Kashmir Economic Review, Volume 31, Issue 2, December 2022

Kashmir Economic Review
ISSN(P): 1011-081X, ISSN(E): 2706-9516
http://www.ker.org.pk

Evaluation of Energy Cleanability Gap and its Impact on Sustainable Economic Development

ABSTRACT

The transition from traditional to sustainable energy is nothing without easy access to clean energy. Therefore, different economies have made smooth transitions, but still, there is a gap in energy cleanability. Here, this study adopted two stage-analyses; initially, it presents an overlook of energy cleanability transition by applying Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) with entropy weightage in low-middle & upper middle-income countries. The fallout of TOPSIS discloses the outcomes and finds more divergence trends in lower-middle-income countries. Furthermore, the current study examined the impact of the energy cleanability gap on economic development in selected panels from 2000 to 2019. Then, unclean energy is to blame for the declining trend in economic development. Furthermore, sustainability in the energy transition is more required as it has its costs and benefits and needs more government commitment and regulatory changes. So, avoiding such vulnerabilities requires massive financing to tackle them and improve flexibility in economic development.

AUTHORS

Muhammad Jaeved Akhtar*
Ph.D. Scholar, University of Management and Technology Lahore, Pakistan.
Author's Contributions: 3,5,6
f2019330012@umt.edu.pk
https://orcid.org/0000-0001-9786-7396

Hafeez ur Rehman
Professor, University of Management and Technology Lahore, Pakistan.
Author's Contributions: 2,4
hafeez.rehman@umt.edu.pk
https://orcid.org/ 0000-0002-3274-6347

Qaiser Abbas
Associate Professor, Department of Economics, Ghazi University, DG Khan, Pakistan.
Author's Contributions: 1,3
qabbas@gudgk.edu.pk
https://orcid.org/ 0000-0001-7217-7970

Keywords
Energy cleanability gap; Economic Development; TOPSIS; Panel Data
JEL Classification
C21, C25, I12

Please cite this article as:
Akhtar, M. J., Rehman, H., & Abbas, Q. (2022). Evaluation of energy cleanability gap and its impact on sustainable economic development. *Kashmir Economic Review*, 31(1), 1-15.

*** Correspondence author**
Author's contribution in the article: 1- Conceived and designed the analysis, 2- Reviewed and compiled the literature, 3- Collected the data, 4- Contributed data or analysis tools, 5- Performed the analysis, 6- Wrote the paper, 7- Financial support for the conduct of the study, 8-Other

1. INTRODUCTION

United Nations General Assembly adopted a resolution in 2015 to make definite access to reliable, affordable, and clean energy for each individual (SDG-7) by 2030. The choices of energy for the kitchen and other purposes are essential to attain SDG-3 (good health and welfare). Furthermore, the literature proves that burning solid fuels releases carbon monoxide and other harmful particulate matter. Primarily, high health concerns are associated with all human beings. Given the above facts, SDG-7 aims to guarantee the achievement of the maximum SDG-2030 objectives.

High-income economies have made significant progress toward their SDG-7 goals in the last few years. Furthermore, these transition progress are connected with an efficient public policy to enhance widespread access to environment-friendly fuels. This transition is relatively low in upper-middle-income economies (UMIE), where 30-35% of households use unclean fuels for cooking. However, such a paradigm shift in low-middle income economies (LMIE) is long behind; primarily, contaminated fuels are still used in rural areas on a large scale. In particular, 70% of rural households rely on unclean energy for cooking due to poor quality of life, income inequality, and other social issues. One of the barriers preventing homes from effectively switching to clean energy could be the frequent unavailability or load shedding in the LMIE. Therefore, many socioeconomic issues originate from unclean fuels and still spreading in LMIE.

Numerous projects are under completion among different regions, and countries anywhere access to clean energy infrastructure is inadequate. Many earlier development projects require better access to low-cost and sustainable energy. An extraordinary transition to energy cleanability is underway in upper and lower-income countries (LMIE & UMIE). Making this transition easy can guide further rapid moves forward in community welfare than would or else be viable. Therefore, a rapid novelty in infrastructure, technology, market, organization, and strategies make energy cleanability transitions more feasible than before (Akhtar, M. J., Ashraf, W., & Rehman, H., 2020).

As well as meeting growing energy demands and extenuating greenhouse gas discharge, transitions to energy cleanability can help households who experience energy and economic poverty. For case, low-cost and clean energy can frankly perk up the income of low-income households by increasing their income status, enhancing productivity in the agricultural sector, and saving precious time. Clean energy also contains other benefits, educational achievement, better literacy, more free time, and improved access to information and news via radio, mobile phone, and television. Moreover, energy cleanability sources can perk up welfare and diminish hard work simultaneously as they expand work and free time. At the same time, empirical studies highlight frequent reimbursement of energy cleanability transition. Understanding the drivers of such changes and their effects on human welfare is critical for the continuing and potential energy cleanability transitions to be successful across countries and regions.

The triennial report of The Committee of Development Plans, Council (2022) revealed that LMIEs are highly vulnerable and face shocks of environmental changes due to their poor socioeconomic condition. Further, these ecological changes slow their pace toward sustainable development and structural reforms. Moreover, as developed countries across the globe set their paths towards attaining significant progress of the SDGs-2030, the LMIE is facing massive poverty and unemployment. Furthermore, these economies face the threat of low illiteracy levels, low life expectancy, and more income inequality. In this view, the UNDP and the University of Oxford (2021) report that these factors drive the LMIE economies un-deliberately towards plain growth instead of sustainable planning.

This paper aims to compare the sustainable energy transition gap in the context of SDGs-2030 in selected countries and estimate the impact of the energy cleanability gap on sustainable economic development for the period 2000-19. The critical research problems with the perspective of SDGs-2030 are:

- What is the current energy cleanability situation in selected countries?
- How does energy cleanability impact economic development?
- How does development expenditure determine economic development?
- How does industrial value addition determine economic development?
- How does trade liberalization determine economic development?

This study has two parts, and the first use the TOPSIS technique to compare where various countries are in their energy cleanability transition. In the 2nd step, a regression process is used to explore the connection between economic development and energy cleanability transition. This study used various predictors of economic development to analyze the impact. The outcomes can assist in making economic development policy to achieve SDGs-2030 with an energy cleanability transition.

2. LITERATURE REVIEW

The literature lacks a unified definition of the energy transition gap (Akhtar, M. J., Rehman, H., & Abbas, Q. (2022). Clean cooking describes the way that does not produce indoor air pollution (such as carbon monoxide or particulate matter) or, if these gases are created, the quantity of these gases is very deficient (Akhtar, M. J., Ashraf, W., & Rehman, H., 2020). Socioeconomic considerations, energy preferences, technological advancements, the availability of energy sources, and energy cost are all critical influencing factors. In addition, the community's preferences, gender standards, recognized traditions, and economic structure are entwined with using unclean fuels for cooking. Economic development, along with the promotion of sustainability, is currently an increasing concern on a worldwide scale. Sustainability requires cooperation, accuracy, responsibility, and teamwork in the economic development plan (Akhtar, M. J., Rehman, H., & Abbas, Q. (2022).

Furthermore, numerous assessments have been produced (Yao et al., 2020; Munten et al., 2021; OECD, 2019; Li et al., 2022; (Akhtar, M. J., Ashraf, W., & Rehman, H., 2020); (Akhtar, M. J., Rehman, H., & Abbas, Q. (2022)):, and others have looked into the relationship between overall economic development, energy consumption, and other critical economic vectors. The study by (Yao et al., 2020) conducted a systematic review and concluded that the same principles do not bind studies to the connection between economic development and energy sources. Their study concluded that numerous scholars had investigated the empirical impact of total energy consumption on economic growth. Moreover, the study of Munten et al. (2021) captured the direct effects of energy concerns on development. It concluded that the spillover effect between total energy consumption & economic growth on human health. Therefore, he further added in his policy implications that clean fuel is a basic need to enhance livelihoods and, more broadly, human development. Now, it is a rising subject of SDGs-2030.

Furthermore, the study of Manole et al. (2017); Li et al. (2022) focused on measures to combat energy-related impacts on health and observed that energy consumption mostly depends on fossil inputs, even in developed countries, which negatively affects health. Furthermore, the study by OECD (2019) observed that unclean energy would continue to dominate the energy mix in the future and remain an essential energy source for 10 to 15 years in LMIE economies worldwide.

The study by Garba and Bellingham (2021) found four potential relationships in the literature (neutral, conservation, growth, and spillover theories). Furthermore, they define the unbiased approach when there is an insignificant relationship between energy and economic development. Moreover, conservation theory focusing on demand management and reducing the use of fossil fuels, among others, would not negatively affect the nation's economy. Thirdly, according to the growth hypothesis, energy is necessary for the nation's economic development. Finally, the spillover theory applies when there is a two-way causal relationship between energy and economic growth.

Regarding low-middle income economies (LMIE), the study by Akhtar, M. J., Rehman, H., & Abbas, Q. (2022) found that the problems with energy are well known, and researchers are increasingly looking at how energy influences the region's growth. More recently, using the Fully Modified Ordinary Least Square (FMOLS) as well as Dynamic Ordinary Least Square (DOLS) method, (Li et al., 2022) studied the relationship between energy use and economic growth in LMIE. Applying the same strategy, (Akhtar, M. J., Ashraf, W., & Rehman, H., 2020) analyzed how energy and economic development. The study by (Li et al., 2022) that looks into the energy-growth nexus for LMIE and the relationship between energy and economic growth are among recent works attempting to understand this relationship. However, the study by (Akhtar, M. J., Rehman, H., & Abbas, Q. (2022) and several other studies investigating these linkages have observed varying conclusions.

This paper crammed a gap in the literature by investigating the energy cleanability gap assessment and its empirical impact on economic development in all income panels segregated by WDI using FMOLS and DOLS techniques. Further, including R&D expenditure, industrial value addition, and trade liberalization in the analysis made this study more comprehensive.

In various aspects, this work makes a sufficient and significant contribution to the growing body of knowledge on the relationship between the use of unclean energy and the success of sustainable development. This research tries to fill in some of the knowledge gaps currently in the study linking impure energy and development outcomes. Initially, this article examines the connections between energy usage from unclean sources as a critical threat to growth from a supply-side perspective, given the relationship between energy produced from filthy energy sources and development, as mentioned in this section. Analysis in earlier studies has concentrated chiefly on demand or overall energy consumption. The modeling paradigm lacks a supply-side analysis considering institutional, economic, and demographic influences on developmental quality.

The use of a broad assessment in this study rather than just one indicator, the energy cleanability gap (ECG) index, is its second contribution to existing knowledge. The ECG records the deterioration of human health, the insecurity of food and water sources, and the existence of toxic compounds that impact the environment. The results based on the ECG offer greater analytical integrity with more substantial policy implications. The ECG hasn't been considered in previous studies' modeling frameworks.

The fact that previous empirical studies did not assess how clean energy influences the world's collective participation in preventing global economic development is a third significant contribution to the new corpus of knowledge. The United States of America's decision to leave the Paris Climate Change Agreement exemplifies the lack of international commitment. Interestingly, there is little empirical research on how committed the global community is to addressing weaknesses in economic growth.

The study's final new insight is that the energy cleanability gap is the primary factor that can result in health problems. Nonetheless, the topic of discussions about international economic development and the energy cleanability gap is infrequent with this in-depth. This research broadens the conversation about how dirty energy affects economic growth and emphasizes that effect. It also provides empirical support for that claim. It attempts to increase awareness and attract more attention to energy-producing nations using unclean energy produced by efficient energy policies to further economic development. It is anticipated that governments of these countries with unclean energy will successfully create their economic development plans to realize their goals for a more healthy and robust global economy.

3. DATA AND METHODOLOGY

This research article contains two different phases. The 1st phase was committed to evaluating the energy cleanability assessment in selected countries for the period 2000–2019 by using TOPSIS (Che et al., 2021). Therefore, we choose the TOPSIS model to incarcerate the performance and dynamics while concurrently evaluating the stability within and across the dimension. In 2nd phase, this study examined the empirical connection among selected variables using panel-FMOLS. Moreover, the study used DOLS for robustness (Li et al., 2022) regression models.

3.1 Data

We focus on the analysis of 73 countries (see Table 1) from 2000 to 2019. Energy cleanability was obtained using the TOPSIS index form using the following variables mentioned in Table 2, and comparative assessments were made among selected countries. Energy cleanability data are obtained from the 2021 WDI and IEA. Finally, the data source of total development expenditure, industrial value addition, and trade liberalization are taken in WDI-2021.

3.2 TOPSIS Analysis

This study employed the TOPSIS methodology. TOPSIS is a mathematical modeling technique introduced by Ching Lai Hwang and Yoon in 1981, with further developments by Yoon in 1987 and Hwang, Lai, and Liu in 1993 wikipedia.org (2019) to evaluate the relative closeness to the ideal situation. In the current analysis, this study engaged TOPSIS to assess the dynamics of energy cleanability during the period 2000–2019. TOPSIS consent exchanges between criteria, where superior outcomes in another standard can cancel a bad result in one measure. This process provides a more natural form of modeling than non-compensatory methods, which include or exclude alternative solutions based on hard cut-offs.

Z is processed to get the standard evaluation matrix.

$$Z = [\beta_{ij}] \tag{1}$$

Where β_{ij} represent the attainment of vectors j for economies. $i, i \in [1, m], j \in [1, 8]$, M is the procedure to acquire the typical decision-based matrix.

$$M = [\gamma_{ij}]_{m\times 8} \tag{2}$$

While the significance of vectors in energy cleanability assessment changes, the weight through entropy is espoused in this study. Agree to $K = [k]_{ij}$ be the standard weighted matrix.

$$k_{ij} = \sum_{i=1}^{m} \gamma_{ij} \times \omega_j, \omega_j > 0 \; and \sum \omega_j = 1 \tag{3}$$

Further, the random assortment towards ideal solutions makes a rank reversal process. The restrictions of each vector right through are defined as complete optimistic and pessimistic idyllic solutions. Due to data availability limitations, the selected panel contains only 129 countries in this study. So, absolute ideal solutions can be written as follows:

$$K^+ = \{k^+_{1worst}, k^+_{2worst}, \cdots, k^+_{8worst}\} \tag{4}$$

Where k^+_{jworst} is the least amount of indicator j.

Table 1: Selected Countries codes and Variables

Code	Countries	Code	Countries	Code	Countries	Code	Countries
ALB	Albania	GTM	Guatemala	VEN	Venezuela, RB	MNG	Mongolia
ARG	Argentina	IRN	Iran, Islamic Rep.	DZA	Algeria	MAR	Morocco
ARM	Armenia	IRQ	Iraq	AGO	Angola	NPL	Nepal
AZE	Azerbaijan	JAM	Jamaica	BGD	Bangladesh	NIC	Nicaragua
BLR	Belarus	JOR	Jordan	BEN	Benin	NGA	Nigeria
BIH	Bosnia and Herzegovina	KAZ	Kazakhstan	BOL	Bolivia	PAK	Pakistan
BWA	Botswana	LBN	Lebanon	KHM	Cambodia	PHL	Philippines
BRA	Brazil	MYS	Malaysia	CMR	Cameroon	SEN	Senegal
BGR	Bulgaria	MEX	Mexico	COG	Congo, Rep.	LKA	Sri Lanka
CHN	China	NAM	Namibia	CIV	Cote d'Ivoire	TZA	Tanzania
COL	Colombia	MKD	North Macedonia	EGY	Egypt, Arab Rep.	TUN	Tunisia
COD	Congo, Dem. Rep.	PRY	Paraguay	SLV	El Salvador	UKR	Ukraine
CRI	Costa Rica	PER	Peru	GHA	Ghana	UZB	Uzbekistan
CUB	Cuba	RUS	Russian Federation	HND	Honduras	VNM	Vietnam
DOM	Dominican Republic	SRB	Serbia	IND	India	ZMB	Zambia
ECU	Ecuador	ZAF	South Africa	IDN	Indonesia	ZWE	Zimbabwe
EST	Estonia	THA	Thailand	KEN	Kenya		
GAB	Gabon	TUR	Turkey	KGZ	Kyrgyz Republic		
GEO	Georgia	TKM	Turkmenistan	MDA	Moldova		

Table 2

Name	Variables	Description	References	Data Source
Clean Energy	Access clean cooking energy	(% population)	(Akhtar, M. J., Rehman, H., & Abbas, Q., 2022; Che et al., 2021)	WDI
	Renewable energy	(% population)	(Akhtar, M. J., Rehman, H., & Abbas, Q., 2022)	IEA
ED	Economic development index	Index (0 to 1)	(Akhtar, M. J., Rehman, H., & Abbas, Q., 2022)	UNDP
IND	Industrial value addition	[Industry (including construction) value Added % of GDP]	(Akhtar, M. J., Rehman, H., & Abbas, Q., 2022)	WDI
TRD	Trade liberalization	[Trade % of GDP]	(Akhtar, M. J., Rehman, H., & Abbas, Q., 2022)	WDI
R&D	Total development expenditure	[Education and Health expense % of GDP]	(Akhtar, M. J., Rehman, H., & Abbas, Q., 2022)	WDI
CL	Energy Cleanability Gap	Index (0 to 1)	(Che et al., 2021)	WDI, IEA, BP

Absolute negative ideal solutions are written as:

$$K^{-} = \{k_{1best}^{-}, k_{2best}^{-}, \cdots, k_{8best}^{-}\} \quad (5)$$

Where k_{jbest}^{-} is maximum of indicator j, virtual negative ideal solutions are introduced to pick up a better ideal condition.

$$K^{*} = \{k_1^{*}, k_2^{*}, \cdots, k_8^{*}\}\ (where k_j^{*} = 2k_{jworst}^{-} - k_{jbes}^{+}) \quad (6)$$

Alteration through the Absolute negative ideal solutions K^{-} and to keep away from Euclidean distance withdrawal.

$$S_i^{+} = \sqrt{\sum_j^8 \left(k_{ij} - K_{jbes}^{+}\right)^2} \quad (7)$$

$$S_i^{-} = \sqrt{\sum_j^8 \left(d_{ij} - K_j^{*}\right)^2} \quad (8)$$

The proximity is apparent as:

$$E_i^{*} = \frac{S_i^{+}}{S_i^{+} + S_i^{-}} \quad (9)$$

Where $0 \leq E_i^{*} \leq 0.1$ the countries with E_i^{*}, in order of least to most significant decrease, are organized and the countries with occurrence lower unclean energy.

3.3 Methodology

This study considers the following regression model:

$$ED_{it} = \alpha_{it} + \delta_1 lnCL_{it} + \delta_2 CL_{it}^2 + \delta_3 lnEXP_{it} + \delta_4 lnTRD_{it} + \delta_5 lnIND_{it} + \varepsilon_{it} \quad (10)$$

Where; $t = 1,2,\ldots,T,\ i = 1,2,\ldots,N,\ t,$ represents time across the period, T; i symbolized here cross-section in the selected panel, α_{it} are intercept and ε_{it} indicate anticipated residual, which reveals the divergence from the long-term association.

In equation (01), if the EKC hypothesis holds, the coefficient of energy cleanability must be statistically significant. Different studies argued that cointegration methods help classify the variables' links in literature. Various techniques are adopted to check data set validation, and unit root tests are one of the more critical techniques for the stationarity characteristics of the selected variables.

3.5 Unit Root Test

The unit root test is necessary for determining the cointegration test procedures. It presumptively predicts that the variable will move toward a long-run equilibrium in its respective period. Because of the prolonged timeframe and inconsistent issues that the panel data in this study confronts, spurious regression is likely to be carried out. In this way, the variables in the model must be stationary for the panel regression process. Thus, the Augmented Dickey-Fuller (henceforth ADF) test gave rise to the Levin et al. (2002) (LLC) method, which is the most often used in the panel methodology for unit root tests. LLC asserted that all groups have the same autoregressive parameters under null and alternative assumptions. Hence, to the description for the leeway of correlation and possible spillage crossways countries, the structure of the LLC analysis may be specified as follows:

$$\Delta Y_{it} = \rho Y_{it} + \alpha_{0i} + \alpha_{1i} t + u_{it},\ i = 1,2,\ldots,N,\ t = 1,2,\ldots,T \quad (11)$$

Where, t includes both the individual special effects (α_i) and the time tendency. To follow a stationary ARMA approach for each individual, u_{it} it is intended to be distributed but independently for every individual.

$$u_{it} = \sum_{j=1}^{\infty} \theta_{ij}\, u_{it-j} + \epsilon_{it} \quad (12)$$

The IPS method is the expansion of LLC however permits heterogeneity by allowing for the employ of means of the ADF analysis and probability chance. Consequently, unlike LLC, short panels are required for a higher test power (Behera et al., 2020). The IPS panel stationarity regression is expressed as follows for observation group N and period T:

$$\Delta X_{it} = \alpha_i + \pi_{it} + \beta_i X_{i,t-1} + \sum_{j=1}^{k} \varphi_{it}\, \Delta X_{i,t-1} + \epsilon_{it} \quad (13)$$

Conversely, both (LLC&IPS) procedures have the shortcoming of pretentious independence crosswise segregation of the selected panel (Garba&Bellingham, 2021). It supposes a homogeneous group.Im et al. (2003) developed the IPS unit root test. Using augmented Dickey-Fuller (ADF) regression, the method obtains the t-statistics value after adjusting for heterogeneity.

3.6 Cointegration Techniques

Furthermore, this study performs cointegration techniques, i.e., Pedroni (2004) and Kao (1999) tests that manage the issue and reliable results. The Pedroni techniques tackle homogeneity and heterogeneity as well. Mathematically it is represented as:

$$ED_{it} = \alpha_i + \lambda_{it} + \sum_{j=1}^{m} \beta_{j,i} CL_{j,it} + \zeta_{it} \quad (15)$$

In this equation; ζ_{it}, are residuals and Kao test based on homogeneity assumption across all panels. They follow a similar draw as Pedroni but are based on the premise of homogeneity across boards with:

$$CL_{it} = \alpha_i * ED_{it}\beta + \omega_{it} \quad (16)$$

$\alpha_i =$ Individual constant term,$\beta = slopeparameter$, as well as $\omega_{it} =$ stationary distribution.

3.7 Estimation Techniques

Substantial complications arise in the estimation process in the fixed and random effects settings. The primary difficulty is that the lagged dependent variable is correlated with the disturbance term, even if it is assumed that ε_{it} (equation 10) is not auto-correlated. In this view, fully modified OLS (FMOLS) and Dynamic panel OLS (DOLS) are better techniques to deal with this situation.

3.7.1 Fully Modified Ordinary Least Square Method

The FMOLS and DOLS methods were proposed by Pedroni (2004), respectively. FMOLS method is also considered a non-parametric estimation technique that corrects OLS biases with endogeneity and serial correlation issues among vectors and residuals. Thus, it has fewer assumptions. In this case, FMOLS estimation can be performed with the following equation:

$$\omega_{GM} = N^{-1} \sum_{i=1}^{N} \left[\sum_{t=1}^{T} (\Delta CL_{it} - CL'_{i})^2\right]^{-1} \left[\sum_{t=1}^{T} CL_{it} - CL'_{i}) ED'_{i} - T\tau_i\right] \quad (17)$$

3.7.2 Dynamic Ordinary Least Square Method

For robustness, we apply the DOLS estimation techniques generated by Pedroni (2004); it is a flexible method owing to allowing the heterogeneous vectors to cointegration within a dimension. Moreover, it is a parametric technique and usually dispersed test which regulates errors during reinforcing stationary regressors by leads and lag values at 1st differences. For example, the following equation can express the DOLS method:

$$ED_t = \gamma_i + CL'_i\beta + d_{1t}\psi_1 \sum_{j=q}^{r} \Delta CL'_{t+j}\delta + \mu_{it} \quad (18)$$

DOLS and FMOLS produced more reliable estimates.

4. ESTIMATION RESULTS

4.1 Performance towards Energy cleanability

The most common measure of the clean energy gap (ECG) in the suggested evaluation method (TOPSIS) is presented in Table 3. Energy is a crucial component of production, and it has played a critical role in supporting livelihoods and propelling economic growth. The study's findings show that from 2002 to 2015, 55% of the 29 UMIC countries moved towards renewable and clean energy. Also, the amount of electricity produced by oil is constantly decreasing. Furthermore, the ECG indices have fluctuated over time for different countries, so 26% of UMIE has faced the divergence. The reason behind this divergence is that the quality of access to clean energy may significantly impact household behavior in fuel selection, and 19% of countries maintain their 2019 from 2015 ECG score. In this context, UMICs have priorities of economic expansion with the traditional energy-based infrastructure of industrialization. Considering the ECG scores of LMIE, 55%from from 34 showed a little convergence. However, their share of clean energy sources in their aggregate energy share is also meager because many factors affect energy prices, which significantly impact the choice of cooking fuel.

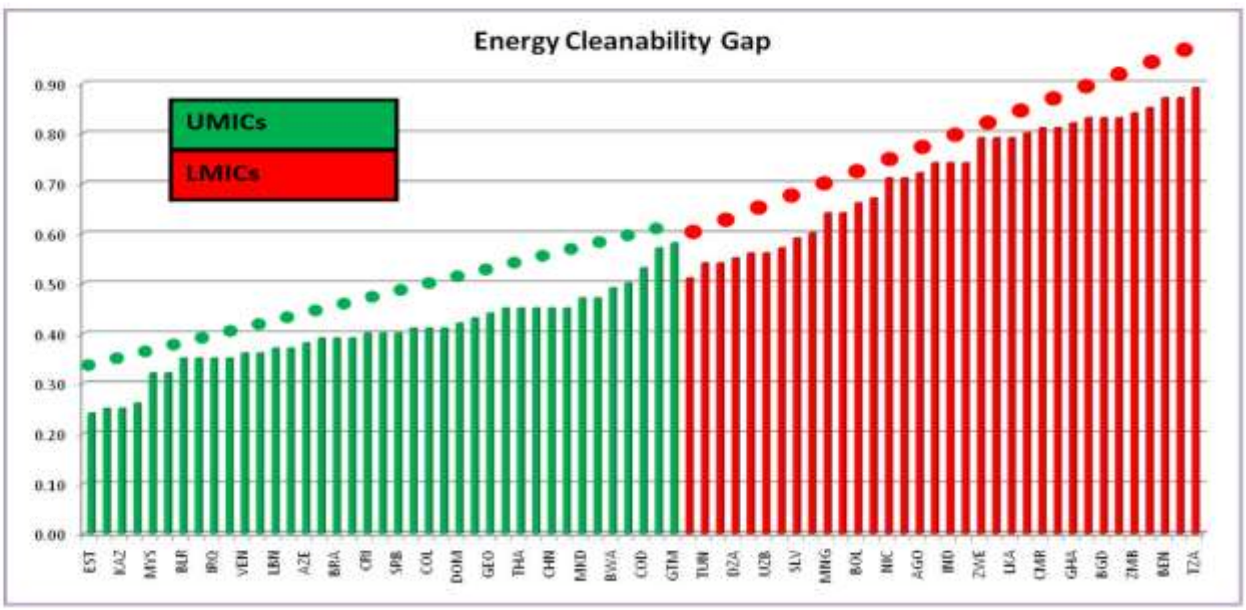

Figure1: Comparison of energy-cleanability gap between low-middle-income & upper middle income countries (Authors' estimation)

The households in Kazakhstan and the Kyrgyz Republic are more inclined to use clean fuels like natural gas since they're situated in areas with abundant gas resources that exist naturally. Furthermore, 34% were kept, while 11% of the LMIE diverged between 2000 and 2015. In addition,t The choice of cooking fuel is influenced by household size. In this way, LMIEs typically have larger households and are more likely to use coal and wood. On the other hand, in urban areas, larger homes are more likely to use electricity and other cleaner fuels as energy input. The figure 1 shows that there is significant difference in the energy cleanability transition gap in selected two panels.

Table 3: Ranks of energy cleanability gap

Code	2000	2005	2010	2015	2019	Code	2000	2005	2010	2016	2019	Code	2000	2005	2010	2016	2019
UMIE																	
RUS	0.32	0.29	0.29	0.25	0.25	CRI	0.43	0.41	0.42	0.41	0.40	THA	0.50	0.48	0.47	0.45	0.45
EST	0.33	0.27	0.26	0.23	0.24	ECU	0.44	0.42	0.41	0.39	0.40	GAB	0.51	0.48	0.47	0.45	0.45
VEN	0.34	0.33	0.34	0.34	0.36	MEX	0.44	0.43	0.43	0.41	0.41	MKD	0.54	0.51	0.50	0.48	0.47
TKM	0.36	0.32	0.30	0.25	0.26	ARM	0.46	0.42	0.41	0.40	0.39	CHN	0.57	0.53	0.49	0.45	0.45
MYS	0.38	0.36	0.34	0.32	0.32	BGR	0.46	0.39	0.39	0.36	0.37	BIH	0.58	0.54	0.50	0.46	0.43
ARG	0.39	0.37	0.37	0.35	0.36	COL	0.46	0.44	0.43	0.42	0.41	BWA	0.58	0.55	0.53	0.51	0.49
BLR	0.39	0.37	0.36	0.34	0.35	DOM	0.46	0.45	0.44	0.42	0.42	ALB	0.59	0.54	0.50	0.46	0.45
TUR	0.39	0.38	0.37	0.35	0.35	AZE	0.47	0.42	0.41	0.38	0.38	GEO	0.59	0.54	0.50	0.45	0.44
JOR	0.40	0.39	0.39	0.38	0.39	IRQ	0.47	0.41	0.39	0.36	0.35	PRY	0.59	0.56	0.54	0.51	0.50
KAZ	0.40	0.33	0.27	0.24	0.25	JAM	0.47	0.44	0.44	0.42	0.41	GTM	0.61	0.60	0.60	0.58	0.58
LBN	0.40	0.38	0.38	0.37	0.37	SRB	0.47	0.45	0.44	0.41	0.40	NAM	0.62	0.60	0.59	0.58	0.57
IRN	0.41	0.37	0.34	0.31	0.32	ZAF	0.48	0.43	0.39	0.36	0.35	PER	0.62	0.55	0.51	0.48	0.47
BRA	0.42	0.41	0.40	0.39	0.39	CUB	0.50	0.48	0.46	0.45	0.45	COD	0.67	0.64	0.61	0.57	0.53
LMIE																	
UKR	0.53	0.50	0.50	0.51	0.51	NIC	0.78	0.76	0.74	0.72	0.71	CMR	0.86	0.85	0.84	0.82	0.81
TUN	0.57	0.56	0.55	0.54	0.54	ZWE	0.78	0.78	0.79	0.79	0.79	COG	0.86	0.85	0.84	0.81	0.81
DZA	0.59	0.57	0.56	0.54	0.55	HND	0.79	0.76	0.74	0.71	0.71	BGD	0.87	0.86	0.85	0.84	0.83
MAR	0.59	0.57	0.56	0.56	0.56	SEN	0.79	0.79	0.79	0.78	0.79	GHA	0.87	0.86	0.85	0.82	0.82
UZB	0.59	0.57	0.56	0.55	0.56	MNG	0.80	0.77	0.73	0.66	0.64	IDN	0.87	0.82	0.75	0.69	0.67
EGY	0.60	0.57	0.56	0.54	0.54	IND	0.82	0.79	0.77	0.74	0.74	KHM	0.88	0.87	0.86	0.84	0.83
MDA	0.66	0.62	0.59	0.57	0.57	PAK	0.82	0.79	0.77	0.75	0.74	BEN	0.89	0.89	0.88	0.87	0.87
BOL	0.67	0.65	0.63	0.67	0.66	CIV	0.83	0.83	0.83	0.83	0.83	KEN	0.89	0.88	0.87	0.85	0.85
SLV	0.70	0.66	0.63	0.60	0.59	LKA	0.84	0.83	0.82	0.80	0.79	NGA	0.89	0.89	0.88	0.88	0.87
KGZ	0.70	0.67	0.64	0.60	0.60	VNM	0.84	0.79	0.73	0.66	0.64	TZA	0.89	0.89	0.89	0.89	0.89
AGO	0.77	0.75	0.74	0.73	0.72	ZMB	0.84	0.84	0.84	0.84	0.84						
PHL	0.77	0.76	0.75	0.74	0.74	NPL	0.85	0.84	0.82	0.81	0.80						

Source: Authors' calculation

Table 5 shows the variance inflation factor to check the issue of multicollinearity using variance inflation factor is an appropriate process and pursue the standard. But, again, the digit should not be as much as 10, and there is no concern about multicollinearity.

Table 4: Variance Inflation Factor

	ED	CL	R&D	IND	TRD
ED	---				
CL	1.097	---			
R&D	1.520	1.010	---		
IND	1.170	1.091	1.261	---	
TRD	1.003	1.010	1.118	1.031	---

Source: Authors' calculation

All variable results after applying the VIF formula of $(1/(1-r2))$ are below the critical value. Hence, all factors demonstrate that multicollinearity is not problematic in selected variables (see Table 4). Within the line or range of 10, the maximum value of VIF for value in these variables is 1.52. Furthermore, various unit root tests are utilized to analyze the stationary variables to avoid erroneous regression results. Table 5 summarizes the results from the various unit root tests. The unit root test's null hypothesis is "there exists a unit root".

Table 5: Results of unit root tests

Variables	LLC	IPS	ADFF	PPF
HDI	-10.17***	4.12	226.26	856.79***
ΔHDI	-11.14***	-10.24***	541.81***	1324.65***
ECG	-3.37***	-2.60***	160.28***	409.03***
ΔECG	-20.20***	-15.26***	375.43***	589.88***
R&D	-4.00***	-0.87	266.82	304.08**
ΔR&D	-19.07	-19.24***	778.02***	1845.22***
IND	-3.56***	0.63	233.15	284.69
ΔIND	-19.75***	-19.19***	776.57***	1848.70***
TRD	-4.60***	-0.56	248.64	243.11
ΔTRD	-20.52***	-18.33***	820.29***	1523.60***

***, **, * shows significance level at 1%, 5% and 10% respectively (Source: Authors calculation)

The findings suggest that a unit root process exists in the panel at the level and that some variables accept the null hypothesis that they are not stationary at the level. Nonetheless, the findings of the stationarity test show that every model variable is stable at the first difference and satisfies the requirements for threshold regression modeling by disproving the unit root hypothesis. Also, two cointegration tests were used in this study to confirm the long-term relationships between the variables examined. The outcomes are presented in table 6.

Table 6:

Cointegration Test		LMIE	UMIE
		Statistic	Statistic
	Modified Phillips-Perron test	4.79***	6.42***
Pedroni	Phillips-Perron test	-6.36***	-3.02***
	Augmented Dickey-Fuller test	-7.09***	-2.58***
Kao	ADF	-3.99***	-2.21**

***, **, * shows significance level at 1%, 5% and 10% respectively (Source: Authors calculation)

The attained outcomes accept the alternative hypothesis of cointegration significantly in LMIE and UMIE panels. Furthermore, the following analysis stage involved evaluating the long-run elasticities. Therefore, FMOLS & DOLS estimators provided the between-dimension "group mean" and allowed for more flexibility in the presence of heterogeneity problems of the cointegrating vectors. Furthermore, the outcomes of FMOLS models are presented in table 7.

Table 71: Long-run Equation (FMOLS)

Panels	LMIE	UMIE	LMIE	UMIE
Variable	FMOLS		DOLS	
ECG	2.04**	2.75***	3.42***	2.52***
ECG2	-1.80***	-2.35***	-2.78***	-2.24***
R&D	0.03**	0.03***	0.03***	0.05***
IND	0.01	-0.06***	0.02	-0.04***
TRD	0.02	0.02***	0.01	0.02***

***, **, * shows significance level at 1%, 5% and 10% respectively (Source: Authors calculation)

The results obtained from the FMOLS model are presented in table 7. The outcome shows that the energy cleanability gap (ECG) significantly impacts Economic Development (ED). The results show that a 1 unit increase in ECG has to increase ED by 1.82 & 2.59 units in L, LMIE&UMIE panels, respectively. Due to the traditional economic structure, the unclean energy pattern has an encouraging influence on income and employment. Therefore, the current ECG positively impacts income development, benefiting private productivity and consumption. However, the effect of ECG2 on ED is significantly negative. In particular, empirical outcomes demonstrate that a 1% increase in ECG2 has to decrease 1.476 & 2.17 ED in the LMIE & UMIE panel, respectively. The ECG2 negatively impacts health from non-clean energy-based economic activity that reduces aggregate economic outcomes through global feedback Sasmaz et al. (2020). The plots show an in-depth analysis of the quadratic effect of ECG on ED using panel GMM and panel FMOLS and DOLS compared to the post-regression graph.

The 3D plots of GMM provide each combination. The figure 2 & figure 3 shows the curvilinear relationship between energy cleanability gap and sustainable economic development in selected two-panel. Here, it can be observed that an increase in the ECG gap has a quadratic effect on ED in LMIE and UMIE panels. But in the case of ECG squares, it turns down its development, which makes an inverted U-shape curve. After post-estimation from FMOLS and DOLS, the graph depicts the same angle, which is a further robustness check of GMM plots except for the LICs panel.

Furthermore, the development expenditure (R&D) also significantly impacts ED in UMIE. The findings show that a 1% increase in R&D increases 0.02% ED in UMIE. R&D is helping to decrease resource depletion, promoting more sustainable practices, and paving the way to sustainable development. As a result, R&D is seen as having a convergent effect since it offers many benefits, including the conservation of resources, raising living standards, expanding access to goods and services at reduced prices, and providing insights for new sources of income. However, R&D does not impact ED in LMIE because, in this panel, R&D is relatively low; it is crucial to speed up economic development and social values Akhtar, M. J., Rehman, H., & Abbas, Q. (2022).

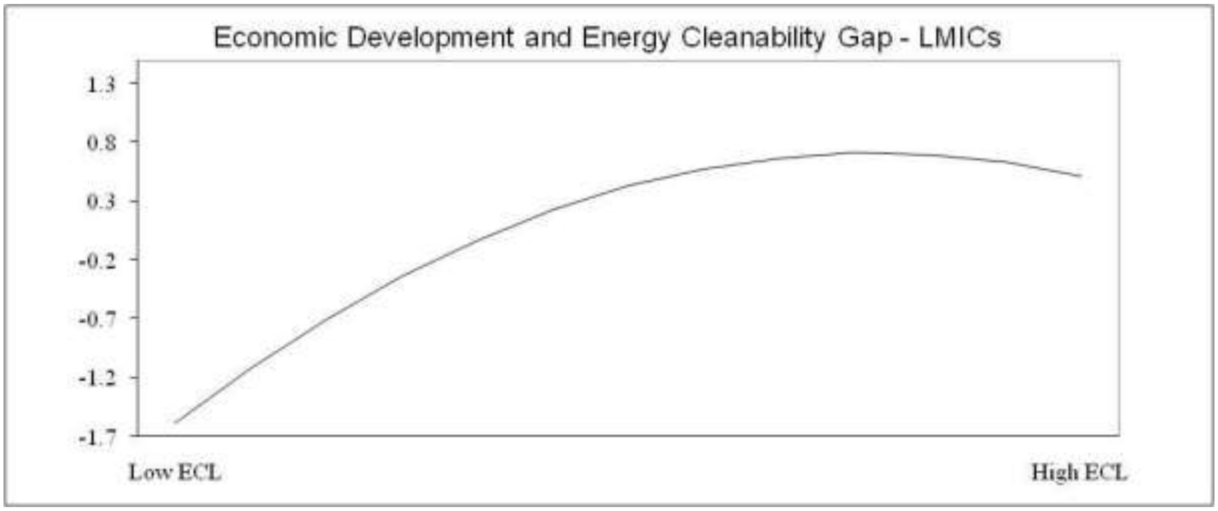

Figure 2: Quadratic Effect of Energy Cleanability on Economic development (Source: Authors calculation)

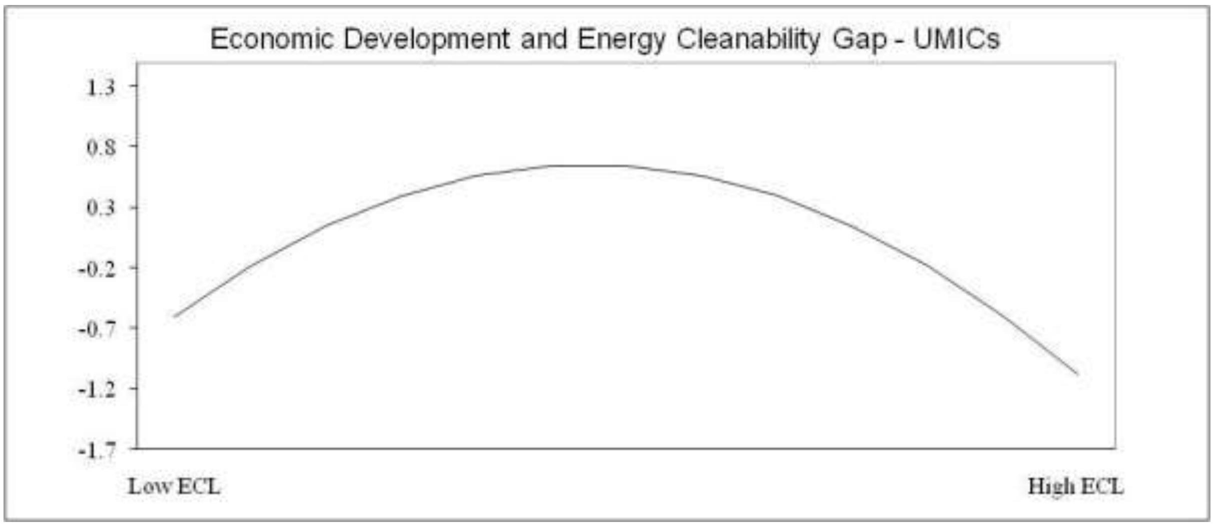

Figure 3: Quadratic Effect of Energy Cleanability on Economic development (Source: Authors calculation)

Furthermore, industrialization (IND) significantly impacts ED in UMIE. Further, a 1% increase in IND has decreased 0.06% ED in UMIE. Therefore, a higher rate of industrialization has increased the demand for unclean energy and significantly impacted health (Hou et al., 2021). Finally, trade liberalization (TRD) has a significant impact: a 1% increase in TRD has increased ED by 0.02 units in UMIE. Therefore, due to TRD, domestic firms can also increase their impact on ED. However, compared to the UMIE, industrial activities and ED is more than the impact in LMIE. These results suggest that TRD, due to technical competence, has not played an essential role in LMIE (Redmond & Nasir, 2020).

5. CONCLUSION AND POLICY IMPLICATIONS

Using data from 73 LMIE & UMIE for 2002–19, this paper examined the empirical evidence of the relationship between dirty energy and economic development. Control variables such as development & research expenditure, industrial value addition, and trade liberalization are employed for the analyses. The panel unit roots tests, panel cointegration, and FMOLS have all been used for this purpose. Using DOLS, it was determined whether the results were robust at each level of the studies. Furthermore, estimated outcomes indicate that the quadratic effect of ECI has a statistically significant impact on economic development with a negative sign in both selected panels. Therefore, an increase in the ECI would have a negative effect on economic development. The long-run dynamics in the proposed model imitate a significantly quadratic effect of ECG on ED in all panels. The result demonstrates that R&D has an incredibly positive impact on ED in UMIE. According to the results, IND has a significantly positive effect on ED in LICs but a negative impact on UMIE panels.

Limitations: The data of ED, ECG, R&D, IND, and TRD of the latest years are missing. These results are estimated with just FMOLS and DOLS econometric techniques. This study considers two income-based panels of 73 economies.

Suggestion: Further research can be extended by applying last year's data of given variables to this model. Further, the empirical analysis can be improved using the latest techniques, such as AMG, CS-ARDL, or DCCE estimation. Finally, the study can be made on different regions and different economies.

Recommendation: The future insight of this study can offer the following essential suggestions. First, the economies should adopt a more effective policy towards energy cleanability with the context of SDGs-2030 to improve the impact on economic development. Second, the development expenditure has a converging impact on sustainable economic development, so it requirs more consistent policy. Third, the industrial sector in UMIE and HICs had a destructive effect on Economic development and should be rearranged. Lastly, pursuing trade liberalization in LMIE, UMIE, and HICs showed a constructive role in Economic development, requiring it to be optimized.

Acknowledgment
The authors acknowledge the comments made by the reviewers and members of the editorial board on the earlier version of this manuscript.

Funding Source:
The author(s) received no specific funding for this work.

Conflict of Interests:
The authors have declared that no competing interests exist.

REFERENCES

Akhtar, M. J., Ashraf, W., & Rehman, H. (20120). The Environmental Kuznets curve : Segregating the Economic Growth into Production Function inputs in G-7 Countries: An Econometrics Analysis. International Review of Social Sciences. Vol. 8.11, 9-23

Akhter, M. J., Rehman, H, & Abbas .Q. (2022). The multidimensional assessment of sustainable energy poverty and its impact on economic development. *Journal of Business & Economics*, 14(14), 1–17. https://doi.org/10.5311/JBE.2022.27.6

Behera, C., Mishra, B. R., Priyadarshini, B. T., & Satpathy, L. D. (2020). Institutional quality and foreign direct investment inflows: Evidence from cross-country data with policy implication. *International Journal of Economics and Business Administration*. https://doi.org/10.35808/ijeba/463

Che, X., Zhu, B., & Wang, P. (2021). Assessing global energy poverty: An integrated approach. *Energy Policy*, *149*. https://doi.org/10.1016/j.enpol.2020.112099

Council, S. (2022). *Review by the Economic and Social Council of subsidiary bodies *. 13*(13).en.wikipedia.org. (2019). *TOPSIS method*. Wikipedia.Org.

Garba, I., & Bellingham, R. (2021). Energy poverty: Estimating the impact of solid cooking fuels on GDP per capita in developing countries - Case of sub-Saharan Africa. *Energy*, *221*, 119770. https://doi.org/10.1016/j.energy.2021.119770

Hou, N., Zhu, Q., Yang, J., Zhang, D., Liu, W., & Chang, H. (2021). The impact of environmental governance on the development of fishery economy—The intermediary role of technological innovation. *Sustainability (Switzerland)*. https://doi.org/10.3390/su132011378

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, *115*(1), 53–74. https://doi.org/10.1016/S0304-4076(03)00092-7

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

Levin, A., Lin, C. F., & Chu, C. S. J. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics*, *108*(1), 1–24. https://doi.org/10.1016/S0304-4076(01)00098-7

Li, P., Akhter, M. J., & Aljarba, A. (2022). *G-20 economies and their environmental commitments : Fresh analysis based on energy consumption and economic growth*. *November* 1–11. https://doi.org/10.3389/fenvs.2022.983136

Munten, P., Vanhamme, J., Maon, F., Swaen, V., & Lindgreen, A. (2021). Addressing tensions in coopetition for sustainable innovation: Insights from the automotive industry. *Journal of Business Research*. https://doi.org/10.1016/j.jbusres.2021.07.020

OECD. (2019). Work on Environment. *Environment*.

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

Redmond, T., & Nasir, M. A. (2020). Role of natural resource abundance, international trade, and financial development in the economic development of selected countries. *Resources Policy*. https://doi.org/10.1016/j.resourpol.2020.101591

Sasmaz, M. U., Sakar, E., Yayla, Y. E., & Akkucuk, U. (2020). The relationship between renewable energy and human development in OECD countries: A panel data analysis. *Sustainability (Switzerland)*. https://doi.org/10.3390/SU12187450

UNDP and University of Oxford. (2021). Peoples's Climate Vote. *United Nations Development Programme*.

Yao, X., Yasmeen, R., Haq Padda, I. U., Hassan Shah, W. U., & Kamal, M. A. (2020). Inequalities by energy sources: An assessment of environmental quality. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0230503