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Structural Transformation and Energy Intensity in Emerging Markets and Developing Economies

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ABSTRACT

Improving energy efficiency is one of the key pillars in the transition to a low-carbon economy and sustainable development. However, amidst increasing urbanisation, labour force growth and renewable energy adoption, energy intensity in emerging markets and developing economies (EMDEs) is still showing a stagnant trend. This indicates the existence of non-sectoral structural dynamics that have not been fully identified in previous literature. This research is motivated by the urgent need to quantitatively examine how demographic transformation and clean energy affect national energy efficiency in Emerging Markets and Developing Economies. This study aims to analyse the influence of urban population (% of total population), labour force participation rate (% of working age population), and renewable energy consumption (% of total final energy consumption) on the energy intensity level of primary energy in 25 EMDEs countries over the period 2017-2021. Based on previous theoretical studies and empirical trends, it is hypothesised that urbanisation and renewable energy consumption reduce energy intensity, while labour force participation tends to increase energy intensity if not accompanied by sectoral and technological reforms. The research methodology uses panel data regression approach with Fixed Effect Model. The analysis shows that partially, urban population and renewable energy consumption have a negative and significant effect on energy intensity, while labour force participation rate shows a positive and significant effect. Simultaneously, the three variables have a significant effect on energy intensity. The coefficient of determination (R^2) of 0.991589 indicates that 99.15% of the variation in energy intensity can be explained by the variation in the three independent variables. This finding confirms the importance of policy formulation that integrates demographic structural transformation and renewable energy transition to sustainably reduce energy intensity in EMDEs countries.

Keywords: Energy Intensity, Urbanisation, Labour Force Participation, Renewable Energy, Structural Transformation, Emerging Markets and Developing Economies

JEL Classifications: O11, Q43, Q56, O14, Q48

1. INTRODUCTION

Energy intensity, which is generally defined as the ratio of energy consumption to Gross Domestic Product, has become a key indicator in measuring the efficiency of a country's energy use. This indicator not only reflects how efficient a country is in utilising energy to produce economic output but also reflects the extent to which a country's economic structure is able to transform towards a low-carbon development model. In the current global context, reducing energy intensity is a key focus in the sustainable energy transition agenda, especially as part of climate change mitigation efforts and achieving net-zero emissions targets. The IEA Energy Efficiency 2023 report notes that to achieve a net-zero scenario by 2050, global energy intensity must decline by an average of 4% per year between 2023 and 2030, far exceeding the historical average decline of 1.3% per year over the period 2013-2022 (IEA, 2023).

Emerging markets and developing economies (EMDEs) are currently at a critical juncture in the global energy transition landscape. Contributing more than 60% to global final energy consumption and about 70% to the increase in world energy demand over the period 2000-2020 (IEA, 2023), EMDEs face a formidable challenge in achieving energy decoupling, i.e. economic growth that is not accompanied by a proportional increase in energy consumption. On the one hand, economic growth in EMDEs is needed for poverty alleviation and basic infrastructure development, but on the other hand, without structural shifts and high energy efficiency, this growth pattern risks exacerbating greenhouse gas emissions. Global commitments such as the Paris Agreement and the sustainable development goals (SDGs), particularly goal 7 (affordable and clean energy) and goal 13 (climate action), require EMDEs to design energy transition strategies that are inclusive, efficient and based on robust empirical data (McCollum et al., 2018).

Since the beginning of the 21st century, EMDEs have undergone a structural transformation characterised by increasing urbanisation, changes in the composition of the workforce, and progressive adoption of renewable energy. The urbanisation rate in EMDEs increases from an average of 36.5% in 1990-52.9% in 2022, with South Asia and Sub-Saharan Africa showing accelerative trends. At the same time, labour force participation rates have also experienced significant dynamics, mainly due to the increasing role of women and rural-urban migration (Sagara et al., 2025). In addition, renewable energy consumption in developing countries has increased consistently, rising from 14% in 2000 to around 27% of total final energy consumption in 2021 (IRENA, 2023). However, this pattern of transformation differs fundamentally from that in developed countries, as urbanisation in EMDEs is often not accompanied by improvements in energy efficiency due to weak basic infrastructure, dependence on fossil energy, and lack of policy integration across sectors.

Despite a significant increase in renewable energy adoption, energy intensity in EMDEs remains high and stagnant. This indicates gaps in the application of energy efficiency technologies, energy governance and spatial planning. Urbanisation, which can theoretically reduce per capita energy consumption through scale efficiency and agglomeration, can actually increase energy intensity if not accompanied by good public transport systems and integrated urban energy management (Burger et al., 2018). On the other hand, changes in the labour force structure such as increased informal participation or the dominance of low-energy service sectors may affect the national energy demand profile, but have not been empirically studied so far. Therefore, reducing energy intensity is not only a technological challenge, but also a structural and multidimensional one. Achieving sustainable energy transition in EMDEs demands a more holistic understanding of how demographic and energy transition variables interact.

Previous studies have examined the linkages between structural change and energy productivity, such as (Sak and Guloglu, 2025) in the context of Türkiye. The study highlights how economic sector shifts (from agriculture to industry and services) contribute to changes in aggregate energy productivity. However, such studies are generally limited to a narrow definition of structural change between conventional production sectors and tend to ignore new structural dimensions based on demographic transformation and clean energy consumption patterns. To date, there are very limited studies across developing countries that empirically examine how urbanisation, labour force participation and renewable energy consumption simultaneously affect energy intensity. In fact, these three variables are important pillars in the formation of new economic and energy structures in developing countries.

This study aims to analyse the energy intensity level of primary energy in EMDEs countries from various developing countries during the period 2017-2021, the effect of non-sectoral structural transformation on national energy efficiency. This research also contributes to the development of a conceptual understanding of structural transformation in the era of energy transition. The main contribution of this study is the provision of a new approach in defining structural transformation that is more contextualised for developing countries, taking into account the demographic and clean energy transition dimensions. Empirically, this study is expected to fill the literature gap on non-sectoral determinants of energy intensity in EMDEs, as well as generate policy recommendations based on scientific analysis to support the decarbonisation, energy efficiency and sustainable development agenda in a structurally dynamic yet highly vulnerable region in the global energy system (Mercure et al., 2014).

2. LITERATUR REVIEW

2.1. Energy Intensity

Energy intensity is a key indicator that measures the efficiency of energy utilisation in economic activities. The energy intensity indicator is the ratio of primary energy supply to gross domestic product calculated based on purchasing power parity. The lower the energy intensity ratio, indicating that a country is able to produce greater economic output with relatively low energy consumption, reflecting high energy efficiency (IEA, 2022).

Energy intensity is influenced by various structural factors of the economy, including the composition of the industrial sector, the technology used, the efficiency of energy infrastructure, as well as demographic and social transformations such as urbanisation and labour force participation. Structural changes that favour high value-added sectors tend to lower energy intensity, as these sectors are relatively more energy-efficient per unit of output. Research by (Mulder and De Groot, 2012) used a panel data approach to analyse the relationship between economic structure and energy intensity in OECD countries. The results showed that the shift to the service sector significantly reduced energy intensity. Meanwhile, (Halicioglu, 2009) examined the determinants of energy intensity in Turkey and found that economic growth and energy efficiency policies have an important role in reducing national energy intensity. In addition, (Wu et al., 2021) used data from developing countries and found that the modernisation of the energy sector and the adoption of renewable energy have a significant impact in reducing energy intensity.

2.2. Urban Population

Urban population refers to the percentage of the population living in urban areas as defined by national statistical agencies. Urbanisation reflects the structural transformation from agrarian to industrial and service societies and contributes to efficient resource distribution and economic concentration (UN-Habitat, 2022).

Urban population growth has the potential to reduce energy intensity through economies of scale, transport efficiency and more advanced infrastructure technologies. However, uncontrolled urbanisation can increase per capita energy consumption due to growth in the transport sector and household energy demand. (Zhang et al., 2018) in a quantitative panel study in the East Asian region found that urbanisation generally has the effect of reducing energy intensity, especially when accompanied by good urban planning policies. However, a study by (Shahbaz et al., 2014) in Pakistan showed that urbanisation without environmentally friendly infrastructure increases energy intensity. This shows the important role of spatial planning policy in optimising the benefits of urbanisation on energy efficiency.

2.3. Labour Force Participation

The labour force participation rate is the proportion of the working-age population that is actively engaged in economic activity, either working or looking for work. This indicator reflects the productive capacity of a country and is an important component of economic structural change (ILO, 2022).

High labour involvement in the formal sector contributes to economic efficiency. Structural transformation from the informal sector to the high-tech formal sector has the potential to reduce energy intensity due to the use of more efficient technology and higher productivity. Research by (Apergis and Payne, 2010) found that an increase in labour participation leads to a decrease in energy intensity in Latin American countries, along with an increase in labour productivity and technology adoption. Meanwhile, Binuomote et al. (2022) stated that changes in the composition of the labour sector from agriculture to industry and services are key in reducing energy intensity, especially in developing countries in Sub-Saharan Africa.

2.4. Renewable Energy Consumption

Renewable energy consumption is the proportion of renewable energy in a country's total final energy consumption. Renewable energy includes resources such as solar, wind, hydro, biomass, and geothermal energy that are sustainable and environmentally friendly (REN21, 2023).

Increased consumption of renewable energy contributes to national energy efficiency, as these energy sources are cleaner, more efficient, and integrated with energy-saving technologies (Wahyudi et al., 2025). The adoption of renewable energy also encourages technological innovation and investment in the modern energy sector, which in turn reduces energy intensity. (Narayan et al., 2021) analysed 20 EMDEs countries and found that increasing renewable energy consumption significantly reduces long-term energy intensity. In addition, research by (Sovacool et al., 2020) revealed that renewable energy integration supported by fiscal incentives and energy reforms resulted in a sharp decline in energy consumption per unit of output in the MENA and South Asia regions.

3. RESEARCH METHODOLOGY

3.1. Statistical Analysis

Statistical analysis is a systematic process that includes collecting, organizing, interpreting, and presenting quantitative data using statistical techniques to identify patterns, trends, and relationships in the data (Gao et al., 2023).

3.2. Classical Assumptions

The classical assumption test is a series of tests conducted to ensure that the regression model used fulfils the basic assumptions to obtain unbiased, consistent, and efficient estimates of the model parameters by going through tests of normality, multicollinearity, heteroscedasticity, and autocorrelation (Khan et al., 2023).

3.3. Model Selection

In panel data analysis, the three main models often used for estimation are the common effect model, fixed effect model, and random effect model. To determine the most appropriate model, a series of tests such as the chow test, hausman test, and Breusch-pagan lagrange multiplier test are required (Gujarati, 2006).

3.4. Panel Data Regression Model

According to (Baltagi, 2005) panel data is generated from observations of a number of individuals monitored over several different time spans. One of the regression models available for panel data is a model that maintains a constant slope but has varying intercept values. In a one-way component model, variation is due to either cross-sectional or time-related units, while in a two-way model, variation is affected by both cross-sectional and time-related units. Panel data regression analysis aims to estimate and predict differences in characteristics between individuals or between times and find the mean value of the data set (both sample and population) by observing the relationship between the variable under study, the dependent variable, and the variable used to explain it, the independent variable. Then mathematically the regression model of this study is arranged as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon \quad (1)$$

Description:
Y: Energy intensity
β_0: Intercept
β_1, β_2: Regression coefficient
X_1: Urban population
X_2: Labor force
X_3: Renewable energy consumption
ε: Error term.

3.5. Statistical Test t (Partial Test)

In research, the significance of the influence of the independent variable on the dependent variable is seen through the t statistical test (Widarjono, 2018). In its use, if t-count> t-table or significance is <(α) 5%, this indicates that there is a partially significant effect between the independent variable and the dependent variable (Gujarati, 2006).

The hypothesis in this test is:

H_0: $\beta_i < 0$ there is no significant effect between the independent variable and the dependent variable partially

H_a: $\beta_i > 0$ there is a significant influence between the independent variables on the dependent variable partially.

The test criteria are as follows:
1. If t-statistic > t-table then H_0 is rejected. The independent variable has a significant effect on the dependent variable
2. If t-statistic < t-table then H_0 is accepted. The independent variable does not have a significant effect on the dependent variable.

3.6. F Statistical Test

The F-statistic test is used to show how the independent variables interact with each other and have an impact on the dependent variable (Wooldridge, 2013). If the F-count exceeds the F-table in the test, then simultaneously the independent variables have a considerable influence on the dependent variable, or the data are consistent with the research hypothesis.
- H_0: $\beta_i < 0$ there is no significant effect between the independent variables on the dependent variable together
- H_a: $\beta_i > 0$ there is a significant influence between the independent variables on the dependent variable jointly.

The test criteria are as follows:
1. If F-statistic > F-table then H_0 is rejected. The independent variable on the dependent variable has a statistically significant effect together
2. If F-statistic < F-table then H_0 is accepted. The independent variable on the dependent variable does not have a statistically significant effect together.

3.7. Test Coefficient of Determination (R^2)

According to Widarjono (2018), the coefficient of determination (R^2) is used to measure the proportion of the contribution of the independent variable in explaining the dependent variable. An R^2 value close to one indicates that the regression model has a good ability to explain data variability, while an R^2 value close to zero indicates limited ability. However, R^2 has the disadvantage that it tends to increase with the addition of independent variables, even though these variables do not necessarily increase the predictive power of the model. Therefore, adjusted R-square is used which corrects for the addition of irrelevant independent variables, so that the adjusted R-square value will not exceed R-square and may decrease or become negative if the addition of independent variables does not improve the quality of the model or if the model shows a low level of fit.

4. RESULTS

4.1. Statistical Analysis

Descriptive Statistical Analysis serves in the description which includes the mean and median of a set of sorted data. In addition, this analysis includes data distribution such as maximum value, minimum value, and standard deviation value as an indicator of data distribution in the study (Jin et al., 2023).

The results of descriptive statistical analysis presented in Table 1 show data distribution characteristics that reflect structural heterogeneity among EMDEs countries in terms of urbanization, labor participation, renewable energy consumption, and energy intensity. The urban population variable (X1) has an average value of 3.990832 with a median of 4.036821, which indicates a relatively moderate level of urbanization but varies across countries, as reflected by a minimum value of 3.011113 to a maximum of 4.524275. Meanwhile, labor force participation (X2) shows an average of 48,567.80 and a median of 56,303.00, indicating a left-skewed distribution of data, with some countries experiencing very low labor force participation. This is also evident from the wide range of values, ranging from 62.00 to 82,559.00. Renewable energy consumption (X3) has an average value of 28.55250 with a median of 25.20000, which indicates that most countries have integrated clean energy into the energy mix, although there is high inequality, reflected by a minimum value of 1.000000 to a maximum of 90.80000. The dependent variable, energy intensity (Y), has an average of 4.310250 with a median of 3.840000, which indicates that most countries are still at a fairly high level of energy intensity, while the maximum value of 8.590000 shows a very large energy dependence in some countries.

Table 1: Statistical analysis

Statistical classifications	X1	X2	X3	Y
Mean	3.9908	48567.80	28.55250	4.310250
Median	4.0368	56303.00	25.20000	3.840000
Maximum	4.5242	82559.00	90.80000	8.590000
Minimum	3.0111	62.00000	1.000000	1.900000

Data Analysis Results, 2025

Table 2: Normality test

Distribution parameters	Statistic	Prob.
Skewness	1.130050	0.129227
Skewness 3/5	1.279862	0.100297
Kurtosis	1.262806	0.103329
Normality	1.504132	0.471392

Data Analysis Results, 2025

Table 3: Multicollinearity test

Correlation coefficient variable	X1	X2	X3
X1	1.000000	0.077987	−0.554633
X2	0.077987	1.000000	0.292942
X3	−0.554633	0.292942	1.000000

Data analysis results, 2025

Table 4: Chow test

No	Test Summary	Chi-square statistic	Chi-square differences	Prob.	Conclusion
1	Fix effect model	558,799	24.9	0.00	H_0 rejected

Data Analysis Results, 2025

Table 5: Hausman test

No	Test summary	Chi-square statistic	Chi-square differences	Prob.	Conclusion
1	Random effect model	8.63277	3	0.03	H_0 rejected

Data Analysis Results, 2025

4.2. Classical Asumptions

Based on Table 2. The Normality Test using the Skewness Kurtosis method, the probability is 0.129227> 0.05. Then the skewness value of 1.130050 and the kurtosis value of 1.262806 indicate that the data follows a normal distribution pattern.

Based on Table 3. The Multicolonierity Test results, it was found that there were no variables with a relationship that exceeded the correlation value of 0.8. Therefore, it can be concluded that there is no significant multicollinearity between the independent variables used in this study. This means that the variables do not show a strong linear relationship or lack of meaningful interrelationships among others, so there is no significant interdependence.

4.3. Model Selection

Based on Table 4. The Chow Test results found that the statistical Chi-square value (558.799689) > Chi-square table (36.415029) at degrees of freedom = 24.92 with a probability level of 0.0000 <0.05 means rejecting H0 so that the Fixed Effect model should be used.

Based on Table 5. The Hausman Test results found that the Chi-square statistical value of 8.632772 > Chi-square critical value of 7.815 at degree of freedom = 3 with a significant level of 0.0346 < 0.05 so that H0 is rejected. Therefore, the Fixed Effect model is the preferred choice.

4.4. Panel Data Regression Result

The regression calculation results show a confidence level of 0.5% which is then transformed into a mathematical form:

$$Y = 22.6084488048 - 4.21647849183*X1 + 2.38918472001e\text{-}06*X2 - 0.0474530307085*X3$$

4.5. Statistical Test t (Partial Test)

Based on Table 6, it is known that the coefficient of urban population (X1) of −4.216478 indicates that every 1 unit increase in the value of Urban Population will reduce Energy Intensity (Y) by 4.216478 assuming other variables remain constant. The t-statistic value is −3.579506 at 5% significance level, and the probability value (0.0006) is smaller than 0.05. Therefore, it can be concluded that Urban Population has a negative and significant effect on Energy Intensity partially.

The coefficient of Labor (X2) of 2.39E−06 indicates that every 1 unit increase in Labor will increase Energy Intensity (Y) by 2.39E−06 assuming other variables remain constant. The t-statistic value is −2.586822 at the 5% significance level, and the probability value (0.0113) is smaller than 0.05. Therefore, it can be concluded that Labor has a positive and significant effect on Energy Intensity partially.

The renewable energy consumption (X3) coefficient of −0.047453 indicates that every 1 unit increase in renewable energy consumption value will decrease energy intensity (Y) by 0.047453 assuming other variables remain constant. The t-statistic value is −4.174539 at 5% significance level, and the probability value (0.0001) is smaller than 0.05. Therefore, it can be concluded that Renewable Energy Consumption has a negative and significant effect on Energy Intensity partially.

4.6. F Statistical Test

The F test is a statistical test conducted to determine how much influence the independent variables together have on the dependent variable. In the ordinary least square estimation results, the probability value is 0.0000 and significant at the 5% degree. So it can be concluded that Urban Population (X1), Labor (X2), and renewable energy consumption (X3) together or simultaneously have a significant effect on Energy Intensity (Y).

4.7. Results of the Coefficient of Determination (R2)

The coefficient of determination is used to measure how much variation in the dependent variable can be explained by variations in the independent variables. In this study, the coefficient of determination is carried out to determine how much the percentage of Urban Population (X1), Labor (X2), and Renewable Energy Consumption (X3) variables together or simultaneously have a significant effect on Energy Intensity (Y). Based on the analysis of the value of the coefficient of determination (R2) of 0.991589. This means that the influence of the variation of the independent variable on the variation of the dependent variable is 99.15% while the remaining 0.85% is explained by variables outside the model.

5. DISCUSSION

5.1. Relationship between Urban Population and Energy Intensity in EMDEs Countries

The regression analysis results in this study show that the Urban

Table 6: OLS calculation results panel data regression equation selected model FEM

Variable	Coefficient	Standard Error	t-Statistic	Prob.
C	22.60845	4.768428	4.741279	0.0000
X1	−4.216478	1.177950	−3.579506	0.0006
X2	2.39E-06	9.24E-07	2.586822	0.0113
X3	−0.047453	0.011367	−4.174539	0.0001
	Effects specification			
Cross-section fixed (dummy variables)				
R-squared	0.9915	Mean dependent var		4.31025
Adjusted R-squared	0.9891	S.D. dependent var		1.71703
S.E. of regression	0.1790	Akaike info criterion		−0.4008
Sum squared resid	2.9507	Schwarz criterion		0.24952
Log likelihood	52.053	Hannan-Quinn criter.		−0.1367
F-statistic	401.725	Durbin-Watson stat		2.02866
Prob (F-statistic)	0.00000			

Source: Data analysis results, 2025

Population variable has a negative and significant influence on energy intensity (Y). Based on the fixed effect model estimation, a coefficient of −4.216 was obtained with a $P < 0.05$. This indicates that a 1% increase in the proportion of population living in urban areas is consistently associated with a decrease in energy intensity by 4.21 units. This finding indicates that urbanisation, to a certain extent, can contribute to improved energy efficiency in Emerging markets and developing economies (EMDEs), as indicated by reduced energy consumption per unit of gross domestic product (Irawan and Hartono, 2022).

Theoretically, the negative relationship between urbanisation and energy intensity can be explained through several conceptual frameworks. Urban Efficiency Theory (Glaeser, 2011) states that the concentration of economic and social activities in urban areas creates positive externalities in the form of economies of scale, efficiency in resource allocation, and more optimal integration of infrastructure, including energy systems. Well-designed urbanisation has the potential to reduce energy demand in the distribution of goods and services through reduced distances, increased population density, and the use of more energy-efficient public transport modes. This is also in line with the concept of agglomeration economies, where population agglomeration in cities enables cost and energy efficiency in the provision of public services, transport and housing. Furthermore, the energy ladder theory approach states that increased urbanisation often accelerates the transition of energy consumption from traditional sources, such as biomass and coal, to more efficient modern energy sources, such as electricity and natural gas (Van der Kroon et al, 2013). Urbanisation is also correlated with the structural transformation of the economy from the primary sector (agriculture and mining) to the relatively less energy-intensive tertiary sector (services and information technology). In the framework of sustainable development, this represents a positive direction towards decoupling between economic growth and energy consumption.

However, the dynamics of urbanisation in EMDEs are highly complex. EMDEs have recorded the fastest urbanisation rate in modern history. According to a report (United Nations Habitat, 2022), more than 90% of global urban population growth by 2050 will occur in developing countries. Sub-Saharan Africa, for example, has seen its urbanisation increase from 31% in 2000 to 45% in 2022. However, this urbanisation is often unplanned, informal and not aligned with modern energy supply capacity. In India, despite the increasing proportion of urbanised population, reliance on energy sources such as LPG and biomass remains high especially in peri-urban areas (IEA, 2022). Meanwhile, in Nigeria, more than 50% of the urban population lives in informal areas that do not have adequate access to modern energy networks.

The urbanisation-energy nexus phenomenon also shows the spatial energy imbalance between major cities and peripheral areas or small towns. Major cities in EMDEs such as Jakarta and Manila have relatively better energy infrastructure, but suburbanisation and the growth of peri-urban areas have led to increased energy consumption, especially in the transport sector (Zhang and Lin, 2023). A study by (Dujardin et al., 2012) notes that the expansion of road networks and increased travel times in these cities have fuelled consumption and increased energy intensity. In Latin America, a similar phenomenon is seen in Mexico and Brazil, which are experiencing increasing energy intensity due to urban sprawl without the integration of efficient public transport systems.

In addition, energy dualism in urban areas is also a challenge. Large cities in EMDEs have access to modern energy technologies, but within the same city many households and micro-enterprises use traditional energy sources such as diesel or small coal generators. For example, almost 30% of urban energy demand in Bangladesh comes from small generators due to unstable conventional electricity supply (IEEJ, 2023). This phenomenon indicates that while in aggregate urbanisation can reduce energy intensity, the effect can be very heterogeneous depending on the quality of infrastructure, spatial distribution, and the level of electrification.

The empirical findings in this study are supported by several previous studies. Zhang et al. (2018) found that urbanisation reduces energy intensity in China, but only if supported by smart urban planning. In contrast, (Shahbaz et al., 2014) showed that urbanisation in Pakistan actually increases energy intensity due to weak regulation and low technology adoption. The report (United Nations Habitat, 2022) explicitly emphasises that the success of urbanisation in reducing energy intensity is largely determined by the quality of urban governance and energy policy integration.

In the context of EMDEs, urbanisation shows rapid but uneven characteristics. On the one hand, urbanisation is often a driver of economic growth. But on the other hand, without adequate energy infrastructure and technology, urbanisation can be a structural burden on energy efficiency. Access to clean energy, public transport systems, building efficiency and city energy policies are key factors in ensuring that urbanisation serves as an instrument of energy efficiency, not the other way around. Countries such as Vietnam and Turkey that experienced urbanisation based on industrial and technological transformation have successfully reduced energy intensity (Koyuncu et al., 2021). In contrast, countries such as Nigeria and Bangladesh, where urbanisation is more informal and spontaneous, show a tendency to stagnate or increase energy intensity. This reinforces the concept of the threshold effect, where a decrease in energy intensity only occurs after the urban population passes a certain threshold and is accompanied by the readiness of the energy system and urban planning.

Based on these findings, policy implications that can be proposed include encouraging sustainable urban development that integrates clean energy infrastructure, low-emission public transport systems, and urban electrification policies. In this context, the development of smart cities and strengthening urban energy governance are key instruments to realise the transition to a more efficient and sustainable energy system (Yetkin et al., 2020).

5.2. The Relationship of Labour to Energy Intensity in EMDEs Countries

The panel regression estimation results using the fixed effect model approach show that the labour variable has a positive and significant influence on energy intensity with a significance level of 0.0113 < 0.05, indicating that a one-unit increase in the percentage of labour participation tends to cause an increase in energy intensity. In other words, the greater the proportion of economically active working-age population, the higher the energy consumption per unit of economic output produced. This finding indicates that the increase in labour force in EMDEs has not fully synergised with energy efficiency, and may actually worsen national energy consumption if not accompanied by structural transformation and the use of energy-efficient technologies (Zaidi et al., 2024).

Theoretically, there are several economic mechanisms that explain the positive relationship between increased labour and energy intensity. First, in most EMDEs, labour is still absorbed into labour-intensive sectors such as light manufacturing, construction, and traditional agriculture that have high energy consumption to output ratios (Kartiasih et al., 2012). Second, the lack of adoption of efficient and low-carbon technologies in these sectors means that the increase in labour participation is not accompanied by a decrease in energy demand. High initial investment costs for clean technologies, lack of access to green financing, and the absence of fiscal incentives that encourage energy efficiency are the main obstacles. Third, labour force growth is accompanied by accelerated urbanisation, which in many cases increases energy demand for transport, housing and public services, especially if not supported by efficient urban planning and low-emission transport systems.

The economic structure in the Middle and Developing Economies reinforces the relationship between labour and energy intensity. High levels of labour informality are a key challenge in this context. According to a report (ILO, 2022), more than 60% of the workforce in the South Asia and Sub-Saharan Africa region is engaged in the informal sector, which is generally unregulated, labour-intensive and relies on production technologies with low energy efficiency. Heavy reliance on fossil fuels still dominates the region's energy mix. A report (IESR, 2023) shows that more than 70% of final energy consumption in ASEAN comes from fossil sources, such as coal and petroleum. Furthermore, resistance to reforming the traditional energy subsidy system is also a significant obstacle to accelerating the transition to renewable energy, while reducing incentives to adopt green technologies in labour-intensive sectors. In addition, clean energy infrastructure in most EMDEs is still at an early stage of development and is unevenly distributed, both spatially and sectorally.

Analysis of cross-country case studies supports this explanation. In Indonesia, despite an increase in labour participation post-COVID-19 pandemic, especially in the manufacturing and logistics sectors, energy transformation towards clean and efficient energy sources has not gone hand in hand. Data from (IESR, 2023) shows the stagnation of energy efficiency in the industrial sector, caused by the dominance of conventional technology and high consumption of coal-based energy. In Bangladesh, the garment sector, which is a key sector of the economy, absorbs millions of female workers, but its energy-intensive production characteristics, as well as reliance on diesel-fuelled generation, contribute to the country's high energy intensity. In contrast, Vietnam has managed to reduce energy intensity despite an increase in employment, due to targeted industrialisation policies, investment in technical training, and incentives that encourage the adoption of energy efficiency technologies integrated with formal sector development.

The findings in this study are in line with the literature study by (Apergis and Payne, 2010) showing that an increase in the number of labour will only have an effect on reducing energy intensity if it is accompanied by an increase in labour productivity and the allocation of labour to the technology-based formal sector. (Mulder and De Groot, 2012) emphasised the importance of sectoral structure in explaining the variation of energy intensity between countries, where labour in the service or technology sector generally has a much lower energy intensity compared to the heavy industry sector. Meanwhile, (Binuomote et al., 2022) highlighted that labour sector reform and its integration with high value-added sectors in Sub-Saharan Africa is a key prerequisite for sustainable energy intensity reduction. The consistency of these findings reinforces the conclusion that the structure of labour and the direction of sectoral transitions are key determinants in the relationship between labour and energy efficiency.

Based on the empirical findings and the structural dynamics outlined, a number of policy implications can be recommended to avoid a situation where an increase in labour leads to an increase in energy intensity. First, EMDEs need to design and implement vocational training systems that are aligned with the needs of green industries and low-carbon economic sectors, with priority on urban and semi-urban areas at the centre of economic growth. Second, governments need to expand fiscal incentives and strengthen access to finance for investment in energy efficiency technologies, especially for labour-intensive business sectors that absorb a large proportion of the workforce. Third, a long-term strategy is needed to reform the energy subsidy scheme, by gradually shifting fossil fuel subsidies towards the development of renewable energy and clean energy infrastructure. This reform will not only contribute to improving national energy efficiency, but also create opportunities for the growth of green jobs. The creation of inclusive and future-oriented green jobs is also considered strategic in facing labour challenges amid the transition to a green economy (Maulana et al., 2023).

5.3. The Relationship of Renewable Energy Consumptions to Energy Intensity in EMDEs Countries

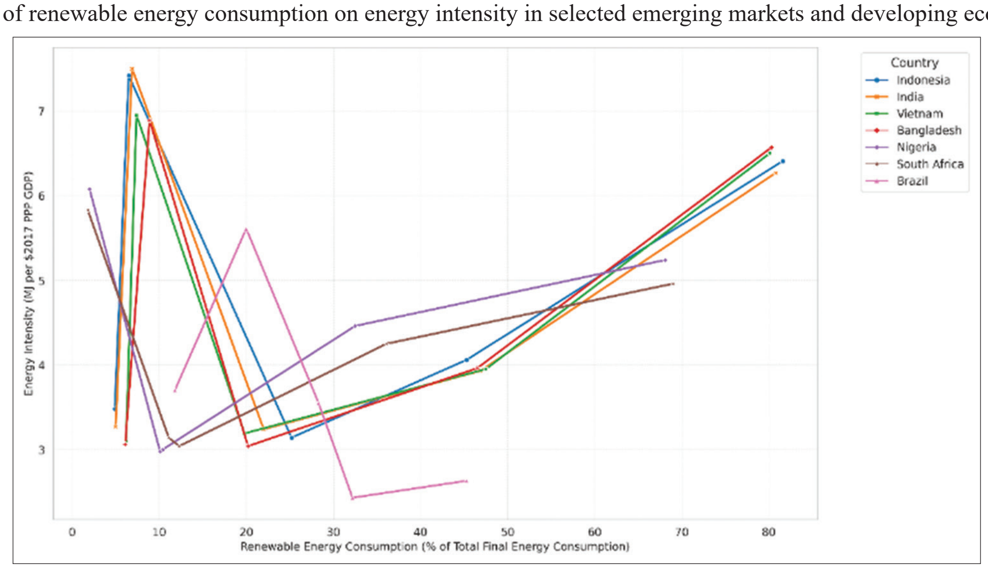
The results of panel data regression estimation using the Fixed Effect Model approach show that the renewable energy consumption variable has a negative and significant relationship with the level of energy intensity. Based on the calculation results, the regression coefficient is −0.047453, the t-statistic value is −4.174, and the probability level is 0.0001. This shows that a 1% increase in the share of renewable energy consumption to total final energy consumption in a country is associated with a 0.047 decrease in the level of energy intensity assuming other variables remain constant. Theoretically, the negative relationship between renewable energy consumption and energy intensity level is in line with the energy transition framework in the environmental and energy economics literature. Energy Transition Theory states that a shift from fossil energy to clean and renewable energy is a prerequisite for achieving energy efficiency and economic decarbonisation. Fossil energy, especially coal and petroleum, has low conversion efficiency and high carbon intensity. In contrast, renewable energy such as solar, wind, hydro and geothermal power offers higher conversion efficiency and produces no carbon emissions in the energy generation process. Furthermore, the Green Growth Paradigm emphasizes that sustainable economic growth can only be achieved through the transformation of the energy system towards clean, efficient and renewable resources. In line with this, the Energy Efficiency Technology Adoption Model explains that renewable energy consumption is often integrated with the application of smart technologies such as smart grids, digital-based automatic control systems, and energy storage systems that drive substantial efficiency in energy distribution and consumption (Bosseboeuf et al., 2024).

The causal mechanism between renewable energy consumption and energy efficiency can be explained through three main dimensions. First, renewable energy sources do not require thermal conversion processes as in fossil fuel combustion, resulting in much higher efficiency of energy conversion into electricity. Second, the integration of renewable energy into the national energy system encourages digitalization through smart meters, load balancing systems, and the adoption of batteries as energy storage, which in aggregate optimizes energy use and lowers energy consumption per unit of gross domestic product. Third, renewable energy serves as a direct substitute for carbon-based energy, so countries that succeed in significantly increasing the share of renewable energy tend to experience a decrease in energy use per unit of economic output. (Herdyanti, 2021) found that there is a long-term relationship between energy consumption, including renewable energy, and economic growth in Indonesia.

Figure 1 below presents a visualization of the dynamic relationship of the effect of renewable energy consumption on energy intensity in Emerging Markets and Developing Economies over the period 2017-2021. The consistent pattern of decline in most countries suggests that increasing the proportion of renewable energy in the national energy mix is associated with higher energy efficiency, as reflected in declining energy intensity.Empirical phenomena in various EMDEs such as Vietnam where the share of renewable energy consumption increased sharply from 15% in 2015 to 34% in 2022, accompanied by a 10% decrease in energy intensity over the same period (IRENA, 2023). This achievement was supported by feed-in tariff policies, net-metering schemes, as well as an influx of foreign investment in the construction of large-scale solar power plants. Morocco shows similar success, with renewable energy accounting for more than 37% of total national electricity by 2021 and a 15% reduction in energy intensity between 2015 and 2022. This strategy is reinforced by the gradual closure of coal-fired power plants and the operation of the Ouarzazate Solar Complex project. In contrast, Bangladesh and India, despite registering an increase in renewable energy consumption, have not been able to significantly reduce energy intensity. In Bangladesh, off-grid solar energy consumption is increasing in rural areas, but the energy distribution infrastructure still relies on diesel generators, reducing systemic efficiency (IEEJ, 2023). India, despite increasing its share of renewable energy from 18% in 2015 to 26% in 2021, faces stagnating energy intensity due to increasing industrial electricity demand and transportation electrification that remains dependent on coal-based energy. In Nigeria, distribution issues are a major constraining factor. Despite statistically increasing renewable energy consumption, 57% of rural communities still rely on inefficient and expensive fossil fuel generators, which in turn increases energy intensity nationwide.

Geographically, cross-regional comparisons show that the impact of renewable energy consumption on energy intensity varies widely. In South Asia such as India, Bangladesh and Pakistan, despite the high penetration of renewable energy, the unequal distribution and dominance of fossil energy in the industrial sector means that its impact on energy intensity is limited. In the Sub-Saharan Africa region, the increase in renewable energy generally comes in the form of small-scale off-grid systems

Figure 1: The effect of renewable energy consumption on energy intensity in selected emerging markets and developing economies (2017-2021)



that have not been able to create a systemic impact on national energy efficiency (Akinmoladun and Akinmoladun, 2020). In contrast, in the Middle East and North Africa (MENA) region such as Morocco, Egypt, and Jordan, the adoption of renewable energy has significantly reduced energy intensity because it is supported by fiscal policy frameworks, long-term planning, and grid infrastructure readiness.

The findings in this study suggest that the combination of renewable energy consumption and urbanization has the potential to amplify energy intensity reduction, especially in urban areas with access to sophisticated and integrated power grids. However, when the increase in renewable energy consumption coincides with the growth of labor absorbed in energy-intensive sectors such as manufacturing or traditional agriculture, the efficiency effect may be reduced. In addition, there is a threshold effect where the impact of renewable energy consumption on energy intensity is only significant when its proportion exceeds 25-30% of total final energy consumption (IRENA, 2023).

Structural challenges that EMDEs face in optimizing the role of renewable energy towards energy efficiency include underinvestment in energy storage technologies, continued fossil fuel subsidies that reduce the competitiveness of clean energy, and limited grid infrastructure that does not yet support the integration of intermittent energy sources such as wind and solar power. In addition, the low quality of energy policies, weak institutional coordination, and lack of fiscal incentives also weaken the ability of renewable energy to significantly reduce energy intensity (REN21, 2023).

The results of this study are consistent with a study by (Narayan et al., 2021) which shows that renewable energy consumption contributes significantly to reducing energy intensity in 20 developing countries, especially when accompanied by technological innovation and supportive policies. (Sovacool et al., 2020) confirmed that countries that prioritize the development of renewable energy experience a faster decline in emissions and energy intensity than countries that rely on nuclear. (Wu et al., 2021) found that the integration of renewable energy and industrial sector digitalization improved energy efficiency in China's manufacturing sector.

Based on the empirical and conceptual findings above, here are some macro policy recommendations for EMDEs. First, it is necessary to reform energy subsidies by shifting support from fossil fuels to investment and incentives for renewable energy development (Coady et al., 2017). Second, the application of feed-in-tariff and net-metering schemes for households and small businesses needs to be expanded. Third, the state needs to encourage the modernization of the national electricity grid to effectively integrate renewable energy sources. Fourth, renewable energy should be part of the strategy to build green industry clusters to support the structural transformation of the economy. Fifth, mobilization of international climate funds such as the Green Climate Fund is important to fund large-scale renewable energy projects in developing countries.

6. CONCLUSION

This study makes an important contribution to understanding the non-sectoral structural dynamics that affect energy efficiency in Emerging Markets and Developing Economies countries. Using a Fixed Effect Model panel data regression approach on 25 countries over the period 2017-2021, it is found that urbanization and renewable energy consumption have a negative and significant effect on energy intensity, while labor force participation shows a significant positive effect. The negative effect of urbanization on energy intensity reflects that increased population concentration in urban areas, when supported by integrated infrastructure and spatial planning, can create scale efficiency through optimization of public transport, consolidation of energy networks, and adoption of energy-efficient technologies. Planned urbanization enables a reduction in energy consumption per unit of Gross Domestic Product (GDP), while reinforcing the direction of low-carbon development. Similarly, the negative effect of renewable energy consumption on energy intensity confirms that the substitution of fossil energy with clean energy improves the efficiency of national energy conversion and distribution, and promotes the modernization of energy systems through the integration of digital technologies such as smart grids and energy storage systems. In contrast, the positive effect of labor force participation on energy intensity suggests that the increase in the number of active workers has not been fully converted into optimal energy efficiency. This is due to the dominance of energy-intensive and informal sectors that absorb most of the labor force in EMDEs, as well as the limited adoption of low-emission production technologies. Thus, without structural transformation towards a formal sector based on clean technology, the expansion of the workforce has the potential to increase the burden of national energy consumption.

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