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What Role Do Economic Factors Play in the Energy Efficiency Changes in Developed and Developing Countries?

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Abstract

Energy efficiency is a crucial concern worldwide, given the significant economic activities and extensive energy consumption. Therefore, further research is necessary to document the latest evidence in this field. The study aims to analyse the effects of various factors on energy efficiency changes, specifically focusing on economic growth, population growth, inflation, energy imports, and foreign direct investment (FDI). The research examines these influences in a sample of five developed economies and five developing economies over the period of 2010–2017. Analysing the relationship between the constructs was done using STATA. The proposed relationship is tested using a robust standard error and fixed effect model. The findings suggest a positive relationship between economic growth, population growth, inflation, energy imports, and FDI and changes in energy efficiency. This study provides valuable guidance to policymakers on formulating energy efficiency policies in the country.

Keywords: Economic Growth, Energy Efficiency Changes, Population Growth, Renewable Energy Production, Inflation, Energy Import.

1. Introduction

The modern world is a hub for various innovative technologies. Power plants and other industries worldwide use various raw materials to produce different products. The discharge of effluents and waste from power plants and industrial units

has led to a significant rise in global pollution and the presence of harmful chemicals. Developed countries such as America, Europe, and Canada operate their own specialised facilities to process and repurpose harmful waste materials for industrial use. The primary factor responsible for the emission of this detrimental smoke is the type of fuel used in industrial manufacturing processes. Waste generation remains a significant concern across all global regions. The extent of this variation differs across high- and low-income countries, specifically in developed and developing nations. One concerning aspect of energy production practices is the increasing threat to natural habitats and the devastating impact on organisms. The variation in population growth between these countries is significant and holds great importance. The power capacity's renewable share is depicted in Figure 1, and it has been steadily increasing over time.

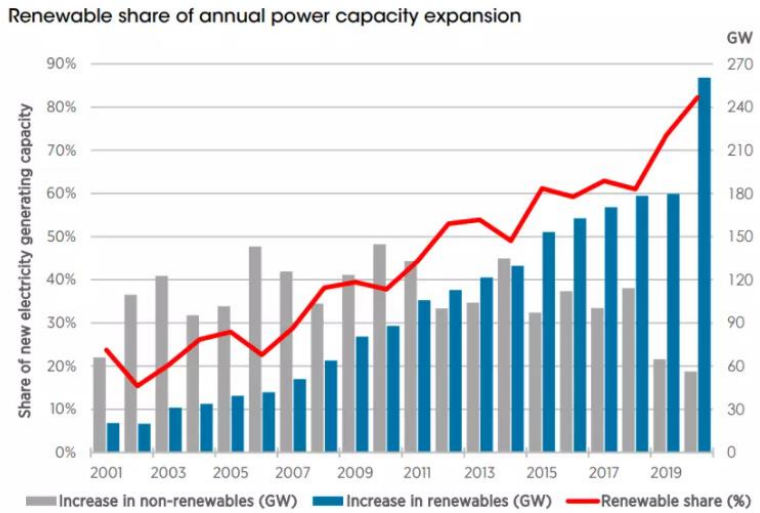

Figure 1: Renewable Share in Power Capacity.

The economic disparities between developed and developing nations have a direct correlation with the rise in carbon dioxide emissions. According to numerous studies (Bai et al., 2020; Haseeb et al., 2017; Khan et al., 2021), environmental pollution has consistently been associated with population growth in developing countries. Foreign Direct Investment plays a crucial role in shaping the economic disparities between nations. Developing countries face significant pollution and a heavy burden of harmful gases in their environment (Khan & Bin, 2020). The rise in population led to a corresponding increase in the industrial manufacturing of various products. Industrial units rely on conventional fossil fuels such as diesel, gasoline, and other non-renewable energy sources. FDI in green energy generation processes is a highly

efficient method of promoting environmental sustainability and benefiting all living beings (Abbasi et al., 2020). The adoption of new and innovative eco-friendly technologies, such as the utilisation of renewable energy resources, can offer a viable solution for the overall welfare and economic advancement of these nations. Key renewable energy sources include agricultural waste, plastic waste, and microbial biomass (Rasheed et al., 2021).

Economic instability and inflation pose significant challenges in both developed and developing economies. These internal issues have created obstacles for investment in new projects (Agyemang et al., 2023). Biofuel products are harmless by-products that can be easily dissolved in nature without causing any harmful effects (Nathaniel & Khan, 2020). Biomass feedstock is a crucial and dependable choice to produce biofuels. In today's world, the economic growth of both developed and developing countries is experiencing significant expansion. Authorities in these nations are actively exploring novel approaches to enhance the generation of environmentally sustainable renewable energy sources. However, the rise in stock exchange trends and the monetary value of assets has exacerbated lifestyle issues in developing countries (Rafique et al., 2020; Rezania et al., 2020). Developing countries are actively exploring methods to increase the production of refined biofuels using affordable energy resources (Arun & Dalai, 2020). Various methods and options exist for enhancing the yield of biofuels in different processes (Kumagai et al., 2021).

The presence of inflation and economic imbalances has created a significant disparity in emerging and developing countries (Beckstrom et al., 2020). Therefore, it is incumbent upon developed economies to address the gap. This action has the potential to enhance international relations and contribute significantly to the resolution of environmental issues. Implementing these regulatory measures is essential for boosting the economy and fostering mutual benefit (Hossain & Morni, 2020). Recent studies have highlighted the importance of energy resources in promoting green energy practices. Developing countries are actively investing in biofuel production. Efforts like these are crucial for fostering global economic growth and ensuring long-term sustainability.

In addition, the present state of countries' socio-economic, political, and

environmental conditions has revealed numerous issues in their respective economies. Despite the unfavourable conditions for innovation, it is imperative that we collectively work towards resolving the challenges at hand. The rising population leads to a corresponding increase in product usage, while the production rate remains significantly low in comparison. When it comes to renewable products, their growth rate is comparatively sluggish compared to non-renewable products. This can be attributed to the high cost associated with their processing. This is the primary factor that discourages industrialists from investing in environmentally friendly procedures. In summary, nations are making significant efforts to mitigate the adverse impact of inflation and economic instability. Nevertheless, these conditions pose obstacles to the attainment of the collective objective.

The current study is structured into five distinct phases. The introduction section, being the initial phase of the study, provides the necessary background information to inform the reader about the identified issues and the motivation behind the research. The second part is connected to synthesised literature, where contemporary studies are examined to emphasise the gap in research. Next, the methodology section delves into the various data methods and techniques that were employed. In the following section, the results are examined in relation to previous research. This analysis is then summarised in the final phase, along with the implications and limitations.

2. Literature Review

Enhancing renewable energy production contributes to economic growth and fosters human well-being. Many countries are experiencing notable economic growth as they focus on meeting their needs and bolstering the production of renewable energy. Wada (2017) Wada (2017) establishes a clear connection between economic growth and energy production. Moreover, it is evident that economic growth plays a crucial role in promoting the development of renewable energy sources, leading to substantial prosperity. Therefore, it is proposed that the promotion of effective and sustainable economic development contributes to the overall increase in renewable energy production. According to Polat (2021), there is ongoing debate and uncertainty

surrounding the relationship between economic growth and renewable energy production and consumption. It was noted that the economic performance of both developing and developed countries has a significant impact on the production of renewable energy.

According to a study by Venkatraja (2023), communities all over the world are actively working to improve renewable practices, which have a significant impact on sustainable economic growth. Various regression techniques have been employed to analyse the relationship between economic growth and renewable energy production. In a study conducted by Bayale et al. (2021), it was found that the relationship between economic growth and renewable energy production is influenced by factors such as financial and socioeconomic conditions. The authors emphasised the importance of considering these external elements when analysing the uncertainty of economic growth at the international and regional level. In their study, Lee and Li (2024) provided a detailed analysis of the stability and hysteresis properties of renewable energy production in relation to both negative and positive shocks in economic growth. Various factors contribute to the production of renewable energy, including biofuel, wind, hydroelectric power, and biomass. These sources play a crucial role in sustaining economic growth. Statistical and econometric approaches have been employed to analyse the emergence of renewable energy production. The results showed that the rise in economic growth has a significant impact on the increase in renewable energy production.

Resource-rich developing countries often rely heavily on population growth because of inadequate infrastructure. By effectively instilling innovation and education, the population's upbringing can significantly enhance the production of renewable energy. In a study conducted by Warner and Jones (2017), it was emphasised that the involvement of population growth in renewable energy production is closely tied to development and innovation. In their study, Chen et al. (2019) discussed the various objectives of population growth, specifically focusing on optimising economic emissions and renewable energy production resources. The production of renewable energy relies heavily on human efforts and would benefit from innovative approaches to accommodate population growth.

In a recent study, Namahoro et al. (2021) emphasized the significance of asymmetry in population growth for the advancement and sustainability of renewable energy components. Research suggests that there is a strong correlation between renewable energy production and population growth. The substantial and impactful potential of population growth plays a vital role in facilitating energy production. Pourmahdavi and Liu (2019) argue that population growth has a positive impact on the working environment, leading to increased performance in renewable energy production. According to a study by Mjachina et al. (2018), there has been a significant increase in the development and exploration of oil and gas resources. The analysis of human endeavour and its development is explained using various statistical and strategic methods. A recent study suggests that the challenges associated with renewable energy production can be addressed through substantial population growth.

In a recent research paper, Fal'tsman (2022) investigated the replacement of energy imports in the defence industry and the promotion of renewable energy production. Renewable energy production is subject to different sanctions because of international policies. One significant factor in mitigating these sanctions is the import of energy. The analysis of energy imports, its potential, and its applications are outlined using statistical methods. Research suggests that energy imports play a crucial role in driving the growth of renewable energy production in developing countries. In their study, Alola and Joshua (2020) highlighted the importance of energy imports for the development of renewable energy production in culturally rich locations with unique ambience and surroundings. There are multiple factors involved in the importation of energy that impact environmental quality and the utilisation of renewable energy sources. The pooled mean group approach has been used to address these issues. The results indicate that energy imports have a definite impact on the promotion of renewable energy and the development of robust production, showing strong causal relationships.

According to a study by Fedoseeva and Zeidan (2018), the significant changes in European markets are of great significance because energy imports are on the rise. The discussions surrounding energy imports stem from the important implications of dynamic, nonlinear, co-integrating approaches. According to the study, energy products

have a greater presence than renewable energy production and rely heavily on energy imports. In their study, Sibilla and Kurul (2020) emphasised the significance of energy imports in facilitating the reconciliation and establishment of efficient systems within the renewable energy production sector. According to a study by Karimi et al. (2018), developed countries' governments implement a variety of incentive schemes for product export and import. Various factors, such as biomass production and plant capacity, support the production of renewable energy. These factors have been extensively studied and analysed using optimised models. Research suggests that energy imports play a significant role in the generation and production of renewable energy.

Developing countries often face challenges in the production of renewable energy, primarily due to limited foreign direct investment. Thus, developing nations can enhance their effectiveness by increasing the magnitude of foreign direct investment interactions. Khan et al. (2020) argue that investment plays a crucial role in bolstering opportunities and sustainability in renewable energy production. Research suggests that foreign direct investment can effectively address health and income concerns associated with renewable energy production. The authors of a recent study (Wall et al., 2019) outlined the various policies related to foreign direct investments that contribute to the growth of renewable energy production. Foreign direct investment has a modest impact on the global diffusion of renewable energy, altering the climate and emissions to some extent. The use of various statistical methods, which offer a thorough analysis, enhances investments in renewable energy. The findings indicate that the reduction of tariffs and taxes, coupled with an increase in foreign direct investment, has a positive impact on the production of renewable energy.

According to a study by Wye (2018), some foreign direct investment channels fall short of filling in the gaps that prevent the global production of renewable energy. The findings indicated that energy efficiency rules are hindering employment growth because of foreign direct investment. According to Shakouri and Khoshnevis Yazdi (2017), foreign direct investment has been shown to provide support for the promotion and long-term viability of renewable energy generation. The autoregressive distributed lag model is used to analyse the relationship between components, which are identified as positively linked with each other. The findings demonstrate the globalisation index,

which highlights the importance of foreign direct investment for countries abundant in resources. Hossain et al. (2020) discussed the enhancement of technology in generating renewable energy in real-time through the participation of foreign direct investment. Most factories in nations with abundant resources are developed with the backing of foreign direct investment. The support enhanced the methodology of renewable energy production by employing econometric and statistical methodologies. The study emphasised the significance of foreign direct investment as a catalyst for increasing the generation of renewable energy.

Inflation is typically regarded as a macroeconomic factor, although inflation in the energy sector may be more pronounced in relation to the consumption and production of renewable energy. The robust growth of the renewable energy sectors, which has significant implications for the formulation of various policies, is the main cause of the rapid increase in energy inflation. According to Alola and Joshua (2020), inflation is relevant to the difficulties of achieving a goal for substantial and effective renewable energy generation. A study proposes that the utilisation and generation of renewable energy, which is efficient in terms of energy consumption, correlates with inflation in the energy sector. Adom et al. (2022) investigated the correlation between development results and energy poverty, as well as its impact on the promotion of green energy. The presence of some external factors significantly impacts the development outcomes in numerous countries, particularly in relation to inflationary limitations. The study found that inflation had a beneficial impact on the energy sector, independent of economic conditions, when using rigorous statistical methodologies.

Ankrah and Lin (2020) examined the progress of renewable energy in Ghana, focusing on its implications, substitution possibilities, concerns, and economic observations. Renewable energy in excess can have significant negative effects on production, but it remains a viable option for consumption. In assessing the impact on economic conditions, inflation is considered a significant factor, particularly in relation to renewable energy production. In their study, Aksoy and Selbaş (2021) examined the impact of fluctuating inflation rates on energy production estimates in both developing and developed countries. In the long-run phase, the rate of inflation and exchange rate both have a significant impact on renewable energy production. The interpretation of

mathematical equations plays a crucial role in directing the efficiency of renewable energy production and inflation. The study highlighted the potential negative impact of even a small increase in inflation on the production of renewable energy.

3. Research Methodology

This study analyses the impact of economic factors on energy efficiency changes in developing and developed economies worldwide. The factors considered include economic growth, population growth, inflation, energy imports, and foreign direct investment (FDI). The WDI database was utilised to gather secondary data from 2010 to 2017 from a selection of developed economies, including Canada, the USA, Japan, Australia, and South Korea, as well as five developing countries such as Indonesia, India, Malaysia, Pakistan, and Vietnam. The STATA software was utilised to analyse the relationship between the constructs. Below is the equation used in the study:

$$REP_{it} = \alpha_0 + \beta_1 EG_{it} + \beta_2 PG_{it} + \beta_3 EI_{it} + \beta_4 FDI_{it} + \beta_5 INF_{it} + e_{ti} \quad \textbf{(1)}$$

Table 1: Measurement of Study Variables.

Variables	Symbol	Measurement
Energy Efficiency Changes.	REP	"Renewable energy production" (% of total energy production).
Economic Growth.	EG	GDP growth (% annum).
Population Growth.	PG	Population growth (% annum).
Energy Import.	EI	Energy import net (energy use in %).
Foreign Direct Investment.	FDI	Net inflow (% of GDP).
Inflation.	INF	Consumer prices (% annum).

Initially, descriptive statistics were used to calculate the mean and standard deviation to assess the properties of the data. A correlation analysis was conducted to assess the relationships between variables. The test is valuable for uncovering directional connections between constructs. VIF has also been utilised to address the problem of multicollinearity. Based on the given criteria, the threshold is less than 5. Below is the equation for VIF:

$$R^2_Y \longrightarrow Y_{it} = \alpha_0 + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it} + \beta_5 X_{5it} + e_{it} \quad \textbf{(2)}$$

$$j = R^2_Y, R^2_{X1}, R^2_{X2,} R^2_{X3,} R^2_{X4,} R^2_{X5} \quad \textbf{(3)}$$

$$Tolrance = 1 - R^2_j \qquad VIF = \frac{1}{Tolerance} \quad \textbf{(4)}$$

Researchers also compare random and fixed models. The Hausman test was used. When doing the "Hausman test," the FEM is recommended if the probability value is less than 0.05. However, the random effects model is valid if the probability is greater than 0.05.

$$H = (b_1 - b_0)\,(Var\,(b_0) - Var\,(b_1))\,(b_1 - b_0) \quad \textbf{(5)}$$

Equation (5) above presents the Hausman test, where "H" denotes the test itself. The symbol b_0 corresponds to the null hypotheses concerning the appropriateness of the REM, while b_1 represents the alternative hypotheses regarding the appropriateness of the FEM. In addition, FEM has been employed because of the use of fixed "model parameters". It also regulates constructs that are omitted and remain constant over time. FEM is suitable in cases where the variables are difficult to observe. In addition, it possesses the capability to estimate the number of additional parameters.

$$Y_{it} = \beta_{1i} + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it} + \beta_5 X_{5it} + u_{it} \quad \textbf{(6)}$$

Equation (6) above includes a subscript (i) to indicate the "individual country" and their respective features. The equation for the FEM with the included constructs is displayed below:

$$REP_{it} = \beta_{1i} + \beta_2 EG_{it} + \beta_3 PG_{it} + \beta_4 EI_{it} + \beta_5 FDI_{it} + \beta_6 INF_{it} + u_{it} \quad \textbf{(7)}$$

The analysis also included the use of "robust standard error" to assess the relationships between the variables under study. This technique is suitable when the data is "cross-sectional dominant." It has also been used to address the common problem of heterogeneity among models. The text also discusses issues related to "heteroscedasticity and auto-correlation". Below is the equation for estimating the robust standard error:

$$REP_{it} = \beta_1 EG_{it} + \beta_2 PG_{it} + \beta_3 EI_{it} + \beta_4 FDI_{it} + \beta_5 INF_{it} + \varepsilon_{it} \quad \textbf{(8)}$$

4. Findings

The study's findings indicate a total observation count of 40. The values in Table 2 show that the mean value for REP is 20.952, EG is 4.032, PG is 1.079, EI is -12.191, FDI is 2.340, and INF is 3.741. Additionally, descriptive statistics are computed for the cross-sectional data. According to Table 3, the lowest REP recorded was 1.637% in South Korea, while the highest was 62.802% in Canada. Furthermore, the minimum EG recorded in Japan was 1.473%, whereas India reported the highest value at 7.005%.

According to the findings, Japan had the lowest PG at -0.124%, whereas Pakistan had the highest at 2.116%. Furthermore, Australia recorded a minimum EI of -173.216%, whereas Japan had the highest EI at 91.257%. Based on the findings, Japan had the lowest FDI at 0.256%, whereas Vietnam had the highest at 5.805%. Furthermore, the INF values ranged from 0.401 in Japan to 7.632 in India.

Table 2: Descriptive Statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
REP	80	20.952	17.539	1.245	63.298
EG	80	4.032	2.055	0.024	8.498
PG	80	1.079	0.594	-0.185	2.197
EI	80	-12.191	78.487	-192.016	93.981
FDI	80	2.340	1.704	-0.014	6.901
INF	80	3.741	3.525	-0.720	18.678

Table 3: Descriptive Statistics (Country).

	REP	EG	PG	EI	FDI	INF
Canada	62.802	2.237	1.040	-64.176	2.686	1.650
United States	12.456	2.231	0.726	12.703	1.930	1.683
Japan	13.428	1.473	-0.124	91.257	0.256	0.401
Australia	12.342	2.604	1.574	-173.216	3.725	2.207
South Korea	1.637	3.522	0.510	81.995	0.762	1.919
Indonesia	12.264	5.496	1.294	-102.208	2.102	5.159
India	16.094	7.005	1.184	32.439	1.712	7.632
Malaysia	8.533	5.531	1.433	-9.518	3.686	2.472
Pakistan	31.399	4.093	2.116	23.820	0.732	7.475
Vietnam	38.561	6.127	1.034	-15.002	5.805	6.810

Calculations are made for descriptive statistics pertaining to time series. According to Table 4, the REP reached its lowest point of 19.264% in 2010 and its highest point of 21.783% in 2014. In addition, the lowest EG recorded was 3.656% in 2011, with the highest being 4.880% in 2010. In the study, it was found that the PG values ranged from 1.021 percent in 2015 to 1.159 percent in 2010. In addition, the EI reached a minimum of -14.605% in 2015 and a maximum of -8.214% in 2010. In the study, it was found that the FDI reached its lowest point at 2.092 percent in 2012 and its highest point at 2.491 percent in 2015. In addition, the lowest INF rate recorded was 2.078% in 2015, while the highest was 6.111% in 2011. The figures can be found in Table 4. The latest research reveals a correlation matrix that demonstrates a positive linkage between EG, PG, EI, FDI, and INF and the REP.

Table 4: Descriptive Statistics (Year).

	REP	EG	PG	EI	FDI	INF
2010	19.264	4.880	1.159	-8.214	2.360	4.945
2011	20.337	3.656	1.105	-9.217	2.478	6.111
2012	20.879	3.742	1.113	-10.089	2.092	4.152
2013	21.390	3.838	1.083	-12.278	2.324	4.037
2014	21.783	4.051	1.067	-14.032	2.370	3.751
2015	21.187	3.967	1.021	-14.605	2.491	2.078
2016	21.352	3.866	1.049	-14.583	2.391	2.182
2017	21.420	4.255	1.033	-14.506	2.211	2.670

Table 5: Matrix of Correlations.

Ariables	Rep	Eg	Pg	Ei	Fdi	Inf
REP	1.000					
EG	0.087	1.000				
PG	0.197	0.388	1.000			
EI	0.203	-0.019	-0.524	1.000		
FDI	0.280	0.327	0.270	-0.522	1.000	
INF	0.139	0.445	0.458	-0.013	0.126	1.000

The findings in Table 6 indicate that the VIF values are below five, suggesting the absence of multicollinearity in the data.

Table 6: VIF.

	VIF	1/VIF
EI	2.236	0.447
PG	2.169	0.461
FDI	1.671	0.598
EG	1.592	0.628
INF	1.510	0.662
Mean VIF	1.835	.

In addition, the researchers also analyse the appropriate model between the random and fixed models. The Hausman test has been utilised for this purpose. The results suggest that the probability value is less than 0.05, indicating that FEM is a suitable method. The figures can be found in Table 7.

Table 7: Hausman Test.

	Coef.
Chi-square test value	3.301
P-value	0.008

Table 8 displays the results of the fixed effect model estimation, revealing a

positive association between energy efficiency changes and factors such as economic growth, population growth, inflation, energy imports, and FDI. In addition, it is worth noting that 44.1% of the variations in REP can be attributed to the study predictors. According to the findings in Table 9, there is a positive correlation between energy efficiency changes and economic growth, population growth, inflation, energy imports, and FDI.

Table 8: Fixed Effect Model.

REP	Beta	S.D.	t-value	p-value	L.L.	U.L.	Sig
EG	0.427	0.158	2.70	0.012	0.941	1.088	**
PG	1.785	0.596	2.99	0.010	0.970	3.400	**
EI	0.084	0.029	2.90	0.011	0.103	1.014	**
FDI	0.904	0.431	2.10	0.040	0.763	1.044	**
INF	0.335	0.102	3.28	0.004	1.169	3.238	***
Constant	26.04	2.951	8.82	0.000	20.146	31.933	***
R-sq		.441	Obs			80	
F-test		2.128	Prob > F			.021	
*** p<.01, ** p<.05, * p<.1							

Table 9: Robust Standard Error.

REP	Beta	S.D.	t	P>t	L.L.	U.L.
EG	0.427	0.089	4.780	0.001	0.629	1.225
PG	1.785	0.487	3.660	0.005	0.887	1.683
EI	0.044	0.009	4.780	0.001	0.066	1.023
FDI	0.904	0.362	2.490	0.034	0.723	1.084
INF	0.135	0.042	3.214	0.016	0.060	1.129
_cons	26.040	1.069	24.360	0.000	23.621	28.458
R-squared		.441	Number of obs		80	

5. Discussion

As previously mentioned, economic growth is closely linked to the production of renewable energy, which in turn affects changes in energy efficiency. Akram et al. (2023) further highlights the need for significant financial resources to drive innovation in energy efficiency, as it is closely linked to economic growth. In a thriving economy, the adoption of energy-efficient technologies, techniques, and innovative procedures is crucial for producing renewable energy on a large scale and improving its quality. This helps to regulate the use of energy from traditional sources and ensures the availability of energy sources for future economic needs. The 2020 Go et

al. report also stressed the importance of economic growth in energy efficiency. This study shows that countries with strong financial progress employ energy efficiency measures more often. When the economy is strong, renewable energy is generated and stored. Hydropower and wind energy use turbines, while solar energy is harnessed by solar panels and stored in energy storage devices. Growing crops and forests with improved technology produces bioenergy. A previous study by Sineviciene et al. (2017) suggests that during periods of significant economic growth, there is a shift towards valuing the production of renewable energy over the continued use of traditional energy sources such as fossil fuels. This is why renewable energy can achieve the same tasks as fossil fuels, but in a more cost-effective and environmentally friendly manner.

The correlation between population growth and REP also aligns with previous research findings. As the population grows, meeting the energy demands from traditional sources like fossil fuels becomes challenging. To ensure future energy needs are met, it is necessary to explore more efficient, reliable, and sustainable energy resources, as highlighted in the study by Khalifa et al. (2022). Therefore, focus is directed towards the development of renewable energy sources that are recyclable and safe and can effectively meet future economic needs. In a similar vein, Razzaq et al. (2023) posited that an increase in population growth rate in any region worldwide necessitates economic stability and growth to ensure sustainable earnings, high living standards, and survival. To achieve sustainable economic growth, it is imperative to utilise energy resources that are environmentally friendly and can be maintained in the long term. Therefore, the need for sustainable energy sources is met through the production of energy from renewable and sustainable sources. Therefore, the growth of the population leads to an increase in energy efficiency. Bashir et al. (2023) asserted that as the population grows, so does the human capital, fostering innovation in economic activities and driving sustainable progress in the economy. Human capital plays a crucial role in promoting and advancing the production of renewable energy sources such as wind power, hydropower, solar power, geothermal power, biomass, and biogas. It serves as a valuable tool for enhancing energy efficiency in the economy and fostering sustainable economic performance.

There is a positive relationship between energy imports and renewable energy production, as indicated by the findings of a study. Gyamfi et al. (2020) further asserted that the rising energy demands in a nation, both for domestic and economic needs, prompt individuals and organisations to import energy sources that can be expensive and environmentally harmful. There is a growing awareness among both government and private entities regarding the need to promote the development of renewable energy sources. These sources are clean and have the potential to meet our energy demands. This process leads to increased energy efficiency within the country. Laslett et al. (2017) found that innovative pollution-free fertilisers, seeds, and agricultural technologies can generate energy from food and non-food crops, crop weeds, crop wastes, and forests. Energy resources and components imported by the country enable renewable energy production and energy efficiency programmes. Malinauskaite and Jouhara (2019) found that energy import facilities encourage solar and hydropower adoption. The study suggests that these infrastructures help import solar panels, wind turbines, and hydroelectric turbines, encouraging sustainable energy generation. This boosts national energy efficiency.

The study results indicate that foreign direct investment is positively associated with renewable energy production, which contributes to improving energy efficiency. The results align with a previous study conducted by Xin-gang et al. (2019), indicating that foreign direct investment has a positive impact on the financial resources of domestically registered and operating companies. The findings of this study highlight the potential for promoting renewable energy sources such as agriculture, hydropower systems, and solar power systems. While these sources do require initial investment, they offer a sustainable and environmentally friendly alternative to fossil fuel energy. The findings are consistent with a previous study by Ben Jebli et al. (2019). Their research indicates that a significant influx of foreign direct investment can assist domestic commercial entities in making informed decisions and plans for sustainable economic development, thereby addressing the issue of limited energy resources. Foreign direct investment can significantly enhance the production of renewable energy sources such as biomass, biogas, solar power, and hydropower. These sources are known for their ease of use, renewability, and sustainability for future generations.

The findings are further corroborated by a previous study conducted by Khan et al. (2020), which highlights the involvement of foreign companies or the government in domestic business enterprises. This investment allows companies to pursue energy efficiency initiatives by utilising renewable energy sources in their production and consumption processes.

The study findings suggest that there is a positive relationship between inflation within the country and foreign direct investment. The findings align with a prior study conducted by Di Giuseppe et al. (2017). Their research demonstrated that, in the face of rising inflation, individuals and organisations tend to prioritise the development of energy efficiency through the production of renewable energy sources. This approach aims to minimise energy consumption and costs while preserving energy resources for future generations. The findings align with the research conducted by Hu et al. (2022), suggesting that organisations strive to maintain productivity levels without incurring additional costs during periods of inflation. Thus, they implement appropriate modifications to policies and energy production and consumption patterns, which can be beneficial in reducing costs. Thus, inflation leads to the generation of renewable energy and the improvement of energy efficiency. The results of the previous study conducted by Saafi and Daouas (2019) further validate these findings. It demonstrates that when there is inflation within the country, there is a high level of productivity and employment. Additionally, it highlights the necessity of abundant energy sources for carrying out economic activities. The development of renewable energy sources and the implementation of energy efficiency measures within the nation satisfy this requirement.

6. Implications

This study has several empirical implications. This study contributes significantly to the existing economic literature. This study examines the energy efficiency using a renewable energy resource indicator that aligns with the goals of energy efficiency. Before this study, most authors have directed their attention towards energy-efficient technologies and the impact of technological changes on

energy efficiency development. Our study makes a significant contribution to the existing literature by addressing a gap in the field. Our study is a valuable contribution to the existing literature on energy efficiency. Considering the growing demand for energy to support population growth and economic expansion, it is necessary to explore strategies to meet these needs effectively. This study holds significant importance for both developing and developed economies, as it provides guidance on promoting energy efficiency through the encouragement of renewable energy production. This study provides guidance to policymakers on formulating energy efficiency policies in the country. This study serves as a valuable resource for government authorities and economists when formulating economic policies. This study proposes that the enhancement of energy efficiency and renewable energy production is linked to factors such as high economic growth, effective population management, significant energy imports, foreign direct investment, and inflation within the country.

7. Conclusion and Limitations

The objective of the study was to examine the impact of five economic factors—economic growth, population growth, energy imports, foreign direct investment, and inflation—on renewable energy production and energy efficiency. The authors conducted an empirical survey of various developing and developed economies, analysing factors such as economic growth, population growth rate, energy imports, foreign direct investment, and inflation rate. The purpose was to examine their impact on renewable energy production and energy efficiency. Based on this empirical analysis, the findings indicate that economic growth, population growth, foreign direct investment, energy imports, and inflation have positive effects on renewable energy production and energy efficiency. The study findings suggest that during periods of rapid economic growth, the adoption of energy-efficient technologies and practices can enable the production of significant quantities of renewable and clean energy. This, in turn, helps to regulate the use of conventional energy sources and ensures the availability of energy resources for future economic needs. The results indicate that as the population grows, there is a demand for additional energy sources

and environmental remediation. Additionally, there is a presence of highly skilled human capital. This promotes the development of renewable energy and energy efficiency in the economy. The findings indicate that as the economy experiences an increase in energy imports, there is a corresponding inclination towards the production of renewable energy and the enhancement of energy efficiency. The results indicated that foreign direct investment has a positive impact on financial resources allocated to renewable energy production and energy efficiency implementation. Additionally, in economies with high inflation, there is an observed increase in renewable energy production and energy efficiency.

Like previous research, the current study also has several limitations. The study is limited in terms of its comprehensiveness, reliability, and validity. It is imperative to address these limitations in future studies to enhance the quality of research. The study focuses solely on examining the impact of economic factors, such as economic growth, population growth, energy import, foreign direct investment, and inflation, on renewable energy production and energy efficiency. Various factors, such as environmental regulations, green finance, and other business concepts, significantly influence the consumption of renewable energy and energy efficiency. These factors have been overlooked, and future authors should consider other factors as well. The study focuses on analysing the impact of economic growth, population growth, energy import, foreign direct investment, and inflation on renewable energy production and energy efficiency within a narrow time frame. Due to the constrained time frame, the study's scope is restricted. Future authors should thoroughly analyse the interconnections between economic growth, population growth, energy imports, foreign direct investment, inflation, and energy efficiency over a long period of time. This will ensure that the study is comprehensive and reliable.

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