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Structural Transformation in the Blue-Green Nexus: Maritime Trade, Conservation Areas, and Energy Intensity Patterns

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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 urbanization, labor force growth, and renewable energy adoption, energy intensity in Emerging markets and developing economies (EMDEs) still shows 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 multidimensional transformation affects national energy efficiency in EMDEs countries. This study aims to analyze the influence of container port traffic (container trade volume), marine protected areas (% of territorial waters), urban population (% of total population), labor 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 EMDEs countries over the period 2017-2021. Based on previous theoretical studies and empirical trends, it is hypothesized that container port traffic, and marine protected areas, urbanization, and renewable energy consumption reduce energy intensity, while labor force participation tends to increase energy intensity if not accompanied by sectoral and technological reforms. The research methodology uses a panel data regression approach with the Fixed Effect Model. The analysis shows that partially, container port traffic, and marine protected areas, urban population, and renewable energy consumption have a negative and significant effect on energy intensity, while labor force participation rate shows a positive and significant effect. Simultaneously, the five variables have a significant effect on energy intensity. The coefficient of determination (R^2) of 0.994898 indicates that 99.48% of the variation in energy intensity can be explained by the variation in the five independent variables. This finding confirms the importance of policy formulation that integrates demographic structural transformation, renewable energy transition, maritime trade infrastructure modernization, and marine environmental governance to sustainably reduce energy intensity in EMDEs countries.

Keywords: Container Trade, Marine Protected Areas, Energy Intensity, Urbanization, Labor Participation, Renewable Energy, Structural Transformation, Emerging Markets and Developing Economies
JEL Classification: O11, Q43, Q56, O14, Q48, R11, Q57

1. INTRODUCTION

Energy intensity, 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 utilizing 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 major focus in the sustainable energy transition agenda, especially as part of efforts to mitigate climate change and achieve 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 strong empirical data (McCollum et al., 2018).

Since the beginning of the 21st century, EMDEs have undergone a structural transformation characterized by increased urbanization, changes in the composition of the workforce, progressive adoption of renewable energy, and expansion of maritime trade infrastructure and marine protected area management. Urbanization rates in EMDEs are increasing from an average of 36.5% in 1990 to 52.9% in 2022, with South Asia and Sub-Saharan Africa showing accelerating trends. At the same time, labor force participation rates are also undergoing 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 is increasing consistently, rising from 14% in 2000 to around 27% of total final energy consumption in 2021 (IRENA, 2023).

Alongside this transformation, maritime trade activity represented by the Container Port Traffic indicator has also experienced significant growth in EMDEs. According to a report (UNCTAD, 2023), the volume of container trade in EMDE ports increased by more than 35% with an average annual growth of 4.7%. This expansion of port infrastructure and intensification of maritime trade flows not only reflects economic openness, but also has implications for the energy consumption of the transportation and logistics sector. For example, major ports in Southeast Asia and East Africa have undergone modernization that integrates automation and digitalization technologies to improve operational efficiency and reduce energy consumption per unit of cargo. But on the other hand, increased port activity also has the potential to increase fossil fuel consumption in the maritime sector, which puts pressure on aggregate energy intensity if not matched by the adoption of green technologies and optimization of logistics systems.

In the environmental aspect, the establishment of Marine Protected Areas has become an instrument of conservation policy in EMDEs. UNEP-WCMC data by 2023 shows that the total officially designated marine protected areas in EMDEs increased from an average of 3.2% of territorial area in 2010 to 8.7% by 2022. These marine protected areas not only play a role in maintaining biodiversity and blue carbon stocks, but also impact maritime economic activity and energy consumption patterns in coastal areas. Research by (Lester et al., 2020) shows that the establishment of MPAs can encourage the restructuring of maritime economic activities from energy-intensive extractive industries such as offshore oil drilling, towards service sectors such as marine ecotourism which are relatively lower in energy intensity. On the other hand, regulating access to and utilization of marine resources through MPAs also has the potential to affect the livelihoods of coastal communities and local energy consumption patterns, especially in areas dependent on traditional fisheries.

Although various structural transformation indicators show positive trends, energy intensity in EMDEs remains high and tends to stagnate. This indicates gaps in the application of energy efficiency technologies, energy governance and spatial planning. Urbanization, 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). Similarly, the expansion of container port infrastructure without the integration of low-carbon technologies and efficient logistics systems risks increasing aggregate energy consumption. On the other hand, changes in the labor force structure such as increased informal participation or the dominance of low-energy service sectors may affect the national energy demand profile, but have so far not been empirically studied. Similarly, the impact of marine protected area designation on national energy intensity still requires a comprehensive study, given the complexity of interactions between environmental governance, maritime economic activity and energy consumption. Therefore, reducing energy intensity is not only a technological challenge, but also a structural and multidimensional one. Achieving sustainable energy transition in EMDEs requires a more holistic understanding of how structural and environmental variables interact.

Previous studies have examined the link between structural change and energy productivity, such as that of Sak and Guloglu (2025) in the context of Türkiye. The study highlighted how economic sector shifts (from agriculture to industry and services) contributed to changes in aggregate energy productivity. Meanwhile, (Wang et al., 2023) analysed the relationship between maritime trade activity and energy efficiency in five ASEAN countries, finding that port infrastructure modernization had a positive impact on reducing energy intensity through logistics efficiency and reduced transit times. On the environmental aspect, (Huang and Chen, 2022) investigated the impact of marine conservation policies on the energy-economic profile of Pacific island countries, indicating the potential for a blue economy transition that promotes long-term energy efficiency.

This study aims to analyze the energy intensity level of primary energy in EMDEs countries from different regions over the period 2017-2021, focusing on the effects of multidimensional structural transformation on national energy efficiency. Specifically, this study investigates how energy intensity is affected by complex interactions between demographic factors (urbanization), employment (labor force participation rate), energy transition (renewable energy consumption), trade infrastructure (container port activity), and environmental governance (marine protected areas). By adopting a panel data econometric approach, this study identifies the structural determinants of energy intensity and explores the heterogeneity of impacts across countries with different socio-economic and geographic characteristics. It also contributes to the development of a conceptual understanding of structural transformation in the energy transition era. The main contribution of this study is the provision of a new approach in defining structural transformation that is more contextualized for developing countries, taking into account the dimensions of demography, trade infrastructure, environmental governance, and clean energy transition. Empirically, this study is expected to fill the literature gap on the multidimensional determinants of energy intensity in EMDEs, as well as generate policy recommendations based on scientific analysis to support the agenda of decarbonization, energy efficiency, sustainable trade, marine ecosystem conservation, and sustainable development 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.

2.5. Container Port Traffic

Container Port Traffic is an indicator that measures the international trade activity and economic openness of a country through the volume of standard 20-foot containers (TEU - Twenty-foot Equivalent Units) handled by ports in a given period of time.

It reflects not only the country's maritime infrastructure capacity but also the level of integration in global supply chains and the intensity of international economic activity (Rodrigue and Notteboom, 2021).

The link between Container Port Traffic and energy intensity can be explained through the theory of economic internationalization which states that an increase in the volume of international trade reflected in Container Port Traffic encourages the transfer of technology and efficient business practices across countries, including energy-saving technologies and more efficient operational standards. Research by (Li and Zhang, 2022) found that the growth of Container Port Traffic in China followed by the development of SEZs contributed to a decrease in regional energy intensity by 3.2% per year over the period 2010-2020.

2.6. Marine Protected Areas

Marine Protected Areas are marine conservation policy instruments defined as legally designated and managed water areas for the protection of biodiversity, natural resources and cultural values associated with marine ecosystems. The percentage of Marine Protected Areas to total territorial waters reflects a country's commitment to maintaining the sustainability of marine ecosystems while optimizing the sustainable use of marine resources (Claudet et al., 2020).

From a theoretical perspective, the link between Marine Protected Areas and energy intensity can be explained through Natural Capital Theory, which states that marine ecosystem protection is a long-term investment in natural assets that support economic efficiency through the provision of sustainable ecosystem services, including climate stability, which plays an important role in energy consumption (Barbier et al., 2018). In addition, the Green Economy Framework suggests that marine conservation promotes economic restructuring from energy-intensive extractive sectors to relatively more energy-efficient service sectors. Marine Protected Areas play an important role in ecosystem resilience to climate change, which indirectly affects national energy consumption. Research (Grorud-Colvert et al., 2021) shows that protected marine ecosystems are better able to sequester carbon and stabilize local sea surface temperatures, contributing to a reduction in cooling needs in coastal areas by up to 12%.

3. RESEARCH METHODOLOGY

3.1. Statistical Analysis

Statistical analysis is a systematic process that includes collecting, organising, 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:

$$Y = \beta 0 + \beta 1\ X1 + \beta 2\ X2 + \beta 3\ X3 + \beta 3\ X4 + \beta 3\ X5 + \varepsilon \qquad (3.1)$$

Description:
Y: Energy intensity
β0: Intercept
β1, β2: Regression coefficient
X1: Urban population
X2: Labor force
X3: Renewable energy consumption
X4: Container port traffic
X5: Marine protected areas (% of territorial waters)
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: βi < 0 There is no significant effect between the independent variable and the dependent variable partially
H_a: βi > 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 the characteristics of data distribution that reflect structural heterogeneity among EMDEs countries. The urban population variable (X1) has a mean value of 4.039709 with a median of 4.078198, which indicates a relatively moderate level of urbanization but varies across countries, as reflected by a minimum value of 3.279482 to a maximum of 4.524275. Meanwhile, labor force participation (X2) has a mean value of 4.064282 and a median of 4.084614, indicating a rather normal distribution. The range of values from 3.655064 to 4.413513 indicates relatively moderate variability in employment characteristics across countries. Renewable energy consumption (X3) shows a mean value of 27.42286 with a median of 25.20000, indicating a slightly right-skewed distribution. Substantial disparity is seen from the range of minimum value of 4.900000 to maximum of 81.80000, reflecting significant heterogeneity in renewable energy adoption among EMDEs. Container Port Traffic (X4) has a mean value of 14.96136 with a median of 15.00083, indicating a highly symmetrical distribution of the data. The range of values from 12.43325 to 16.80225 indicates relatively limited variability in maritime trade activity, reflecting a relatively homogeneous reliance on container-based international trade across the sample of EMDEs countries. Marine Protected Areas (X5) shows a mean of 7.090993 with a much lower median of 1.200000, indicating a heavily right-skewed distribution. Extreme disparity is seen from a minimum value of 0.097406 to a maximum of 50.70000, indicating a very significant gap in the implementation of marine conservation policies among EMDEs countries. The dependent variable, energy intensity (Y), has an average of 3.858762 with a median of 3.530000, which indicates that most countries are still at a fairly high level of energy intensity, while the maximum value of 7.500000 shows a very large energy dependence in some countries.

4.2. Classical Asumptions

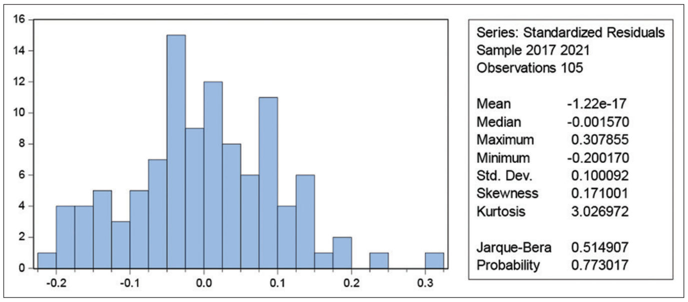
Based on the normality test results shown in Figure 1, the probability value is 0.773017 > 0.05. Additionally, the Jarque-Bera value is less than the Chi-Square critical value, which indicates that the data follows a normal distribution pattern.

Based on the multicollinearity test results presented in Table 2, 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

The Chow Test results presented in Table 3 found that the statistical Chi-square value (539.483387) > 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.

Figure 1: Normality test



Data Analysis Results, 2025

The Hausman Test results presented in Table 4 found that the statistical Chi-square value is 11.465593 > Chi-square table 11.07050 at degree of freedom = 5 with a significant level of 0.0429 < 0.05, 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 mathematical form: Y = 16.1802589826 - 1.59192754407*X1 + 0.189219020733*X2 - 0.0507689232273*X3 - 0.251610495325*X4 - 0.00495420731264*X5

4.5. Statistical Test t (Partial Test)

Based on Table 5, the coefficient of urban population (X1) of −1.591928 indicates that every 1 unit increase in the value of Urban Population will decrease Energy Intensity (Y) by 1.591928 assuming other variables remain constant. The t-statistic value is −1.654375 at 5% significance level, and the probability value (0.0102) 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 0.189219 indicates that every 1 unit increase in Labor will increase Energy Intensity (Y) by

Table 1: Statistical analysis

Statistical classifications	X1	X2	X3	X4	X5	Y
Mean	4.0397	4.0642	27.422	14.961	7.0909	3.8587
Median	4.0781	4.0846	25.200	15.000	1.2000	3.5300
Maximum	4.5242	4.4135	81.800	16.802	50.700	7.5000
Minimum	3.2794	3.6550	4.9000	12.433	0.0974	1.9000

Data analysis results, 2025

Table 2: Multicollinearity test

Correlation coefficient variable	X1	X2	X3	X4	X5
X1	1.000000	−0.114875	−0.425972	−0.233319	0.425953
X2	−0.114875	1.000000	0.548878	0.047676	−0.003439
X3	−0.425972	0.548878	1.000000	−0.046603	0.049278
X4	−0.233319	0.047676	−0.046603	1.000000	0.022946
X5	0.425953	−0.003439	0.049278	0.022946	1.000000

Data analysis results, 2025

Table 3: Chow test

Test summary	Chi-square statistic	Chi-square difference	Probability	Conclusion
Fix effect model	539,48338	24,92	0.000	H_0 rejected

Data analysis results, 2025

Table 4: Hausman test

Test summary	Chi-square statistic	Chi-square difference	Probability	Conclusion
Random effect model	11,465593	5	0.0429	H_0 is rejected

Data analysis results, 2025

Table 5: OLS calculation results panel data regression equation selected model FEM

Variable	Coefficient	Standard error	t-statistic	Probability
C	16.18026	3.758432	4.305056	0.0000
X1	−1.591928	0.962253	−1.654375	0.0102
X2	0.189219	0.259172	0.730090	0.0467
X3	−0.050769	0.008099	−6.268535	0.0000
X4	−0.251610	0.119499	−2.105553	0.0384
X5	−0.004954	0.001741	−2.845841	0.0056
Effects specification				
Cross-section fixed (dummy variables)				
R-squared	0.994898	Mean dependent variable		3.858762
Adjusted R-squared	0.993283	S.D. dependent variable		1.401236
S.E. of regression	0.114843	Akaike info criterion		−1.279777
Sum squared resid	1.041923	Schwarz criterion		−0.622606
Log likelihood	93.18829	Hannan-Quinn criter.		−1.013478
F-statistic	616.1490	Durbin-Watson stat		1.758758
Probability (F-statistic)	0.000000			

Source: Data analysis results, 2025
SD: Standard deviation

0.189219 assuming other variables remain constant. The t-statistic value is 0.730090 at the 5% significance level, and the probability value (0.0467) is smaller than 0.05. Therefore, it can be concluded that Labor has a positive and significant influence on Energy Intensity partially.

The Renewable Energy Consumption (X3) coefficient of −0.050769 indicates that every 1 unit increase in Renewable Energy Consumption value will decrease Energy Intensity (Y) by 0.050769 assuming other variables remain constant. The t-statistic value is −6.268535 at the 5% significance level, and the probability value (0.0000) is smaller than 0.05. Therefore, it can be concluded that Renewable Energy Consumption has a negative and significant effect on Energy Intensity partially.

The coefficient of Container Port Traffic (X4) of −0.251610 indicates that every 1 unit increase in the value of Container Port Traffic will decrease Energy Intensity (Y) by 0.251610 assuming other variables remain constant. The t-statistic value is −2.105553 at 5% significance level, and the probability value (0.0384) is smaller than 0.05. Therefore, it can be concluded that Container Port Traffic has a negative and significant effect on Energy Intensity partially.

The coefficient of marine protected areas (X5) of −0.004954 indicates that every 1 unit increase in the value of Marine Protected Areas will decrease Energy Intensity (Y) by 0.004954 assuming other variables remain constant. The t-statistic value is −2.845841 at 5% significance level, and the probability value (0.0056) is smaller than 0.05. Therefore, it can be concluded that Marine Protected Areas have a negative and significant influence 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), renewable energy consumption (X3), container port traffic (X4), and marine protected areas (X5) 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), renewable energy consumption (X3), Container Port Traffic (X4), and Marine Protected Areas (X5) variables together or simultaneously have a significant effect on Energy Intensity (Y). Based on the analysis of the value of the coefficient of determination (R^2) of 0.994898. This means that the influence of the variation of the independent variable on the variation of the dependent variable is 99.48% while the remaining 0.52% is explained by variables outside the model.

5. DISCUSSION

5.1. Relationship of Container Port Traffic to Energy Intensity in EMDEs Countries

The estimation results in this study show that the container port traffic variable has a negative and significant effect on Energy Intensity with a coefficient of −0.251610 at a significance level of $\alpha = 5\%$ ($P = 0.0384$). This finding confirms the hypothesis that port infrastructure modernization and increased maritime trade volume contribute to national energy efficiency in EMDEs. Conceptually, the negative relationship between Container Port Traffic and energy intensity can be explained through several theoretical frameworks. International Trade Efficiency Theory suggests that increased international trade encourages cross-country technology diffusion and promotes efficient allocation of resources, including energy resources (Grossman and Krueger, 1995). In this context, container port infrastructure expansion represents an increase in trade volume, modernizing national and international logistics systems. Porter's hypothesis is also relevant in explaining the dynamics of increased international competition encouraging firms to adopt more efficient technologies and business practices to maintain competitiveness (Porter and van der Linde, 1995). This includes optimizing energy use in the production to distribution value chain. In addition, Scale Economy Theory asserts that the expansion of maritime trade creates economies of scale that enable efficient use of resources, including energy consumption per unit of output (Rodrigue and Notteboom, 2021).

The transmission mechanism of Container Port Traffic's influence on energy efficiency can be outlined in several pathways. First, increased container port activity reflects integration into global value chains (GVCs), which is generally accompanied by technology transfer and international operational standards, including energy efficiency practices (Gereffi and Fernandez-Stark, 2016). Second, modern ports with high container volumes tend to adopt automation and digitization technologies such as automated guided vehicles (AGVs), electric cranes, and integrated terminal management systems that are intrinsically more energy efficient than conventional manual operations. Third, increased Container Port Traffic encourages investment in better and more efficient infrastructure, including multimodal connectivity and mass transportation systems that have the potential to lower overall energy intensity in national logistics chains (Notteboom et al., 2021). An empirical analysis of Container Port Traffic patterns in EMDEs over the period 2017-2021 shows a trend that container port volumes in Southeast Asian countries such as Vietnam and Malaysia increased by an average of 6.2% per year over the period, while in Sub-Saharan Africa the growth was more moderate at around 3.8% per year. Significant differences were seen in the level of port modernization, with the Liner shipping connectivity index (LCI) of East and Southeast Asian countries reaching an average of 62.4%, while that of Africa and South Asia only reached 32.7%. This differentiation contributes to variations in the effectiveness of Container Port Traffic in influencing energy intensity between regions.

Case studies in several EMDEs countries reinforce the quantitative findings in this study. The country of Vietnam saw Container Port

Traffic increase from 11.6 million TEU in 2017 to 17.8 million TEU in 2021, successfully reducing energy intensity by 12%. The expansion of major ports such as Hai Phong and Ho Chi Minh City was accompanied by the implementation of smart port management systems and modernization of loading and unloading equipment, which contributed to overall energy efficiency. In Malaysia, the development of Tanjung Pelepas and Klang ports integrated with industrial parks and multimodal transportation systems has lowered the energy intensity of the logistics sector by 15%. In contrast, while Nigeria and Kenya have recorded positive growth in Container Port Traffic, they have not shown a significant reduction in energy intensity. This can be explained by limitations in the adoption of modern technology, inadequate supporting infrastructure, and inefficiencies in connectivity between transportation modes. The analysis in this study also reveals a threshold effect, where the negative effect of Container Port Traffic on energy intensity is only significant when the volume of container ports reaches a scale above 5 million TEU per year. This is consistent with the economies of scale theory which states that optimal efficiency is only achieved once operations reach a certain scale that allows investment in modern technology and system optimization. At smaller scales, operational and energy costs per unit of handling tend to be higher due to limitations in capacity utilization and technology. The findings of this study reinforce and extend the results of a study by (Li and Zhang, 2022) showing that the growth of Container Port Traffic in China contributed to the decline in regional energy intensity.

Based on the empirical findings and contextual analysis, several policy implications can be formulated. First, EMDEs countries need to prioritize investment in container port modernization, especially through the adoption of automation and digitalization technologies that improve energy efficiency in port operations. Second, the development of supporting infrastructure such as railways to and from ports (hinterland connectivity) needs to be strengthened to maximize energy efficiency in the national logistics chain. Third, trade facilitation policies such as simplifying administrative procedures and using a single window system can reduce the waiting time of ships at the port, which has implications for reducing idle energy consumption. Fourth, spatial planning that integrates ports with industrial areas and logistics centers (port-centric logistics) should be encouraged to reduce transportation distances and improve overall energy efficiency. Fifth, the adoption of international standards in green port operations such as ISO 50001 for energy management and the use of renewable energy in port facilities needs to be included in the national policy agenda (International Maritime Organization, 2023).

5.2. Relationship of Marine Protected Areas to Energy Intensity in EMDEs Countries

The regression analysis results show that the marine protected areas (MPAs) variable has a negative and significant influence on Energy Intensity with a coefficient of −0.004954 and a P = 0.0056 (<0.05). Theoretically, the negative relationship between marine protected areas and energy intensity can be explained through three conceptual frameworks. First, Natural Capital Theory (Barbier et al., 2018) asserts that marine ecosystem protection is a strategic investment in natural capital that supports economic efficiency through the provision of sustainable ecosystem services. Effectively managed MPAs contribute to coastal microclimate stability, sea surface temperature regulation and carbon sequestration with implications for reducing energy requirements for cooling in coastal areas. Second, the Structural transformation hypothesis proposed by (Claudet et al., 2020) explains that the establishment of marine protected areas encourages the restructuring of coastal economies from energy-intensive extractive sectors such as trawl fishing and offshore oil drilling to sustainable maritime service sectors such as marine ecotourism and aquaculture that are relatively lower in energy intensity. Third, the Blue Economy Framework developed by (Bennett et al., 2021) states that marine conservation acts as a catalyst for the transition from a conventional marine economy to a sustainable blue economy that integrates energy efficiency.

Based on empirical analysis of panel data from 2017 to 2021, there are four pathways through which MPAs affect national energy efficiency. First, sustainable maritime spatial planning that creates optimal zoning between conservation areas and economic use, thereby increasing the efficiency of marine resource utilization including in the aspect of energy consumption. Second, climate regulation service where protected marine ecosystems such as coral reefs and mangroves function as carbon sinks that absorb up to 5-10 times more carbon than terrestrial ecosystems per unit area, thus contributing to the mitigation of global warming which impacts the need for cooling energy (Macreadie et al., 2021). Third, economic restructuring effect where MPAs encourage the transition from energy-intensive, large-scale conventional fishing industries to more energy-efficient, community-scale sustainable fishing practices (Golden et al., 2022). Fourth, innovation spillover where strict regulations within MPAs encourage the adoption of environmentally friendly and energy-efficient technologies that then spread to other sectors of the maritime economy.

The heterogeneity analysis of the effect of MPAs on energy intensity in different EMDEs regions shows a varied pattern. In Small Island developing states (SIDS) such as Maldives, Fiji, and Seychelles, the establishment of MPAs reached more than 30% of territorial waters and correlated with a decrease in energy intensity by 8-12% over the period 2015-2022. This phenomenon is influenced by the high economic dependence on the marine tourism sector, which is undergoing a transformation towards low-carbon ecotourism along with the expansion of marine protected areas. Meanwhile, in EMDEs with large coastal areas such as Indonesia, Mexico, and South Africa, the effect of MPAs on energy intensity is relatively moderate (3-6% decrease) due to wider economic diversification and the dominance of non-maritime sectors in the national economic structure. In the Latin American region, Brazil is an illustrative case where the expansion of MPAs from 1.5% to 26.5% of the marine area in the period 2016-2021 contributed to a 7.3% decrease in energy intensity, mainly through the restructuring of the fishing industry and coastal tourism (Leal et al., 2023). In the Southeast Asia region, the Philippines, with more than 1,800 Marine Protected Areas spread across its archipelago, has integrated MPA management with renewable energy-based electrification programs in coastal areas, amplifying the national energy intensity reduction effect (Pomeroy et al., 2022).

Empirical research by (Grorud-Colvert et al., 2021) identified that only marine protected areas with high governance scores (>70%) significantly contributed to reducing the energy intensity of the maritime sector. Another factor is the level of economic integration, with countries with strong economic linkages between coastal and inland areas likely to experience wider spillover effects of MPAs on national energy efficiency. In addition, the level of diversification of the maritime economy also affects the magnitude of the impact of MPAs, with more diversified maritime economies showing higher elasticity to changes in energy intensity. The Secretariat of the Convention on Biological Diversity reported in 2022 that the effectiveness of MPAs in reducing energy intensity increased by 35% after the conservation area had been in operation for more than 5 years. This phenomenon is closely related to the ecological recovery process that takes time to reach optimal conditions in the provision of ecosystem services, including climate regulation with implications for energy efficiency. The longitudinal data also revealed a dynamic threshold effect, where the significant effect of MPAs on energy intensity is only detected when the coverage of conservation areas reaches at least 10% of the total territorial water area.

Based on the empirical and conceptual findings described, the following policy implications can be formulated. First, the integration of marine conservation strategies into national energy planning through a holistic ocean-energy nexus approach. Second, optimizing the design and management of MPAs by considering ecological criteria and their potential contribution to national energy efficiency. Third, the development of economic incentive mechanisms for coastal communities that adopt low-carbon maritime practices within the buffer zone of MPAs. Fourth, strengthening innovative financing instruments such as blue bonds and carbon offsetting to support the expansion and effectiveness of MPAs management. Fifth, improving institutional capacity and collaborative governance involving multi-stakeholders in the management of MPAs to maximize socio-economic benefits including energy efficiency aspects (Northrop et al., 2022).

5.3. Relationship of Urban Population to Energy Intensity in EMDEs Countries

The results of the regression analysis in this study show that the Urban Population variable has a negative and significant effect on Energy Intensity (Y). Based on the Fixed Effect Model estimation, a coefficient of −1.5919 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 1.59 unit decrease in energy intensity. This finding indicates that urbanization, to some 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 urbanization 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 urbanization 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, transportation, and housing. Furthermore, the energy ladder theory approach states that increased urbanization 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). Urbanization 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 urbanization in EMDEs are highly complex. EMDEs have recorded the fastest urbanization 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 urbanization increase from 31% in 2000 to 45% in 2022. However, this urbanization is often unplanned, informal and not aligned with modern energy supply capacity. In India, despite the increasing proportion of urbanized 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 urbanization-energy nexus phenomenon also shows a spatial energy imbalance between major cities and peri-urban areas or small towns. Major cities in EMDEs such as Jakarta and Manila have relatively better energy infrastructure, but suburbanization 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 driven fuel consumption and increased energy intensity. In Latin America, a similar phenomenon is seen in Mexico and Brazil, which are experiencing increased energy intensity due to urban sprawl without the integration of efficient public transportation 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, nearly 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 urbanization can reduce energy intensity, the effect can be very heterogeneous depending on the quality of infrastructure, spatial distribution, and level of electrification.

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

In the context of EMDEs, urbanization shows rapid but uneven characteristics. On the one hand, urbanization is often a driver of economic growth. But on the other hand, without adequate energy infrastructure and technology, urbanization 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 urbanization serves as an instrument of energy efficiency, not the other way around. Countries such as Vietnam and Turkey, which experienced urbanization based on industrial and technological transformation, managed to reduce energy intensity (Koyuncu et al., 2021). In contrast, countries such as Nigeria and Bangladesh, where urbanization 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 transportation systems, and urban electrification policies. In this context, the development of smart cities and strengthening urban energy governance are key instruments to realize the transition to a more efficient and sustainable energy system (Yetkin et al., 2020).

5.4. Relationship of Labour to Energy Intensity in EMDEs Countries

The panel regression estimation results using the fixed effect model approach show that the labor variable has a positive and significant influence on energy intensity with a significance level of $0.0467 < 0.05$ which indicates that a one-unit increase in the percentage of labor 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 labor force in EMDEs has not fully synergized 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 labor and energy intensity. First, in most EMDEs, labor is still absorbed into labor-intensive sectors such as light manufacturing, construction, and traditional agriculture that have a high ratio of energy consumption to output (Kartiasih et al., 2012). Second, the lack of adoption of efficient and low-carbon technologies in these sectors means that the increase in labor 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, workforce growth is accompanied by accelerated urbanization, 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 labor and energy intensity. High levels of labor informality are a major 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, labor-intensive and relies on production technologies with low energy efficiency. Heavy reliance on fossil fuels still dominates the region's energy mix. A report by (IESR, 2023) shows that more than 70% of final energy consumption in ASEAN comes from fossil sources, such as coal and oil. 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 labor-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 labor 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 dependence on diesel-fueled generation, contribute to the country's high energy intensity. In contrast, Vietnam has managed to reduce energy intensity despite a growing workforce, due to targeted industrialization policies, investments 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 workers will only affect the decrease in energy intensity if it is accompanied by an increase in labor productivity and the allocation of labor to the technology-based formal sector. (Mulder and de Groot, 2012) emphasized the importance of sectoral structure in explaining variations in energy intensity between countries, where labor 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 labor sector reform and its integration with high value-added sectors in Sub-Saharan Africa are key prerequisites for sustainable energy intensity reduction. The consistency of these findings reinforces the conclusion that the structure of employment and the direction of sectoral transition are key determinants in the relationship between labor and energy efficiency.

Based on the empirical findings and structural dynamics outlined, a number of policy implications can be recommended to avoid a situation where an increase in labor force leads to an increase in energy intensity. First, EMDEs need to design and implement a vocational training system that is aligned with the needs of green industries and low-carbon economic sectors, with priority on urban and semi-urban areas that are the center of economic growth. Second, governments need to expand fiscal incentives and strengthen access to finance for investment in energy efficiency technologies, especially for labor-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 employment challenges amid the transition to a green economy (Maulana et al., 2023).

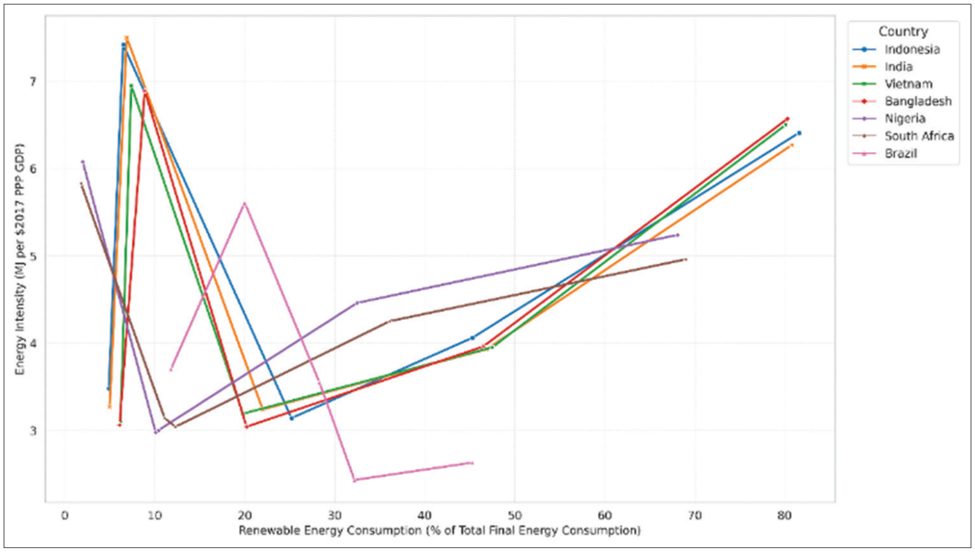
5.5. Relationship of Renewable Energy Consumptions to Energy Intensity in EMDEs Countries

The panel data regression estimation results 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 −0.050769, the t-statistic value is −6.2685 and the probability level is 0.0000. 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 decrease in the level of energy intensity by 0.050 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 decarbonization. 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 offer higher conversion efficiency and do not produce 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 a thermal conversion process as in fossil fuel combustion, so the efficiency of energy conversion into electricity is much higher. 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 2 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

Figure 2: The effect of renewable energy consumption on energy intensity in selected EMDEs (2017-2021)



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 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 research 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 EMDEs over the period 2017-2021, it is found that container port traffic, marine protected areas, urbanization, and renewable energy consumption have a negative and significant effect on energy intensity, while labor force participation shows a significant positive effect. Container port traffic reduces energy intensity through port infrastructure modernization, technology diffusion, and logistics system optimization, while marine protected areas promote the transformation from a conventional energy-intensive marine economy to a sustainable blue economy. The negative effect of urbanization reflects scale efficiency through public transport optimization and energy grid consolidation, while renewable energy consumption contributes to improving the efficiency of national energy conversion and distribution. In contrast, the positive effect of labor force participation indicates that without transformation towards a clean technology- based formal sector, labor force expansion increases the burden of national energy consumption. The study concludes that a multidimensional transformative approach is required to achieve sustainable energy intensity reduction in EMDEs. Policy integration of planned urbanization, accelerated renewable energy penetration, container port modernization, strengthened marine protected area governance, and low-carbon technology-based labor reforms are strategic imperatives in the energy transition agenda.

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