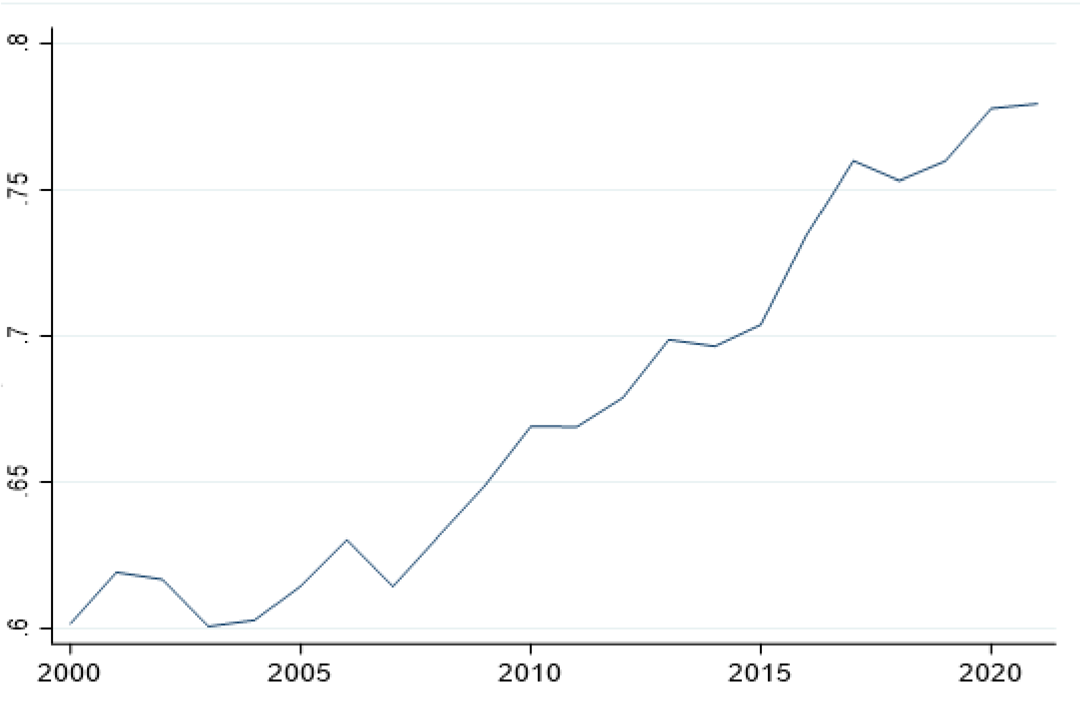
2. Stylized Facts, Theoretical Underpinnings and Empirical Literature

2.1 Stylized Facts

2.1.1 Analysis of stylized facts on the evolution of energy consumption

As apparent in Figure 1, in 2000, the World Bank report noted that around 1.2 billion people in developing countries had no access to electricity. This figure has fallen to around 759 million in 2019, a drop of around 37% over the period. This rise is due to increased investment in electricity networks. In 2000, some 2.8 billion people still used polluting fuels such as wood or charcoal for cooking. This number has now fallen to around 2.6 billion in 2019. Despite this progress, energy poverty is constantly the principal problem in many developing countries, requiring ambitious investment and policies to ensure universal access to modern energy.

Figure 1: Energy consumption in developing countries

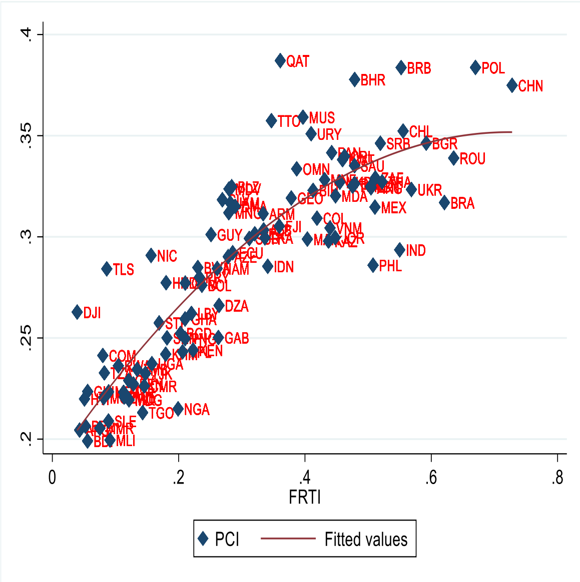


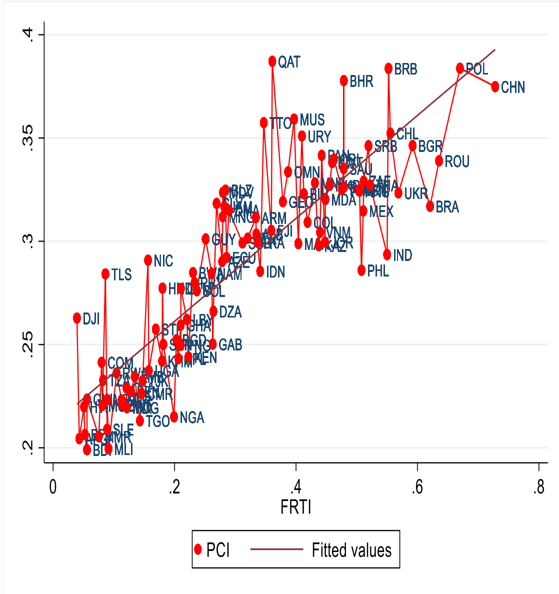
Source: Authors own work

2.1.2 Joint evolution of the state of readiness for advanced technologies and level of production capacity in developing countries

Figure 2, based on data from the World Bank and UNCTAD (2022), shows that in some countries, a low rate of energy poverty is a characteristic of a high level of advanced technology. This implies that countries with a high level of technological readiness and innovation also have a high energy capacity. On the other hand, in other countries, low energy capacity is correlated with a low level of high-tech readiness. Nevertheless, there are economies in which the level of advanced technology is high, but the level of energy capacity is low.

Figure 2: Positive correlation between energy poverty and advanced technology





Source: Authors own work

2.2 Empirical Literature

A vast literature questions the factors underlying energy poverty. As countries actively seek to mitigate the effects of energy poverty. Thus, a good number of determinants are identified in several empirical studies as main determinants of energy poverty. Also, several aspects of the literature have highlighted the link between advanced technologies and energy shortage. This part highlights a literature review of the determinants of energy poverty and the transmission mechanisms that explain how advanced technologies influence energy poverty. The equivalent literature is debated in three key strands, particularly as it pertains to: (i) economic determinants of energy poverty; (ii) geographical and socio-cultural determinants of energy poverty and (iii) institutional drivers of energy poverty. The three main strands are extended chronologically as depicted above.

2.2.1 Economic Determinants of Energy Poverty

Economic determinants are discussed in terms of public expenditure, foreign direct investment (FDI), economic growth and financial development. First, with regard of public expenditure, according to the work of Ko-tera et al. (2017) an increase in public expenditure can improve access to electricity. Guseh (1997) underlined the perspective that there is a non-linear relationship between the level of public expenditure and energy poverty. Indeed, public expenditure represents a policy aimed at redistributing income based on equity. The work of Lyubimov (2017) showed that the effect of public expenditure is not always effective in reducing income disparity in emerging markets. However, income inequality influences energy prosperity, which suggests that public tax expenditures can influence energy shortage through income disparity (Sarkodie and Samuel, 2020).

Second, recent literature on FDI has largely fixated on the impact of FDI on economic growth (Acquah and Ibrahim, 2023; Aluko et al., 2021), and also environmental degradation (Opoku and Boachie, 2020; Bokpin, 2017). Few studies give importance to access to electricity, including in the United Nations (UN) Sustainable Development Goals (SDGs). However, the work of Amelio et al. (2016) showed us that multinationals have two main reasons that lead them to operate in developing countries, namely to: (i) address the lack of electricity infrastructure and (ii) improve access to electricity, thereby leading to the reduction of energy poverty.

Third, looking at economic growth, the level of economic performance of a country on the macroeconomic level via economic growth is a principal cause of energy poverty. Gafa and Egbendewe (2021) show in their empirical work that income increases household access to electricity and, therefore, plays an important role in reducing energy poverty. Similarly, many other authors in economic study demonstrated that a rise in household income helps reduce energy shortages in emerging countries (Crentsil et al., 2019; Zhang et al., 2019). Indeed, households are more interested in their well-being, and therefore will opt for the use of clean energy as their income increases (Nguea et al., 2022).

Fourth, as concerns financial development, theoretical literature on financial development shows that it is a crucial element in the sphere of economic development (Blackburn et al., 2012). However, the impact of financial advancement on energy poverty an be observed on both the demand and supply sides (Capasso and Jappelli, 2013). On the demand side, the advancement of the monetary sector is an important feature in generating funds for residents to acquire and utilize electricity (Canh et al., 2020). Indeed, financial development helps increase household income, thus promoting the energy transformation process, towards clean energy and the effective utilization of biomass cooking and heating technology (Le et al., 2024).

On the energy supply side, financial development plays a critical role in developing the energy sector in developing countries (Hall et al., 2016). Similarly, financial development is a means to support electricity generation and transmission to provide electricity to citizens across large areas (Peng and Poudineh, 2017). In other words, financial development helps reduce energy poverty on both sides (Nguyen et al., 2021).

2.2.2 Geographical and Socio-cultural Determinants of Energy Poverty

This section is discussed in three main strands, especially as it related to natural resources, urbanization and education. These are extended chronologically as described. First, with respects to natural resources, the hypothesis of the resource endowment curse or abundance or paradox of plenty is discussed at length in the economic literature (Sachs and Warner, 1995). We speak of a resource curse if countries that originally possesses abundant natural resoureces, also have economic, social and institutional underperformance (Sachs and Warner, 1995, 1999). The impact of natural resources on energy poverty is also observed through income disparity (Fum and Hodler, 2010). Indeed, an abundance of resources causes a rise in income disparity (Carmignani, 2013; Farzanegan and Krieger, 2019). This is explained by the fact that mining rents are often distributed inequitably, such that only important political leaders benefit from them (Basedau and Lay, 2009). However, recent work by Nguyen and Nasir (2021) showed that inequality reduces access to electricity in developing countries. Similarly, Sarkodie and Adams (2020) found that in Sub-Saharan Africa, income inequality increases poverty, thereby limiting access to electricity to households in poverty.

Second, with respect to urbanization, the relationship between urbanization and energy poverty is very ambiguous in the economic literature. Many studies on the effects of urbanization provide strong arguments that an increase in population density leads to local, national and global economic growth (Duranton, 2008). Similarly, studies on energy poverty in poor countries have shown that the level of energy poverty is relatively lower in urban areas than in rural areas (Adusah-Poku and Takeuchi, 2019).

Third, as concerns education, the percentage of literates generally determines the level of productivity of a country. The work of Apergis et al. (2022) analyzes the influence of education on electricity assessment, using a panel of 30 countries and over a period from 2001 to 2016. The results revealed that an increase in education level also increases individuals' access to electricity, which helps reduce energy poverty. Indeed, households that are not educated have less access to clean forms of energy, such as electricity, and mainly use traditional fuels such as wood and charcoal, which generate large quantities of emissions from carbon dioxide (CO_2), which are very harmful to the environment. These results are also found in the work of Acharya and Sadath (2019) who, in their microeconomic study, examine the effect of education on energy poverty in China.

2.2.3Institutional Determinants of Energy Poverty

The empirical literature on institutional factors that explain energy poverty is discussed from two main perspectives, namely: democracy and female parliamentarians. First, in terms of democracy, several theoretical studies showed that democratic regimes are far more promising to the creation of public goods than authoritarianism. Accordingly, when political authorities are held responsible to the masses through consistent and just elections, they are more motivated to provide public goods and services (Acemoglu and Robinson, 2006). The work of Ahlborg et al. (2015) indeed showed that democratic institutions improve access to electricity in emerging markets. Accordingly, in democratic systems, leaders are generally elected based on their ability to meet the population's need for the creation of public services and goods just like electricity (Borãng et al, 2021). Moreover, at the end of democratic term, citizens examine whether political leaders have respected their commitment in order to renew their contract in the next elections (Baskaran et al., 2015). Otherwise, they will simply be replaced (Schmitter and Karl, 1991; Acemoglu and Robinson, 2006).

Second, in relation to female parliamentarians, the literature on the effects of female parliamentarians on energy poverty is generally done through the channel of corruption control (Swamy et al., 2001; Djeunankan et al., 2023). Indeed, theoretical analysis shows that female parliamentarians have a negative effect on energy poverty by improving the quality of institutions, through the reduction of corruption in a country (Hessami and da Fonseca, 2020). Unlike men, female politicians are socially known to be more honest and trustworthy (Barnes and Beaulieu, 2019). Thus, the probability of engaging in corrupt practices is lower among women than among men politicians (Eggers et al., 2018).

3. Data and Methodology

3.1Data, Source and Description of Variables

The data for this study come from secondary sources, particularly for the measurement of advanced technologies by the United Nations Conference on Trade and Development (UNCTAD). In regards to the independent variables, we used data from the World Development Indicators (WDI) of the World Bank. All of these data cover the period 2000 to 2021. The start and end date, as well as the number of countries are due to data availability. The frequency of the data is annual, and the data set includes 99 countries with the list of countries pprovided in the appendix).

The main dependent variable of this study is energy poverty. Many attempts have been made to define energy poverty, but there is no universally accepted definition. From these different definitions, it emerges that energy shortages can be referred to as the scarcity of possibilities to access sufficient, cheap, dependable, safe, environmentally friendly and high-quality goods and services to assist both economic and human development (Djeunankan et al., 2024). In a bid to dissect the multidimensional of concept of energy shortages, we must get inspiration from Nguyen and Nasir (2021) and we also consider three main indicators of energy shortages. (i) the percentage of the total population that has access to electricity (EPO1); (ii) the percentage of the urban population that has access to electricity (EPO2); and (iii) percentage of the rural population that has access to electricity (EPO3). For reasons of heftiness, we utlize five other approaches of energy poverty: (i) the perecentage of the total population that has to hygienic cooking gas and technologies (EPO4); (ii) the percentage of the urban population that has access to hygienic cooking gas and technologies (EPO5); (iii) the percentage of the rural populace that has access to hygienic cooking gas and technologies (EPO6), electricity consumption per capita (EPO7), and (iv) energy consumption (EPO8). Indeed, authors such as (Ochoa & Graizbord, 2016; Romero et al., 2018; Kyprianou et al., 2019) used in their work respectively the other five measueres of energy poverty to verify whether this had the same effect on development. They came to similar conclusions that these five alternative measures of energy poverty had the negative effect on development. The main independent variable is the index of the level of preparation for advanced technologies.

The study uses the Advanced Technology Readiness Index as a measure of advanced technologies for each country and for the world. The overall Advanced Technology Readiness Index is generated through a principal component analysis (PCA). Thus, the value of an index close to 1 shows that a country is fully equipped for the implementation and utilization of advanced machineries. Conversely, the value of an index that is close to 0 shows that the country is not fully equipped. The Advanced Technology Readiness Index reflects the readiness of frontier technologies. As per UNCTAD (2021) and recently Bakouan and

Sawadogo (2024), frontier technologies use digitization and connectivity. These technologies encompass artificial intelligence, the internet of things, blockchain, big data, 5G, 3D printing, robotics, gene editing, drones, nanotechnology, and solar photovoltaics. The Advanced Technology Readiness Index is evaluated each year. It assesses countries based on their preparedness for advanced technologies using five key criteria: industrial activity, ICT deployment, research and development, skills, and access to finance.

In order to account for variable omission bias, a number of factors are controlled for. Accordingly, income level, trade openness, financial development and income tax are considered as control variables. These variables are discussed in chronological order. First, income leve is proxied with GDP per capita.

This is a measure commonly used in the literature that captures the level of growth of the economy. Regarding its link with energy poverty, the literature suggests that its effect differs (Lawal et al., 2020). Specifically in developing countries, growth tends to lead to a sharp increase in energy consumption, especially for domestic uses and transport. While in developed countries, growth is accompanied by a smaller increase in consumption, thanks to technical progress and structural changes (Doganalp et al., 2021). In other words, economic growth tends to increase energy demand, but the extent of this particular increase solely depends on the rate of advancement and the execution of appropriate energy policies and procedures.

Second, the trade openness which is measured by the total of imports and exports as a proportion of GDP has complex effects on energy consumption, which can vary across countries and economic sectors. Indeed, trade openness generally stimulates economic growth, which tends to increase overall energy demand (Mignamissi and Nguekeng, 2022). Also, trade openness can change the structure of a country's economy, favoring certain sectors that are more or less energy-intensive. Specifically, the rise of energy-intensive manufacturing sectors in some developing countries may have increased their energy consumption. From another angle, trade openness can stimulate innovation and energy efficiency gains in certain sectors (Oum, 2019). This can help reduce energy consumption per unit of production.

Third, financial development which is the deepening and sophistication of a country's financial system, can have various effects on energy consumption. An advanced monetary system facilitates the availability of loans and funding, which can stimulate economic growth (Shahbaz et al., 2019). As mentioned earlier, economic growth usually comes with a higher increase in energy consumption. Also, a more developed financial system allows for a better allocation of capital to the most productive sectors. This can promote the development of less energy-intensive sectors and stimulate technological innovation. Then, easier access to finance can permit families and businesses to capitalize on more effective energy devices (Kinda and Sawadogo, 2023). This can translate into a decrease in energy consumption per unit of production or consumption. Indeed, financial development can also facilitate investments in renewable energies, which tend to replace fossil fuels.

Fourth, with respect to income tax, tax pressure can have a significant impact on energy consumption in developing countries. Indeed, an increase in taxes on fuels and electricity tends to reduce energy consumption, by encouraging households and businesses to be more energy efficient or to turn to alternative energy sources (Nguyen et al., 2023). On the contrary, numerous emerging nations fund the prices of energy just to make it cheaper to afford. But these subsidies have a high tax cost and can encourage waste. Their reduction can therefore impact consumption. Conversely, tax incentives for investments in energy efficiency or renewable energy can stimulate the transition to more sustainable energy uses (Raghutla and Chittedi, 2022). At the household income level, a high tax pressure can reduce the purchasing power of households, forcing them to limit their basic energy consumption (heating, cooking, lighting). Thus, fiscal policy is an important lever to guide energy consumption behaviors, according to the sustainable development objectives of each country (Lee and Yuan, 2024).

3.2 Methodological Strategy

The aim of this research paper is to examine the impact of advanced technology on energy poverty in developing countries. To do this, the corresponding Equation (1) is as follows:

$$P\_Energ = f(Tech,\ X) \qquad (1)$$

where , X is represents the matrix of independent variables showcased above. Therefore, we employ a multi-step econometric approach. Indeed, we utilize some estimation approaches that are from the literature, such as the OLS with fixed effects, Driscoll-Kraay with fixed effects and Generalized Least Squares (GLS) for the elementary estimator. The usage of these approaches makes it doable and simple to solve an assembly of econometric issues, such as:

First, we apply the OLS absorbing multiple fixed effects developed by Correia (2016). This method enables the study to analyze the direct effect of the stability of the country on the size of the informal economy by absorbing several levels of fixed effects. This is a generalization of the fixed effects model; to allow multidirectional clustering of errors. Error clustering is a technique to control heteroscedasticity and autocorrelation. On the contrary, as regards models with traditional fixed effects, clustering is one-way. The model that will be analyzed is as follows in Equation (2) :

$$Y = Z\beta + D_1\alpha + D_2\gamma + \varepsilon \qquad (2)$$

where D_1 and D_2 are representative of fixed effects in a panel but with different dimensions.

Secondly, it is important to note that while fixed effects account for country specific differences, and help correct this issue, working with panel data may lead to cross-sectional dependence. Therefore, to address the problem, we can apply the Driscoll-Kraay (1998) estimation method. Thirdly, both the OLS estimator with fixed effects and the Driscoll-Kraay with fixed effects assume a static correlation between the model's distinct variables, but this is not usually true. The utilization of these two estimation methods do not always capture certain hiden differences between variables and it may still allow for endogeneity and autocorrelation which may arise when the observation in the model are not all completely independent.

In an attempt to solve the auticorrelarion issue in our model, we utilize the GLS estimation which was previously created by Aitken (1936). Undeniably, the GLS estimation forsee that there is presence of a firm degree of relationship between the residuals and this permits us to put into consideration the unknown parameters when analyzing the regression model. This approach is more effective than the OLS and the ordinary weighted least squares because considering connections of the residuals in their estimation methods can be statistically worthless. This estimator is used for the following model in Equation (3):

$$P\_Energ_{it} = \beta_0 + \beta_1 \text{Tech}_{it} + \beta_3 X_{it} + +\zeta_{it} \quad (3)$$

where P_Energ_{it} corresponds to energy poverty in the country i at the périod t. Tech_{it} is the level of cutting-edge technology in the country. X_{it} is the vector of the control variables growth, trade openness, financial development and income taxes. ζ_{it} is the error term.

Fourth, fixed-effects OLS, fixed-effects Driscoll-Kraay and GLS helps improve the model but they do not account for hidden differences in certain variables. This therefore suggests the possibility of heteroscedasticity and endogeneity in our model (Baum et al., 2003). Additionally, due to Equation (1) specification, our model may be affected by Nickel bias (1981) and therefore, to address this bias, using the GMM methods becomes pertinent as it helps to control the memory effect in the lagged dependent variable. As commonly discussed in the existing literature, there are two principal methods: the difference GMM and the system GMM (Roodman, 2009a; Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998). Previously introduced by the pioneering work of Arellano and Bond (1991), the GMM estimator for dynamic panel data is designed to handle endogeneity problems effectively.

However, the GMM system estimator is accompanied with two key tests: the model overidentification test (Hansen test), in which the soundness of the unstruments applied is checked, in a way that they must be related to the variables but not to the error terms; and the Arellano and Bond (1991) error autocorrelation test, which checks for first order serial correlation of the residuals in level (AR1) and also checks the second-order serial correlation of the differenced errors (AR2). This is because in the GMM system estimator, the first differenced error terms are naturally correlated in the first order. Based on these criteria, the reliability of the GMM system estimator is based on two factors. One, the quality of the chosen instruments (Hansan test), and two, the absence of second-order autocorrelation in the differenced equation (AR2). The dynamic model to be estimated by this approach is as follows in Equation (4):

$$P\_Energ_{it} = \alpha + \beta_1 P\_Energ_{it-1} + \beta_2 \mathrm{Tech}_{it} + \eta_i + \mu_t + \varepsilon_{it} \quad (4)$$

where P_Energ_{it-1} corresponds to the size of energy poverty delayed by one year. η_i is an unobserved country-specific effect, μ_t is the time fixed effect.

4. Empirical Results and Discussion

4.1 Analyses of Preliminary and Basic Results

Table 1 in the appendix presents some descriptive statistics, namely the average, standard deviation, and the minimum and maximum variables over the entire sample. The first observation that we can make from this table is that over the selected period (2000-2021), most of our variables are positive. They reveal a low dispersion of the data given the low standard deviations. Indeed, we discovered that usually, the rate of energy consumption in developing countries is 28.664 and with a 5.043 estimated standard deviation value. This means that in other words energy consumption is low in these countries. In some of these countries, the level of energy consumption remains very low (17.348) while in others it is well above the average (40.813). This is justified by the fact that some countries do not have a high level of technological development.

4.2. Presentation of Results, Robustness Test and Sensitivity Analysis

Table 1 presents the basic results of OLS, Driscoll and Kraay, and GLS estimations. Particularly, we showcased in columns (1), (3) and (5) bivariate regressions. The results show that the estimated coefficients associated with advanced technologies has a direct relationship and are statistically significant at the 1% level. This argues that an increase in technological innovation improves energy consumption typically. A reasonable description for this result that energy is needed for the extraction of raw materials, processing and transport of finished products to distribution sites, which promotes technological innovation.

Table 1. Basic analysis of the effect of advanced technologies on energy poverty

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS		Driscoll-Kraay		GLS estimation	
VARIABLES	EPV1					
FRTI	**1.162*** (0.0225)**	**0.769*** (0.0300)**	**1.161*** (0.0622)**	**0.722*** (0.0487)**	**1.054*** (0.0135)**	**0.610*** (0.0187)**
GDP_perc		1.028*** (0.0631)		1.072*** (0.0831)		1.011*** (0.0587)
Trade		0.622*** (0.162)		0.416** (0.188)		0.351*** (0.0937)
Dev_fin		0.320** (0.155)		0.676*** (0.218)		0.591*** (0.0933)
Tax_rev		1.197* (0.707)		1.514* (0.841)		3.493*** (0.607)
Constant	0.299*** (0.0227)	0.358*** (0.0368)	0.390*** (0.0388)	0.407*** (0.0332)	0.451*** (0.00611)	0.453*** (0.0110)
Observations	2,614	1,199	2,614	1,199	2,614	1,199
R-squared	0.526	0.569	0.492	0.540		

Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: Authors own work

Concerning the independent variables, the results contained in Table 1 above suggest that they all variables possess a direct relationship and a significant impact on the energy capacity of developing economies regardless of the estimation technique used. In other words, GDP, trade openness, financial development and tax pressure all possess a direct (positive) and significant impact on the demand for energy of the developing countries. This is consistent with the literature and the results gotten from several authors **(**Shahbaz et al., 2013; Rafindadi & Ozturk, 2016; Aydin & Turan, 2020). Specifically, the study argues that the rate of income is a lever for energy consumption (Amores et al., 2023). To this end, growth tends to lead to a sharp increase in energy consumption, especially for domestic uses and transport. This result is verified in developed countries where growth is sometimes accompanied by a lesser increase in energy consumption, thanks to technical progress and structural changes (Doganalp et al., 2021). In other words, economic growth tends to increase the demand for energy, but the extent of this increase depends on the level of development and the implementation of appropriate energy policies.

Regarding trade openness, Mignamissi and Nguekeng (2022) report that it generally stimulates economic growth, which tends to increase overall energy demand. It can therefore change the structure of a country's economy, favoring more or less certain energy-intensive sectors. Specifically, the growth of energy-intensive manufacturing sectors in some developing countries may have increased their energy consumption (Oum, 2019).

Regarding financial development, the literature suggests that a developed financial system facilitates access to credit and investments, which can stimulate economic growth (Shahbaz et al., 2019). As stated previously, economic growth usually comes with an increase in energy consumption. Also, a more developed financial system allows for a better allocation of capital to the most productive sectors. This can promote the development of less energy-intensive sectors and stimulate technological innovation. Moreover, access to finance can permit businesses and families to capitalize more on effective energy devices (Kinda and Sawadogo, 2023). This can result in an increase in energy consumption per unit of production or consumption. Indeed, financial development can also facilitate investments in renewable energies, which tend to replace fossil fuels.

As for the tax burden, Nguyen et al. (2023) reported that a reduction in taxes on fuel and electricity tends to increase consumption, by encouraging households and businesses to be energy effective. On the contrary, numerous emerging nations fund energy process to make it cheaper. But these subsidies have a high tax cost and can encourage waste. Their reduction can therefore impact consumption. Conversely, tax incentives for investments in energy efficiency or renewable energy can stimulate the transition to more sustainable energy uses

(Raghutla and Chittedi, 2022). Thus, tax policy is an important lever for guiding energy consumption behaviors, according to each country's sustainable development objectives (Lee and Yuan, 2024).

4.3 Controlling for Endogeneity

One of the advatages of the fixed effects, Driscoll and Kraay, and GLS is that they permit us to enhance our model but irrespective of this advantage, they fail to take into account the unnoticed heterogeneity of some of the variables, thereby signifying a belief that there is a presence of heteroscedasticity and perhaps, endogeneity in our model. Therefore, to these two issues mentioned above, we will utilize the GMM estimation technique instead of the OLS. However, the coefficients of the lagged endogenous variable are relatively huge at the 1% significance level as depicted in Table 2. This therefore argues that energy onsumption has a solid tenacity over time, and also its former levels are robustly related with its present levels. More precisely, countries that enjoy higher energy consumption will tend to perform better economically in the future.

Table 2. System GMM estimation

	(1)	(2)
	System -GMM	
VARIABLES	EPV1	
L.EPV1	0.973***	0.963***
	(0.000886)	(0.000651)
FRTI	**0.0188*** **	**0.0215*** **
	(0.00201)	**(0.00171)**
PIB par tête		-0.0457***
		(0.00494)
Ttade		0.0592***
		(0.00698)
Dev_fin		-0.0148**
		(0.00685)
Tax_rev		0.348***
		(0.0124)
Constant	0.0221***	0.0235***
	(0.000613)	(0.000281)
Observations	2,458	1,173
Number of groups	99	82
Instruments	81	66
AR (1) p-value	0.000	0.000
AR (2) p-value	0.238	0.269
Hansen p-value	0.203	0.249

Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1
Source: Authors own work

4.4 Robustness and Sensitivity Tests

Testing robustness and sensitivity is necessary to validate the robustness of the results. Thus, the robustness analysis of this study is multiple. First, we use an alternative measure to control for endogeneity using the instrumental variables method and then we check whether our results remain robust using the alternative measure of energy consumption. Second, we test sensitivity by checking for regional effects.

4.4.1 Alternative Approaches to Control for Endogeneity

First and foremost, in order to confirm that our results are not subject to instrumentation issues, we utilize the instrumental variables techniques as clearly shown in Table 3. Nevertheless, the problem of utilizing the instrumental variables techniques is the search and discovery of an ideal exogenous and suitable instrument. According to Baum et al. (2012), an instrument can only be suitable if it is significantly related with the endogenous variable, and if it fulfills the orthogonality condition and also, if it is properly removed from the model so that its impact on the dependent variable can only be an indirect one. Consequently, the intricacies in implementing these conditions makes the search for an exogenous instrument challenging, even though the instrumental variables valuation approach of Lewbel (2012) provides an improved substitute when the search for an ideal exogenous instrument becomes difficult, just as it is in our case. This approach is crucial to discover structural parameters in regression models that has endogenous or weakly measured explanatory variables without conventional references. The heteroskedasticity-based instruments are integrated into the Lwebel 2SLS. The leftover values of the auxiliary equation are multiplied by each external variable, adjusted to have a mean of zero, to create the internal instruments. This approach prevents the usual exclusion limitations and this is because the Lwebel's 2SLS estimates without external instruments are very close to those obtained using external instruments (Lewbel, 2012). Many studies in the literature have applied this estimation techniques (Domguia et al., 2022). However, the key results remain consistent after addressing endogeneity with the Lewbel technique (2012).

Table 3. Approaches to IV-2SLS LEWBEL, (2012)

	(1)	(2)	(3)
	IV-2SLS	IV-LIML	IV-GMM2S
VARIABLES	EPV1	EPV1	EPV1
FRTI	**0.896*** **	**0.984*** **	**0.789*** **
	(0.0654)	**(0.102)**	**(0.0632)**
GDP_perc	0.840***	0.722***	0.964***
	(0.0826)	(0.120)	(0.0752)
Trade	0.456**	0.477***	0.475***

	(0.178)	(0.183)	(0.176)
Dev_fin	0.226	-0.00199	0.494**
	(0.233)	(0.313)	(0.227)
Tax_rev	1.483**	1.467**	1.843**
	(0.735)	(0.708)	(0.729)
Constant	0.373***	0.356***	0.394***
	(0.0251)	(0.0304)	(0.0248)
Observations	1,199	1,199	1,199
R-squared	0.531	0.518	0.538
KPLM pvalue	0.000	0.000	0.000
KPLM (statistic)	28.02	28.02	28.02
Rkf	28.02	28.02	28.02

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Source: Authors own work

4.4.2. Alternative Measures of Energy Poverty

The robustness analysis is crucial because it permits us to confirm if the observed association between advanced technology readiness and energy consumption are consistent when considering different types of energy consumption. Also, as mentioned above, the energy poverty literature measures is not unanimous. Therefore, several indicators could also be used to quantify energy poverty, such as the share of income spent on energy, the failure to sustain an adequate indoor temperature, and the use of hazardous or inefficient energy sources. We examine how our results change using several measures of energy poverty, specifically, the proportion of the total urban and rural population that has access to clean cooking fuel and technologies (EPO4, EPO5, and EPO6, respectively. The variables, which replicate access to modernized energy services, quantify an essential dimension of energy poverty (Djeunankan et al., 2024).

Furthermore, recognizing that energy access does not essentially connote effective energy consumption, particularly in African countries where individuals, despite being connected to the electricity grid, still experience power outages, we use electrical energy consumption to resolve this problem (EPO 7). Additionally, we also put into consideration a more universal measure of energy poverty, such as energy consumption (EPO8). The findings from this robustness analysis are presented in Table 4. These result findings depict that the effect of advanced technologies on all other measures of energy poverty remains identical to the main result with a value of 1%. Based on the results, we could deduce that our results are robust to the utilization of other measures of energy poverty.

Table 4. Robustness on alternative measures of energy poverty

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	EPV2	EPV3	EPV4	EPV5	EPV6	EPV7	EPV8
L.EPV2	0.961***						
	(0.000504)						
FRTI	**0.0462*** **	**0.0160*** **	**0.0165*** **	**0.00745*** **	**0.0124*** **	**1.406*** **	**0.187*** **
	(0.00145)	**(0.00114)**	**(0.00105)**	**(0.00171)**	**(0.00266)**	**(0.0719)**	**(0.102)**
PIB par tête	-0.0586***	-0.0160***	-0.0531***	-0.0319**	-0.0331***	5.305***	1.367***
	(0.00561)	(0.00539)	(0.00241)	(0.0128)	(0.00707)	(0.530)	(0.178)
Trade	0.0467***	0.0169**	-0.0354***	-0.0286	0.0194***	1.673***	0.818**
	(0.00581)	(0.00813)	(0.00628)	(0.0239)	(0.00496)	(0.221)	(0.317)
Dev_fin	0.0630***	0.0185*	0.193***	0.295***	0.0968***	5.613***	3.529***
	(0.00990)	(0.0103)	(0.00361)	(0.0326)	(0.0160)	(0.793)	(0.392)
Tax_rev	0.0152	0.489***	-0.262***	0.0966	-0.535***	-36.92***	-16.51***
	(0.0561)	(0.0287)	(0.00717)	(0.160)	(0.0751)	(4.083)	(1.978)
L.EPV3		0.927***					
		(0.00161)					
L.EPV4			0.999***				
			(0.000746)				
L.EPV5				0.999***			
				(0.00209)			
L.EPV6					0.989***		
					(0.00157)		
L.EPV7						0.991***	
						(0.000646)	
L.EPV8							0.993***
							(0.00176)
Constant	0.0192***	0.0580***	0.0139***	-0.000252	0.0224***	-0.136***	0.0922**
	(0.000801)	(0.00144)	(0.000967)	(0.00255)	(0.000787)	(0.0477)	(0.0405)
Observations	1,138	1,173	1,135	1,135	1,135	617	630
Nombre de groupes	82	82	89	80	80	66	71
Instruments	66	66	65	40	55	53	55
AR (1) p-value	0.000	0.0454	0.000	0.0226	0.031	0.000	0.0257
AR (2) p-value	0.541	0.765	0.543	0.456	0.184	0.693	0.505
Hansen p-value	0.181	0.373	0.204	0.417	0.607	0.216	0.412

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
Source: Authors own work

4.4.3 Controls for the Limited Nature of the Dependent Variable

Since the dependent variable is limited to a range of [0-100], therefore using the OLS or other related methods could lead to a misleading result. Infact, OLS result are also not suitable with limited dependent variables that has a huge number of variations. Sometimes, a dependent variable may be continuous within certain intervals but can also take specific fixed values with

a certain probability. Models for restricted dependent variables are designed to handle cases where data is either cut off (truncated) or partially observed (censored samples).
To correct this issue, some specialized estimators are required. In this study, we utilize the Tobit model, censored poisson and truncated negative binomial estimators. These models are known as count models because they measure how often an event occurs. More specifically, they also account for the issues of data limitations due to censoring and truncation. It is pertinent to know that turncation happens when some data points that should be included are completely left out. On the contrary, censoring occurred when all data points are included but some information about them is missing. In essence, any of these situations could be applicable to the extreme values (0 and 100) in measuring energy poverty. The results in Table 5 remain consistent with the earlier findings.

Table 5. Controlling for the limited nature of the dependent variable

	(1)	(2)	(3)	(4)
	Fractional model			
	Probit	Logit	CPoisson	Nbreg
VARIABLES		EPV1		
FRTI	**2.418*** **	**4.015*** **	**0.912*** **	**0.912*** **
	(0.168)	**(0.323)**	**(0.217)**	**(0.217)**
GDP_perc	18.67***	39.38***	1.225*	1.225*
	(1.307)	(2.875)	(0.642)	(0.642)
Trade	1.392*	0.891	0.500	0.500
	(0.782)	(1.291)	(1.061)	(1.061)
Dev_fin	4.376***	10.47***	0.727	0.727
	(1.232)	(2.346)	(1.143)	(1.143)
Tax_rev	-1.385	-0.536	2.596	2.596
	(1.774)	(2.819)	(4.131)	(4.131)
Constant	-0.718***	-1.359***	-0.741***	-0.741***
	(0.0581)	(0.0960)	(0.117)	(0.117)
Observations	1,199	1,199	1,199	1,199

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Source: Authors own work

4.4.4 Sensitivity Analysis by Adding Control Variables

Inspired by the study conducted by Ongo et al. (2023), we proceed to add other control variables. Indeed, the literature on the determinants of energy consumption is widely documented by work in development economics. The determinants usually highlighted are relevant to each other. Therefore, in order to limit the potential biases linked to the arbitrary choice of control variables as well as the omission of certain variables relevant to the explanation of energy consumption, we resort to the addition of three control variables. More specifically, these are natural resource rents and their sub-dimensions, namely oil, mineral, gas, coal and forest rents. All the results are contained in Table 6. Table 6 shows firstly that the effect of natural resources measured by total natural resource rent on energy poverty is negative and significant at the order of 1%. This result is the same when we take into account all five sub-dimensions of rent which corroborates our main result on the one hand and confirms the existence of the natural resource curse on the other hand.

Table 6. Additions of additional variables: verification of the natural resource curse hypothesis

	(1)	(2)	(3)	(4)	(5)
VARIABLES			EPV1		
L.EPV1	0.928***	0.969***	0.965***	0.958***	0.966***
	(0.00314)	(0.000898)	(0.000472)	(0.00114)	(0.00168)
FRTI	**0.0208*** **	**0.0217*** **	**0.0223*** **	**0.0208*** **	**0.0196*** **
	(0.00213)	**(0.00194)**	**(0.00143)**	**(0.00236)**	**(0.00207)**
GDP_perc	-0.0374***	-0.0590***	-0.0601***	-0.0416***	-0.0620***
	(0.00438)	(0.00430)	(0.00205)	(0.00826)	(0.00593)
Trade	0.0426***	0.144***	0.100***	0.0287***	0.130***
	(0.00888)	(0.00858)	(0.00447)	(0.00631)	(0.0111)
Dev_fin	-0.0208*	-0.0289***	0.00958	0.0266**	-0.00414
	(0.0113)	(0.00923)	(0.00612)	(0.0127)	(0.0128)
Tax_rev	0.256***	-0.784***	-0.401***	0.540***	-0.702***
	(0.0586)	(0.0398)	(0.0143)	(0.0351)	(0.0837)
Forest	**-0.635*** **				
	(0.0471)				
Oils		**-0.0347*** **			
		(0.00600)			
Coal_re			**-0.0317*** **		
			(0.00706)		
Mine_r				**-0.201*** **	
				(0.0271)	
TNR					**-0.0314*** **
					(0.00436)
Constant	0.0632***	0.0319***	0.0296***	0.0281***	0.0354***
	(0.00305)	(0.000963)	(0.000250)	(0.00134)	(0.00185)

Observations	1,173	1,167	1,168	1,173	1,168
Number of groups	89	84	90	97	82
Instruments	71	68	72	76	66
AR (1) p-value	0.000	0.000	0.000	0.000	0.000
AR (2) p-value	0.412	0.395	0.298	0.237	0.270
Hansen p-value	0.346	0.151	0.228	0.259	0.938

Standard errors in parentheses

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

Source: Authors own work

4.4.5 Sensitivity Analysis: Heterogeneity by Income Level

We also aim to confirm if the initial results of the estimation vary according to the income level of developing countries. To do this, we carry out an estimation by subgroup. The results are reported in Table 7 below. The analysis of Table 7 shows us that advanced technologies are positively associated with the energy consumption index in three (3) sub-regions of developing countries. In addition, the effect is greater in high-income developing countries, this is justified by the fact that these are countries with a high industrial level and a high score in research and development. Followed by intermediary and countries with middle income. **In countries with low income,** a negative effect of technological preparation on energy consumption is apparent.

Table 7. Income level heterogeneity

	(1)	(2)	(3)	(4)
	Low income	Lower middle income	Upper middle income	High income
VARIABLES	EPV1			
FRTI	**0.888*** **	**0.620*** **	**0.362*** **	**-0.0212***
	(0.265)	**(0.0560)**	**(0.0329)**	**(0.0108)**
GDP_perc	4.596**	0.534*	-0.379**	0.241***
	(1.853)	(0.289)	(0.176)	(0.0320)
Trade	1.842	-0.0318	0.375***	0.521***
	(1.133)	(0.296)	(0.112)	(0.0522)
Dev_fin	-0.289	3.064***	-0.461***	0.0715*
	(2.449)	(0.398)	(0.125)	(0.0422)
Tax_rev	-0.736	1.423**	-8.253***	-0.661**

	(6.786)	(0.697)	(0.704)	(0.303)
Constant	0.0846	0.404***	0.930***	0.928***
	(0.0705)	(0.0284)	(0.0182)	(0.0123)
Observations	127	419	555	132
R-squared	0.840	0.587	0.424	0.958

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Source: Authors own work

5. Conclusion, Implications and Future Research Directions

5.1 Conclusion

This study analyzed the effect of advanced technologies on energy poverty in a panel of 99 developing countries between 2000 and 2021. It mobilizes some estimation methods from the study, such as; OLS with fixed effects, Driscoll-Kraay with fixed effects and generalized least squares (GLS). The main conclusion is that advanced technologies significantly reduce energy poverty in developing countries. Similarly, this effect remains robust to changing estimation approaches, such as the system Generalized Method of Momets (GMM) and Tobit estimation techniques. In addition, we find the effect of advanced technologies on all alternative measures of energy poverty remains identical to the main result. Based on these findings, we can conclusively say that our results are strong to the usage of other methods of energy poverty.

Moreover, by adding natural resources measured by the sum of natural resource rent into the model, it is apparent that natural resources have an inverse impact on energy poverty. This result is the same when taking into account all five sub-dimensions of the rent, which corroborates our main result on the one hand and confirms the existence of the natural resource curse on the other hand. Taking into consideration the heterogeneity of the countries per income level, we find that the effect of advanced technology on energy consumption is greater in high-income developing countries. This is acceptable with the fact that these countries are countries that possess a high industrial level and a high R&D score. Followed by countries with middle and low income. However, in countries with low income, technological readiness has a negative effect on energy consumption.

5.2 Policy Implications

The findings from the study argue that governments in emerging countries should fund and capitalize on Research and Development (R&D) to foster technological innovation. This could include subsidies for technology companies and training programs to build local skills. Policies should encourage the implementation of developed-innovative technologies in the energy sector. This may involve tax incentives for companies that capitalize on sustainable and innovative energy outcomes. Given that natural resources has an inverse impact on energy poverty, it is crucial to put in place policies that promote sustainable resource management. This includes strictly regulating the misuse of natural resources to prevent the resource curse.

In addition, developing countries should attract foreign direct investment (FDI) in the technology sector. FDI-friendly policies can stimulate job creation and improve energy infrastructure. Adopting advanced technologies can improve the competitiveness of developing countries in the global market by reducing energy costs and increasing the efficiency of industrial processes. By integrating advanced technologies, countries can minimize their reliance on traditional energy sources, which can cause a decline in energy costs for consumers and producers. The findings also highlight the need to address income inequality. Policies should ensure that the benefits of advanced technologies are accessible to all segments of the population, particularly in low-income countries.

5.3 Limitations and Future Research Directions

The results of the present study apparently allows for more investigation for future research, in particular to understand whether the conventional findings meets up to experimental insection in country-specific contexts. In considering this suggested direction for future research, robust country-specific empirical strategies should be critically engaged. Furthermore, given the present study's focus on energy poverty, revisiting the empirical analysis in the context of other United Nations (UN) Sustainable Development Goals (SDGs) is an interesting future research direction. including assessing the effect of advanced technology on poverty, inequality, climate vulnerability.

References

Acemoglu, D., & Robinson, J. A. (2006). De facto political power and institutional persistence", *American Economic Review*, *96*(2), 325-330.

Acharya, R. H., & Sadath, A. C. (2019). "Energy poverty and economic development: Household-level evidence from India", *Energy and Buildings*, *183*, 785-791.

Acquah, A. M., & Ibrahim, M. (2020). Foreign direct investment, economic growth and financial sector development in Africa", *Journal of Sustainable Finance & Investment*, *10*(4), 315-334.

Adusah-Poku, F., & Takeuchi, K. (2019). Energy poverty in Ghana: any progress so far?", *Renewable and Sustainable Energy Reviews*, *112*, 853-864.

Ahlborg, H., Boräng, F., Jagers, S. C., & Söderholm, P. (2015). Provision of electricity to African households: The importance of democracy and institutional quality", *Energy Policy*, *87*, 125-135.

Aitken, A. C. (1936). IV. On least squares and linear combination of observations", *Proceedings of the Royal Society of Edinburgh*, *55*, 42-48.

Aluko, O. A., Ibrahim, M., & Vo, X. V. (2023). On the foreign direct investment–economic growth relationship in Africa: does economic freedom mediate this relationship?", *International Journal of Emerging Markets*, *18*(9), 3245-3263.

Amores, A. F., Maier, S., & Ricci, M. (2023). Taxing household energy consumption in the EU: The tax burden and its redistributive effect. *Energy Policy*, *182*, 113721.

Apergis, N., Polemis, M., & Soursou, S. E. (2022). Energy poverty and education: Fresh evidence from a panel of developing countries", *Energy Economics*, *106*, 105430.

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations", *The Review of Economic Studies*, *58*(2), 277-297.

Arellano, M., & Bover, O. (1995). Another look at the instrumental-variable estimation of error", Journal *of Econometrics, 1995 (68): 29—51*.

Asongu, S., & Odhiambo, N. M. (2024). The role of financial inclusion in moderating the incidence of entrepreneurship on energy poverty in Ghana. Journal of Entrepreneurship in Emerging Economies, 16(6), 1481-1499.

Asongu, S. A., Ogbonna, A. O., & Mete, M. C. (2024). Marriage as an argument for energy poverty reduction: the moderating role of financial inclusion. Diversity & Inclusion Research, 1(2), e70001.

Aydin, M., & Turan, Y. E. (2020). The influence of financial openness, trade openness, and energy intensity on ecological footprint: revisiting the environmental Kuznets curve hypothesis for BRICS countries. *Environmental Science and Pollution Research*, *27*(34), 43233-43245.

Barnes, T. D., & Beaulieu, E. (2019). Women politicians, institutions, and perceptions of corruption", *Comparative Political Studies*, *52*(1), 134-167.

Basedau, M., & Lay, J. (2009). Resource curse or rentier peace? The ambiguous effects of oil wealth and oil dependence on violent conflict", *Journal of Peace Research*, *46*(6), 757-776.

Baskaran, T., Min, B., & Uppal, Y. (2015). Election cycles and electricity provision: Evidence from a quasi-experiment with Indian special elections", *Journal of Public Economics*, *126*, 64-73.

Baum, C. F., Lewbel, A., Schaffer, M. E., & Talavera, O. (2012). Instrumental variables estimation using heteroskedasticity-based instruments. In *United Kingdom Stata User's Group Meetings* (Vol. 7). Stata Users Group.

Baum, C. F., Schaffer, M. E., & Stillman, S. (2003). Instrumental variables and GMM: Estimation and testing", *The Stata Journal*, *3*(1), 1-31.

Blackburn, K., Bose, N., & Capasso, S. (2012). Tax evasion, the underground economy and financial development", *Journal of Economic Behavior & Organization*, *83*(2), 243-253.

Blundell, R., & Bond, S. (1998)," Initial conditions and moment restrictions in dynamic panel data models", *Journal of Econometrics*, *87*(1), 115-143.

Bokpin, G. A. (2017), "Foreign direct investment and environmental sustainability in Africa: The role of institutions and governance", *Research in International Business and Finance*, *39*, 239-247.

Boräng, F., & Grimes, M. (2021), "Social accountability and quality of government", *The Oxford Handbook of the Quality of Government*, 268-289.

Bakouan, P., & Sawadogo, R. (2024). BioTrade and income inequality: Does frontier technology readiness matter?. Structural Change and Economic Dynamics, 70, 650-665.

Boutabba, M. A., Diaw, D., Laré, A., & Lessoua, A. (2020). The impact of microfinance on energy access: a case study from peripheral districts of Lomé, Togo. *Applied Economics*, *52*(45), 4927-4951.

Canh, N. P., Thanh, S. D., & Nasir, M. A. (2020). Nexus between financial development & energy intensity: two sides of a coin?", *Journal of Environmental Management*, *270*, 110902.

Capasso, S., & Jappelli, T. (2013). Financial development and the underground economy", *Journal of Development Economics*, *101*, 167-178.

Carmignani, F. (2013). Development outcomes, resource abundance, and the transmission through inequality", *Resource and Energy Economics*, *35*(3), 412-428.

Cheng, Z., Tani, M., & Wang, H. (2021). Energy poverty and entrepreneurship. *Energy Economics*, *102*, 105469.

Correia, S. (2016). A feasible estimator for linear models with multi-way fixed effects. Retrieved from Preprint at http://scorreia. com/research/hdfe. pdf.

Crentsil, A. O., Asuman, D., & Fenny, A. P. (2019). Assessing the determinants and drivers of multidimensional energy poverty in Ghana", *Energy Policy*, *133*, 110884.

D'Amelio, M., Garrone, P., & Piscitello, L. (2016). Can multinational enterprises light up developing countries? Evidences from the access to electricity in sub-Saharan Africa", *World Development*, *88*, 12-32.

Discroll, J., & Kraay, A. C. (1980). Consistent Covariance Matrix Estimation with Spatially Dependent Data", *Review of Economics and Statistics*, *80*, 541-560.

Djeunankan, R., Njangang, H., & Oumbé, H. T. (2024). Examining the Effect of Economic Complexity on Energy Poverty in Developing Countries", *Environmental Modeling & Assessment*, 1-31.

Djeunankan, R., Tadadjeu, S., & Kamguia, B. (2024). Linking energy poverty and industrialization: Empirical evidence from African countries. Energy, 292, 130374.

Doğanalp, N., Ozsolak, B., & Aslan, A. (2021). The effects of energy poverty on economic growth: a panel data analysis for BRICS countries", *Environmental Science and Pollution Research*, *28*(36), 50167-50178.

Domguia, E. N., Pondie, T. M., Ngounou, B. A., & Nkengfack, H. (2022). Does environmental tax kill employment? Evidence from OECD and non-OECD countries", *Journal of Cleaner Production*, *380*, 134873.

Duranton, G. (2008). From cities to productivity and growth in developing countries", *Canadian Journal of Economics/Revue canadienne d'économique*, *41*(3), 689-736.

Eggers, A. C., Vivyan, N., & Wagner, M. (2018). Corruption, accountability, and gender: Do female politicians face higher standards in public life?", *The Journal of Politics*, *80*(1), 321-326.

Farzanegan, M. R., & Krieger, T. (2019). Oil booms and inequality in Iran", *Review of Development Economics*, 23(2), 830-859.

Fum, R. M., & Hodler, R. (2010). Natural resources and income inequality: The role of ethnic divisions", *Economics Letters*, *107*(3), 360-363.

Gafa, D. W., & Egbendewe, A. Y. (2021). Energy poverty in rural West Africa and its determinants: Evidence from Senegal and Togo", *Energy Policy*, *156*, 112476.

Guseh, J. S. (1997). Government size and economic growth in developing countries: a political-economy framework", *Journal of Macroeconomics*, *19*(1), 175-192.

Hall, K. D., Chen, K. Y., Guo, J., Lam, Y. Y., Leibel, R. L., Mayer, L. E., & Ravussin, E. (2016). Energy expenditure and body composition changes after an isocaloric ketogenic diet in overweight and obese men", *The American Journal of Clinical Nutrition*, *104*(2), 324-333.

Hessami, Z., & da Fonseca, M. L. (2020). Female political representation and substantive effects on policies: A literature review", *European Journal of Political Economy*, *63*, 101896.

Kiambu, D.J., Kabikissa, F. J. D., Kaninda, N.A., Moussavou, F., & Tchandema, É. K. (2021). Libéralisation financière et croissance économique. dans la CEMAC: une analyse empirique en panel dynamique », *Marché et organisations*, *42*(3), 163-212.

Kinda, S. R., & Sawadogo, R. (2023). Does financial development really spur industrialization in sub-Saharan African countries?", *African Development Review*, *35*(4), 390-402.

Kyprianou, I., Serghides, D. K., Varo, A., Gouveia, J. P., Kopeva, D., & Murauskaite, L. (2019). Energy poverty policies and measures in 5 EU countries: A comparative study. *Energy and Buildings*, *196*, 46-60.

Lawal, A. I., Ozturk, I., Olanipekun, I. O., & Asaleye, A. J. (2020). Examining the linkages between electricity consumption and economic growth in African economies", *Energy*, *208*, 118363.

Le, T. H., Nguyen, C. P., & Park, D. (2020). Financing renewable energy development: Insights from 55 countries", *Energy Research & Social Science*, *68*, 101537.

Lee, C. C., & Yuan, Z. (2024). Impact of energy poverty on public health: A non-linear study from an international perspective", *World Development*, *174*, 106444.

Lewbel, A. (2012). Using heteroscedasticity to identify and estimate mismeasured and endogenous regressor models", *Journal of Business & Economic Statistics*, *30*(1), 67-80.

Lyubimov, I. (2017). Income inequality revisited 60 years later: Piketty vs Kuznets", *Russian Journal of Economics*, *3*(1), 42-53.

Mignamissi, D., & Nguekeng, B. (2022). Trade openness-industrialization nexus revisited in Africa", *Economic Change and Restructuring*, *55*(4), 2547-2575.

Nguea, S. M., Fotio, H. K., & Baida, L. A. (2022). Investigating the effects of globalization on economic sophistication in selected African countries", *African Development Review*, *34*(3), 324-338.

Nguyen, C. P., & Nasir, M. A. (2021). An inquiry into the nexus between energy poverty and income inequality in the light of global evidence", *Energy Economics*, 99, 105289.

Nguyen, C. P., Su, T. D., Bui, T. D., Dang, V. T. B., & Nguyen, B. Q. (2021). Financial development and energy poverty: global evidence", *Environmental Science and Pollution Research*, *28*, 35188-35225.

Nguyen, T. T., Nguyen, D. N., & Pham, H. T. L. (2023). Survey data on energy-saving policies, energy price, crisis and household energy-saving behavior", *Data in Brief*, *51*, 109646.

Nickell, S. (1981). Biases in dynamic models with fixed effects", Econometrica, 49 (6): 1417–1426. *International Journal of Economic Perspectives ISSN*, 1307-1637.

Ochoa, R. G., & Graizbord, B. (2016). Privation of energy services in Mexican households: An alternative measure of energy poverty. *Energy Research & Social Science*, *18*, 36-49.

Ongo Nkoa, B. E., Mamadou Asngar, T., Atangana Zambo, C. C., & Okere Atanga, D. F. (2023). Does institutional quality accelerate the growth of financial markets in Africa?", *SN Business & Economics*, *3*(4), 87.

Opoku, E. E. O., & Boachie, M. K. (2020). The environmental impact of industrialization and foreign direct investment", *Energy Policy*, *137*, 111178.

Oum, S. (2019). Energy poverty in the Lao PDR and its impacts on education and health", *Energy Policy*, *132*, 247-253.

Peng, D., & Poudineh, R. (2017). An appraisal of investment vehicles in the Tanzania's electricity sector", *Utilities Policy*, *48*, 51-68.

Rafindadi, A. A., & Ozturk, I. (2016). Effects of financial development, economic growth and trade on electricity consumption: Evidence from post-Fukushima Japan. *Renewable and Sustainable Energy Reviews*, *54*, 1073-1084.

Raghutla, C., & Chittedi, K. R. (2022). Energy poverty and economic development: evidence from BRICS economies", *Environmental Science and Pollution Research*, *29*(7), 9707-9721.

Romero, J. C., Linares, P., & López, X. (2018). The policy implications of energy poverty indicators. *Energy Policy*, *115*, 98-108.

Roodman, D. (2009). How to do xtabond2: An introduction to difference and system GMM in Stata", *The Stata Journal*, 9(1), 86-136.

Sachs, J. D., & Warner, A. M. (1999). The big push, natural resource booms and growth", *Journal of Development Economics*, *59*(1), 43-76.

Sachs, J.D., & Warner, A.M. (1995). Natural Resource Abundance and Economic Growth, NBER Working Papers 5398, National Bureau of Economic Research, Inc.

Sarkodie, S. A., & Adams, S. (2020). Electricity access and income inequality in South Africa: evidence from Bayesian and NARDL analyses", *Energy Strategy Reviews*, *29*, 100480.

Schmitter, P.C. and Karl T.L. (1991). What Democracy is... and is Not", *Journal of Democracy*, 2(3): 67-73.

Shahbaz, M., Balsalobre-Lorente, D., & Sinha, A. (2019). Foreign direct Investment–CO2 emissions nexus in Middle East and North African countries: Importance of biomass energy consumption", *Journal of Cleaner Production*, *217*, 603-614.

Shahbaz, M., Khan, S., & Tahir, M. I. (2013). The dynamic links between energy consumption, economic growth, financial development and trade in China: fresh evidence from multivariate framework analysis. *Energy Economics*, *40*, 8-21.

Swamy, A., Knack, S., Lee, Y., & Azfar, O. (2001). Gender and corruption", *Journal of Development Economics*, *64*(1), 25-55.

Tadadjeu, D., Tadadjeu, S., Njangang, H., & Djeunankan, R. (2023). Women's political participation and energy poverty in Sub-Saharan Africa: Effects and transmission channels. *Revue d'économie politique*, *133*(2), 263-300.

UNCTAD. (2021). Technology and Innovation Report 2021. https://unctad.org/system/files/officialdocument/tir2020_en.pdf

Varo, A., Jiglau, G., Grossmann, K., & Guyet, R. (2022). Addressing energy poverty through technological and governance innovation. Energy, Sustainability and Society, 12(1), 49.

Zhang, T., Shi, X., Zhang, D., & Xiao, J. (2019). Socio-economic development and electricity access in developing economies: A long-run model averaging approach", *Energy Policy*, *132*, 223-231.

Appendix

Table 1. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Access to electricity (total)	2618	74.864	30.244	2.538	100
Access to electricity (urban)	2488	67.54	36.04	.562	100
Access to electricity (rural)	2598	88.222	17.611	20	100
Access to fuels (total)	2552	55.785	38.044	.1	100
Access to fuels (urban)	2552	44.614	39.713	0	100
Access to fuels (rural)	2552	67.592	36.23	.1	100
Access to electrical energy	1350	2268.307	3230.755	22.482	21230.07
Access to combustible energy	1409	1757	2768.065	58.504	21420.62
Advanced technologies	2614	.309	.183	0	.865
GDP per capita	2580	5783.983	8107.691	255.1	73493.2
Trade openness	2282	76.347	34.831	4.128	347.997
Financial development	2278	36.527	29.236	.002	182.868
Income taxes	1514	15.336	7.768	.915	147.64
Oil rent	2580	4.727	10.716	0	65.158
Mining rent	2604	1.153	2.838	0	28.813
Forest rent	2604	1.968	3.775	0	40.408
Coal rent	2576	.403	2.352	0	48.722
Natural resources (% GDP)	2593	8.941	11.847	0	79.431

Source: Authors own work

Table A1. List of sample countries

Country Name			
Afghanistan	Comoros	Malawi	Sao Tome and Principe
Albania	Costa Rica	Maldives	Saudi Arabia
Algeria	Cote d'Ivoire	Mali	Senegal
Argentina	Djibouti	Mauritania	Serbia
Armenia	Dominica	Mauritius	Sierra Leone
Azerbaijan	Ecuador	Mexico	South Africa
Bahrain	El Salvador	Moldova	Sri Lanka
Bangladesh	Fiji	Mongolia	Suriname
Barbados	Gabon	Montenegro	Tajikistan
Belarus	Georgia	Morocco	Tanzania
Belize	Ghana	Mozambique	Thailand
Benin	Guatemala	Myanmar	Timor-Leste
Bolivia	Guinea	Namibia	Togo
Bosnia and Herzegovina	Guyana	Nepal	Trinidad and Tobago
Botswana	Haiti	Nicaragua	Tunisia

Brazil	Honduras	Nigeria	Uganda
Bulgaria	India	North Macedonia	Ukraine
Burkina Faso	Indonesia	Oman	Uruguay
Burundi	Iraq	Panama	Vietnam
Cambodia	Jamaica	Papua New Guinea	Zambia
Cameroon	Jordan	Paraguay	Zimbabwe
Chile	Kazakhstan	Peru	
China	Kenya	Philippines	
Colombia	Kuwait	Poland	
	Lebanon	Qatar	
	Libya	Romania	
	Madagascar	Rwanda	

Source: Authors own work

Table A2. 3 Basic Test

Different test	*Statistics*	*Test*	*Problem with our sample panel*	*Correction method*
Pesaran test	*CD test*	*95.421*	*Dependancy problem cross-sectionnal*	*Driscoll-Kraay (1998)*
	P-value	*0.000*		
Wooldridge test	*Fisher*	*52.185*	*Autocorrelation problem*	*GLS Methods*
	P-value	*0.000*		
Breusch-Pagan test	*Chi2*	*34.82*	*Heteroscedasticity problem*	*SYS-GMM (Baum et al., (2006)*
	P-value	*0.0006*		
Shapiro-Wilk	*Wilk test*	*0.75320*	*Normality problem*	*Quantile regression (Koenker and Bassett, 1978)*
	P-value	*0.000*		

Source: Authors own work