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DOES HUMAN DEVELOPMENT INFLUENCE ENERGY INTENSITY IN PAKISTAN? AN EMPIRICAL INSIGHT

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Abstract

Over the past three decades, energy efficiency has become a central topic in global discussions, influencing economic interests and impacting various aspects such as energy, economics, social factors, environmental considerations, and national security. The determinants of changes in energy efficiency, including human development and the global shift in energy intensity, have gained prominence in debates at political, research, and scientific levels. This research shows that inefficient use of energy plays a dominant role in increasing the energy intensity in a country. The well- known co-integration techniques of ARDL and ARDL bound test have been used to investigate the Impact of Human development on Energy Intensity in Pakistan. The finding of study indicate that Higher Human Development (Education Level) is strongly and negatively associated with Energy Intensity, signifying that increased education levels lead to a substantial reduction in energy intensity and improve the efficiency of energy use in the economy. Foreign Direct Investment (FDI) demonstrates a noteworthy negative relationship with energy intensity, indicating that as FDI rises, there is a significant decrease in energy consumption per unit of output. Surprisingly, Trade Openness (TRO) shows a positive correlation with Energy Intensity, challenging traditional economic expectations. However, the study emphasizes the need for strategic measures to enhance energy efficiency and harmonize international trade with sustainable practices. The research also underscores a substantial negative relationship between exports (EXP) and Energy Intensity, suggesting economic growth potential through increased exports alongside energy efficiency. To reduce energy intensity in Pakistan, prioritize education for sustainable practices, attract Foreign Direct Investment (FDI) by streamlining regulations and promoting energy-efficient technologies, and implement strategic trade policies that balance economic gains with environmental considerations.

Keywords: Energy Intensity, Human Development, ARDL and Pakistan.

1. INTRODUCTION

Over the past three decades, energy efficiency concerns have garnered significant attention and discussion worldwide among policymakers and researchers. The effective utilization of energy has emerged as a crucial factor influencing the economic interests of nations, exerting considerable impacts on energy, economics, social aspects,

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environmental considerations, and national security. In the global context of energy priorities, there is a heightened emphasis on reducing energy consumption and enhancing energy efficiency, particularly in the current era where the concepts of green economy and sustainable development have become widespread themes in the global economic landscape.

The determinants influencing changes in energy efficiency have become a focal point of debates and discussions at political, research, and scientific levels in the contemporary era. Through extensive discussions and research, several key determinants have been identified, including human development, FDI, Trade openness, and Export. Energy efficiency is achieved by utilizing fewer energy units while maintaining a consistent level of economic activity. Essentially, energy intensity, representing the amount of energy consumed per unit of output, serves as a crucial metric. The evaluation of energy efficiency and its changes is measured through this energy intensity, recognized as a significant indicator of sustainable development (Freeman and Niefer, 1997; Streimikiene, 2007). Energy efficiency, a reflection of technological advancement, denotes the ability to produce more units using the same amount of energy (Xiu et al., 2007). Quantifying energy efficiency is a intricate process, typically assessed by the ratio of value added to energy use, essentially representing the reciprocal of energy intensity (Nanduri, 1996). The most significant and valued indicators are those that align with the objectives, clarity, feasibility, reliability, and accessibility of data, as emphasized by (Golusin and Munitlak-Ivanovi, 2009). Changes in energy intensity result from a combination of multiple determinants since energy intensity serves as a proxy for energy efficiency. Notably, among these determinants, the Human Development of the economy emerges as the most reliable and crucial factor influencing energy intensity. Human Development plays a pivotal role as the primary driver for enhancing energy efficiency; a higher level of Human Development can have a cascading impact on other determinants associated with energy efficiency.

The global shift in energy intensity, representing the ratio of energy consumption to Gross Domestic Product (GDP) and serving as an eco-efficiency indicator, has been identified as a significant aspect in the realms of energy and economics (Csereklyei et al., 2016). Notably, empirical evidence reveals a consistent decline in energy intensity over time, establishing a negative correlation with per capita output. This observation suggests that as countries experience economic growth, there is a simultaneous decrease in energy intensity. One plausible explanation for this correlation is that the efficiency gains associated with economic development lead to a more effective utilization of energy resources. Consequently, the decline in energy intensity is likely a concomitant outcome of both economic growth and technological advancements. In empirical discussions, the influence of GDP per capita on energy intensity remains a prominent topic. If we acknowledge that the level of economic development dictates energy intensity, a logical inference is that higher income levels exert pressure on energy demand, consequently leading to increased energy intensity. Conversely, this argument implies that income plays a decisive role in determining the level of development. With such development, there is an expectation that households and producers will adopt energy-saving tools and

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new technologies, ultimately resulting in a reduction in energy intensity. Nevertheless, various authors have employed econometric analysis to demonstrate that the energy intensity of an economy follows an inverted U-shaped pattern as per capita income surges (Medlock and Soligo, 2001). In other words, as economic development progresses, shifts in the GDP structure initially lead to an increase and subsequently a decrease in energy intensity. This pattern aligns with the theory of de-materialization (Bernardini and Galli, 1993), suggesting that energy intensity rises initially and then declines with the increase in GDP per capita, indicating a non-monotonic relationship between energy intensity and GDP per capita. Alternatively, the decline in energy intensity is also linked to the structural evolution of the economy. A shift toward a more service-oriented and less industry-centric economic structure tends to contribute to the reduction in energy intensity (Metcalf G, 2008; Sahu & Narayanan, 2010; and Wu, 2012). However, findings from the study by Mulder et al. (2014) highlight that the service sector may not exhibit high energy efficiency when assessed across a panel of countries. More recently, Chang (2015) emphasized the role of financial markets in diminishing energy intensity. Specifically, the author observed that while energy consumption generally increases with income per capita, this trend deviates for highly advanced economies with well-established financial markets. Pakistan has faced a severe energy crisis in recent past, particularly the shortage of electricity. It resulted in output reduction, rise in unemployment level, less competitive products globally. The usage of energy is more in Pakistan for the production in terms to GDP per unit compared to India, Japan, USA and china (Green stone and Alcott, 2012). The consumption of oil was raised by 12% in 2011 from its consumption in 1971, consumption of gas is raised by 7%however consumption of electricity by 9% (Ullah et. ai, 2011).

Recent micro and case studies have delved into the environmental and climate change awareness of students, underscoring a discernible surge in interest in these topics integrated into academic curricula. An illustration of this burgeoning interest is evident in the work of (Hoang and Kato, 2016), who explored the environmental education of elementary school students in Da Nang city, Vietnam. The study found that students' environmental awareness exhibited improvement following engagement in environmental education activities. Similarly, (Alaydin et al., 2014) investigated students' environmental awareness in elementary schools in Zonguldak, Turkey, while (Yeh et al., 2017) scrutinized awareness levels among high school students in Taiwan. The collective findings suggest that students generally demonstrated familiarity with the topics covered in their educational institutions and expressed positive attitudes toward energy saving. Furthermore, students with parents possessing higher levels of education tend to exhibit significantly greater knowledge compared to their peers. This pattern suggests the influence of home-based practices and parental education in shaping students' awareness of environmental issues. Studies conducted by (Ntanos et al. 2018 and Lefkel et al., 2018) delved into the behavior of secondary and elementary students in Greece, respectively, highlighting the pivotal role of education in fostering environmental awareness and promoting energy-saving and environmentally friendly practices. Additionally, (Van den, 2015) argues that schools should prioritize up-to-date curricula and classroom activities based on contemporary insights into human learning processes

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to enhance students' environmental awareness. The acceptance of renewable energies within communities constitutes a related but less-explored topic, particularly in terms of the role of schooling (Human Development), an aspect not extensively addressed in existing literature (Gaede & Rowlands, 2018). This study employs the concepts of Human Development, specifically education and schooling levels, interchangeably, while acknowledging their distinct scopes and measures. Although human development encompasses both education and in-work experience, both of which can contribute to decreasing energy intensity, the focus of this model centers on the concept of education within the broader framework of Human Development. In the empirical application, schooling is utilized as the variable of choice due to its broader availability of data.

We have not found studies specifically addressing the relationship between education and energy intensity at the country level, creating a research gap we aim to address. Previous analyses of energy intensity have primarily focused on regional studies with limited data scopes, employing primarily descriptive methods or, at most, basic econometric tools such as Ordinary Least Squares (OLS). Our goal is to expand the examination of factors influencing energy intensity to encompass a comprehensive dataset from specific country, concentrating specifically the impact of Human Development (schooling/education) on energy intensity in Pakistan. To achieve this, we incorporate variables commonly associated with energy intensity, including Human development, FDI, Trade openness, Export, and also consider convergence in energy intensity. The results reveal a robust and significantly negative effect of Human development (schooling/education) in reducing energy intensity, aligning with our proposed theory. We posit that a more educated population not only learns how to enhance energy utilization, consequently reducing its intensity in economic activities, but also becomes more cognizant of global warming and pollution issues, leading to more efficient energy usage. Notably, when Human development (schooling/education) is not considered, per capita income exhibits a strong negative effect, albeit only in the short run, while external dependence has a marginal negative impact on energy intensity, also confined to the short run. Thus, this paper stands as the first to emphasize the pivotal role of education in diminishing energy intensity, substituting the role of per capita income while retaining the significance of other major determinants of energy intensity.

This paper holds evident policy implications, emphasizing the need to consider the impact of education on energy use when formulating educational policies. Moreover, the discernible influence of education on energy intensity provides valuable insights for environmental policy formulation. Recognizing the significant role of education, environmental policies can leverage the educational system to more effectively attain and advance environmental objectives. This underscores the interconnectedness between education policies and broader environmental goals, advocating for a holistic and integrated approach in policy design.

The study is organized into distinct sections following the introductory phase. The second part reviews of literature consists of two sections. The first section establishes a theoretical framework elucidating the relationship among variables and energy intensity, while the second section delves into relevant literature on energy intensity. The third

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section details the methodology employed, with the initial part describing the construction of variables and model specification, and the subsequent part providing a comprehensive discussion of the estimation techniques used. The fourth section presents all results obtained from the analysis. Finally, the fifth section concludes the study and offers policy recommendations based on the findings.

2. LITERATURE REVIEW

Theoretical Framework of Energy Intensity

The energy intensity and rise in the prices of energy in the international concern, inefficient energy supplies and global warming, is an important factor regarding policies of energy (Jimenez and Mercado 2013). Despite this energy consumption per unit to GDP is more in Pakistan comparatively to other countries i.e. Japan, Germany, USA, India and china. Despite of huge rise in aggregate gross output and consumption of energy the energy intensity has diminished in last eras (Alcott and G, 2012). There are various explanatory elements which helps to improve the index of Energy intensity. Awareness regarding efficient modes of production and produces more given the level of energy consumption. People get aware tends to rise in productivity for instance Global warming, environmental Hazards. Literate masses well aware of the importance of these issues and it improves the wellbeing of mankind. This awareness helps them to use energy efficiently and declines its intensity per unit. Therefore, Human development (HD) has a negative relationship with energy intensity. Industrial sector is consuming more energy than service sector. The significance of de-industrialization explains that energy intensity reduces (Kongsamut, 2001). There is the simple structural transformation model application. Therefore, rise in service and fall in industry in an economy will evaluate the decline in energy intensity.

However, Human development part in falling energy intensity is needed to be illustrate. In this part, we give an easy illustration as how schooling help in declining energy intensity. Thus indirect contribution to reduce danger caused by energy intensity. This demonstration is related with instinctive phenomenon. There is particular amount needed for consumption in order to survive. Consequently, the choice amid human development and consumption relates to rapid growth of human capital. Human development cause increases knowledge and it reduces Energy intensity. The negative relationship of FDI comes in form new energy efficient technology which reclines the use of energy per unit of production. This means that as FDI increases the use of energy in production declines. A proxy, Trade openness is that to what extend a country is impacted all over the world, as a matter of fact it macadamizes the new path for modern energy efficient technologies to enter into a country and also enlarges competition level which asserts the domestic producer to take advantage of new energy efficient technologies. Consequently, energy intensity reduces with the rise in trade openness, there is a negative relationship amid energy intensity and trade openness. Huge exports rise the prices in a country and enlarge the profit margin of the producers that allow them to opt modern technologies to produce more efficiently Exports inversely affected the energy intensity.

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Review on Energy intensity

In their study, (Ziolo.M et al., 2020) delved into the relationship between energy efficiency and the pursuit of a sustainable economy, along with its impact on financial development in OECD countries. The study's conclusion emphasizes the imperative for global economies to address the challenge posed by escalating energy consumption and environmental concerns (CE). The findings highlight a positive relationship between economic development and energy efficiency. Additionally, the study notes a negative correlation between energy intensity and economic growth, particularly in economically disadvantaged countries. The study of (Baloch et al., 2020) focus on the trilemma assessment involving energy intensity, efficiency, and environmental indices. The study delves into the evaluation of energy density and efficiency, proposing the creation of a significant indicator for assessing environmental performance. Through this research, an in-depth examination of energy security and the sustainability of the environment is undertaken, shedding light on the intricate interplay between these crucial facets. In 2019 the study of, (Samargandi.N, 2019) explored the Energy Intensity and its determinants within OPEC countries. This investigation specifically delves into the impact of trade openness, technological advancements, and energy prices on energy intensity in OPEC nations. The study's outcomes indicate a noteworthy role played by trade openness in reducing energy intensity. Furthermore, it highlights that technological modernization shows a relatively insignificant association with energy intensity. Conversely, the research underscores a significant correlation between renewable energy and energy intensity. The study of (Cao.W et al., 2019) conducted a study examining the potential impact of Foreign Direct Investment on Energy Intensity, specifically focusing on developing countries. The research aimed to uncover whether Foreign Direct Investment (FDI) had a discernible effect on the intensity of energy use. The study's findings indicate that FDI does not have a significant impact on energy intensity. Furthermore, the research reveals heterogeneity in energy intensity among BRICS countries, with these economies demonstrating more developed conditions compared to non-BRICS counterparts. The implications of these findings suggest the need for tailored policies to enhance the effectiveness of FDI in the context of energy intensity.

The study conducted by (Aller. C et al., 2018) explores the impact of financial development on energy intensity in China, specifically investigating the relationship between energy intensity and financial development across 28 Chinese provinces from 1999 to 2014. The findings suggest that a poorly functioning financial system hinders the reduction of energy intensity in various regions, providing insights to enhance sustainable economic growth. Further the study of (Mayer.A, 2017) focuses on democratic institutions and energy intensity of well-being, asserting that energy consumption is essential for human well-being. Contrary to expectations, the study using international data concludes that democracies do not leverage their energy consumption more effectively to improve well-being, suggesting limited improvement in sustainability. In a study by (Lefkeli et al., 2018) on the behavior of elementary school students in Greece, education emerges as a key factor influencing students' environmental awareness. The research underscores the role of renewable energy resources in sustaining the environment, advocating for

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awareness programs to foster environmentally friendly behavior. Similarly, (Ntanos et al., 2018) examine the behavior of students in secondary education, expressing concern about the alarming state of environmental sustainability. The objective is to explore multiple profiles of environmental awareness among secondary education students, emphasizing the role of well-informed students in promoting sustainability. (Yeh et al., 2017) observe energy literacy and misconceptions among junior high students in Taiwan, highlighting the crucial role of informed citizens in implementing modern policies to address issues such as carbon emissions and climate change. The impact of energy on anthropogenic greenhouse gas emissions and its subsequent effects, including rising temperatures, is emphasized. (Csereklyei et al., 2016) delve into the relationship between energy and economic growth. Summarizing their research, they note that economic growth and energy exhibit a set of stylized facts. The study observes a cross-sectional association between energy usage per capita and its elasticity concerning income, revealing that the elasticity is less than one (unity).

Shahiduzzaman and Alam (2012) employed the logarithmic mean Divisia index (LMDI) technique to dissect energy intensity into components such as energy efficiency, fuel mix, and structural changes in Australia over the period 1978-2009. Through their decomposition analysis, they revealed that energy efficiency played a pivotal role in reducing energy intensity, surpassing the impact of structural composition. Notably, they found that the fuel mix had a relatively minor effect on reducing energy intensity. This methodology aligns with similar research conducted by (Ang and Zhang, 2000; Chung et al., 2013; and Lotz and Blignaut, 2011), who utilized LMDI for decomposing energy consumption in various contexts, such as the Chinese transport sector and South Africa's sectoral energy consumption. The study of (Song and Zheng, 2012) conducted a study using province-level panel data for the period 1995-2009, employing the Fisher Ideal index to decompose the determinants of energy intensity in China. Their analysis involved breaking down energy intensity into components of energy efficiency and structural changes. The findings revealed that nearly 90 percent of the decline in energy intensity could be attributed to improvements in energy efficiency. Their econometric analysis indicated a minimal impact of the price effect on reducing energy intensity, while income exhibited a U-shaped relationship with energy intensity. Additionally, the study suggested that policy interventions, recognizing energy and capital as substitutes, played a role in decreasing energy intensity in Chinese provinces. The observed increase in energy intensity was also attributed to high investment and rapid urbanization experienced in China.

Wu (2011) conducted a study utilizing regional data from 1997-2007 to investigate the determinants of energy intensity in China. His empirical findings indicated that energy efficiency played a significant role in reducing energy intensity, with the share of structural adjustment being relatively small. The results from his partial adjustment model further highlighted that both high energy prices and high income levels contributed to the decline in energy intensity. This study by (Elliott et al., 2011) explored the interplay between income per capita, energy intensity, and Foreign Direct Investment (FDI) by utilizing fixed and random effect models on panel data from 206 cities in China spanning the years

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2005-2008. Their study contributed to the theoretical understanding of the inverted U-shaped relationship between income per capita and energy intensity. The positive relationship between FDI and energy intensity was attributed to two factors: firstly, foreign firms introduced energy-saving technologies, and secondly, these foreign firms disseminated these technologies to domestic firms, thereby enhancing productivity and simultaneously reducing energy intensity. Further the study by (Wachsmann et al., 2009) employed structural decomposition analysis to break down Brazilian industrial and residential energy usage into eight components. Their results revealed that among these eight factors, population, economic affluence, and inter-sectoral dependencies exerted the most significant influence on energy use in Brazil. Notably, factors such as energy intensity and per capita household energy were found to contribute to the reduction of overall energy consumption in the country.

The study of (Lai et al., 2006) demonstrated that trade openness in China has a positive impact on reducing energy consumption. (Cole, 2006) highlighted that the influence of trade openness on energy efficiency is contingent upon the composition of a country's imports and exports. Consequently, the ultimate effect of this determinant hinges on the proportion of energy-intensive exports and energy-saving imports within the overall trade structure of the nation. Although trade openness itself does not directly affect Energy Intensity (EI), its impact is mediated by the diffusion of technologies resulting from increased openness to trade. (Shi, 2002) observed that the enhancement of energy efficiency in the Chinese economy is linked to the country's policy of promoting trade openness. Conversely, (Adom and Kwakwa, 2014) argued that trade openness has exacerbated energy inefficiency in Ghana. Akal (2016) reached a similar conclusion for the Turkish economy, suggesting that Energy Intensity rises with an expanding energy gap or increased imports.

Metcalf. G (2008) conducted an empirical analysis focused on energy intensity and its components at the domestic level. The study observed economic forces influencing the variations in the efficiency and activity factors of energy intensity. Utilizing a dataset spanning from 1970 to 2001 on domestic energy consumption, the research identified that an increase in income per capita and higher energy prices contributed to a reduction in energy intensity. (Birol and Keppler, 2000) discovered that international energy prices play a role in decreasing energy intensity and improving energy efficiency in a country. (Van den, 2015) noted a decline in energy intensity in China since 1990, attributing it to the reduction in the proportion of coal energy in total consumption and the shift from energy-intensive secondary industry to the less energy-intensive service sector. (Alam.S, 2002) applied parametric Divisia Index (PDM) methods to analyze electricity consumption in Pakistan's industrial sector. The findings revealed a shrinking efficiency of electricity consumption in the industrial sector, suggesting an improvement in the regulation of electricity efficiency during the study period. Further the study of (Alam and But, 2002) explored the causal relationship between energy and economic growth in Pakistan using Johansen and Juselius co-integration technique and error-correction models. The study indicated a long-run relationship among energy consumption, economic growth, capital, and labor.

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Another study by (Alam and But, 2001) investigated the Drain model of usage and energy intensity from 1960 to 1998, employing Marshall Edge worth techniques for a complete decomposition model. The research identified structural change as the primary cause of the rise in total energy intensity, with aggregate energy use increasing due to both the activity effect and structural change. Similarly work done by (Alam and But, 2000) examined aggregate energy efficiency in Pakistan using the Divisia Index techniques.

The study highlighted that variations in economic output contributed to a 9% annual improvement in the aggregate intensity index. The results indicated a decline in the efficiency of energy use at the same rate, while the trend factor, influenced by changes in consumer choices and technology development, led to a 2.4% annual reduction in the aggregate intensity index.

In the realm of energy economics literature, numerous studies focus on delineating the connection between energy consumption and economic growth, exploring energy demand in households and industries, role of international energy prices on energy intensity, impact of financial development on energy intensity, focuses on democratic institutions and energy intensity of well-being, the potential impact of Foreign Direct Investment on Energy Intensity, energy efficiency and the pursuit of a sustainable economy, trade openness and energy intensity, and impact of technological advancements on energy intensity. While extensive research has been conducted to understand the correlation between Energy Intensity and climate change issues, there is a notable scarcity of studies that specifically address the relationship between energy intensity and Human Development (HD) in Pakistan. In this study we explore the effect of Human Development on Energy Intensity in Pakistan.

3. METHODOLOGY AND MODEL SPECIFICATION

The practical investigation of this research paper highlighted the problems for the present study was developed model specification and econometrics methods. In this study we will focused on problems, models and mainly process of estimation used for the empirical analysis.

Data Sources

This study primarily involves yearly time series information spanning from 1985 to 2018 in Pakistan. It focuses on the overall energy usage, comprising oil, electricity, and gas consumption.

The energy consumption data are sourced from multiple editions of the Pakistan Energy Year Book and the Pakistan Economic Survey. Specifically, electricity data are gathered from the Pakistan Energy Year Book and the Water and Power Development Authority (WAPDA) through webinfo@wapda.gov.pk.

Additionally, information on enrollment in educational institutions, Gross Domestic Product (GDP), and sector-specific GDP is obtained from the World Development Indicators (WDI) and the State Bank of Pakistan.

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Model Specification

Energy intensity is the amount of energy used per unit of activity. There is negative relationship amid energy intensity and energy efficiency. The energy efficiency estimation is constructed below:

$$EI_t = \frac{EU_t}{Y_t} \qquad (1)$$

Where

EI_t is the energy intensity in time period t.

EU_t is the final energy use in time period "t"

Y_t is the total output in time period "t"

The energy intensity index can be measured as mentioned above, indicates the transition in technology and product mix according to individual sector. After calculating energy intensity index would be estimated its explanatory variable shown in the following model. Human development (HD) (equation 2) is constructed by the summation of all students enrolled in tertiary, Graduation and intermediate level and divided by population age from 15 to 40 multiplied by hundred. Moreover Human development (HD) is emerged as an education's proxy to find out the importance and significance of education on energy efficiency, Furthermore this variable is considered as policy variable and remaining variables are used as control variables.

$$EI_t = \alpha_1 + \alpha_2 HD + \alpha_3 LEXP + \alpha_4 TOPs + \alpha_5 LFDI \qquad (2)$$

Where;

LEI_t	Log of Energy Intensity index
HD	Human Development
LEXP	Log of export in local currency
$TOPs = \frac{Exp+Imp}{GDP}$	Trade Openness
LFDI	Log of Foreign Direct Investment

Estimation Technique

Unit root test

Phillip perron (PP) and the Augmented Dickey Fuller (ADF) unit root estimates are investigated to find out the Stationarity of data. This test used to determine the properties of Stationarity for long run co integration of existing variables in the model. The ADF test is consist on following equation given below:

$$\Delta Yt = \beta_0 + \beta_1 Y_{t-1} + \sum_{n=1}^{\infty} di \Delta Y_{t\,j} + \mu_t \qquad (3)$$

Where Δ is 1st difference operator, Y_t is a time series variable, β_0 is a constant and ∞ is the the maximum number of lags of the repressor. Above equation of ADF presented that whether estimated parameters are equal to zero. This test provide t-statics and probs

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value for making decision about stationary of data. Now present Phillip-perron model which is given below,

$$\Delta Yt = \beta + л Y_{t-1} + \mu_t \qquad (4)$$

This test also consist of t-statistic and probs values which is associated with estimated parameter of лin the given model.

ARDL Approach

The autoregressive distribution lag approach is consisted of two stages. In this test at initial level we perform the long run co integration with all variables in the model and to compute F-statistics value and its critical value, if calculated value is greater than critical value of upper bound than alternative hypothesis will be accepted, it represents the existence of co-integration in the long run with all variables in the model. Particularly for long run co integration, we imposed the ARDL bound test method. In addition, the second step illustrated the association amid the parameters of long run and short run. This method will establish the error correction term, it is appropriate if all factors are stationary at level and first difference. The econometrics model is shown underneath.

$$LEI_t = \boldsymbol{\alpha}_1 + \sum_{t=1}^{n} \boldsymbol{\alpha}_2\, LEI_{t-1} + \sum_{t=1}^{n} \boldsymbol{\alpha}_3\, HD_{t-1} + \sum_{t=1}^{n} \boldsymbol{\alpha}_4\, LEXP_{t-1} + \sum_{t=1}^{n} \boldsymbol{\alpha}_5 TOPs_{t-1} + \sum_{t=1}^{n} \alpha_6\, LFDI_{t-1} + \mu \ldots (5)$$

The above equation (5) represents the long-run Energy intensity index model. In above model HD used as a policy variable to check long-run relationship of the all variables. We will implement the significance of F-statistics on energy intensity index model. The critical value of F-statics will compare to the computed value of F-statistic. This table has established (Persaran et.al, 2001). Furthermore this table contained of two critical bounds which consisted of upper I(1) and lower I(0) and if the computed F-value is higher than lower and upper bound than it indicates that there is existence of long run co-integration of all the variables in the model. The critical value F-statics is above the estimated value of static than there will be no association among the set of all variables in the model. In addition, we cannot take a decision if the computed F-statics value fall amid upper I(1) and lower I(0) bound. After all this discussion if we found the long run association amid Human development(HD) and variables such as Trade openness, export and FDI with energy intensity than we employ short run concept of ARDL Method.

$$\Delta LEI_t = \boldsymbol{\alpha}_1 + \sum_{t=1}^{n} \boldsymbol{\alpha}_2\, \Delta(LEI)_{t-1} + \sum_{t=1}^{n} \boldsymbol{\alpha}_3\, \Delta(LHD)_{t-1} + \sum_{t=1}^{n} \boldsymbol{\alpha}_4\, \Delta(LEXP)_{t-1} + \sum_{i=1}^{n} \boldsymbol{\alpha}_5 \Delta(TOP)_{t-1} + л(ECM)_{t-1} + \mu \ldots (6)$$

The equations 6 depicts parameter of short run model. In this model we estimated the ECM term which tells us about the speed of adjustment from the short run to the long run. If the coefficient of ECM term exist a significant and negative, its illustrates that there is co integration in the short and long run among the all variables in the estimated model. Here ECM_{t-1} is the value of lag of the error correction term, л is the coefficient of error correction term which illustrates the conversion speed to equilibrium.

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4. DISCUSSION ON EMPIRICAL RESULT

Augmented Dickey fuller and Phillips Peron test are imposed on all variable in this model to test Stationarity. Stationarity in the variables is very important in order to avoid the problem of spurious regression problem. The result depicts that the variables of the model either variables are stationary at level or at first difference. The results of ADF and PP are illustrated below.

Table: 1 Unit Root Test

	ADF				Phillips-Peron			
	Level		1st Difference		Level		1st Difference	
	t-stat	p-value	t-stat	p-stat	t-stat	p-value	t-stat	p-value
LEI_{t-0}	-8.81	0.00	-3.64	0.01	-7.1	0.00	-5.06	0.00
HD_{t-1}	0.13	0.96	-8.69	0.00	-0.14	0.93	-9.5	0.00
$EXPT_{t-1}$	-2.62	0.09	-5.46	0.00	-2.59	0.10	-5.46	0.00
TRO_{t-0}	-4.18	0.01	-5.71	0.00	-2.18	0.21	-5.79	0.00
$FDIt_{-1}$	-3.84	0.02	-4.61	0.00	-2.29	0.42	-4.65	0.00

The table 1 presents the results of both Augmented Dickey-Fuller (ADF) and Phillips-Perron tests for the level and first difference of various economic indicators, as Energy Intensity (LEIt-0), Human Development (HDt-1), Exports (EXPTt-1), Trade Openness (TROt-0), and Foreign Direct Investment (FDIt-1). In the level form, both tests indicate rejection of the null hypothesis of a unit root for several variables, implying stationarity. Specifically, Energy Intensity, Human Development, and Trade Openness exhibit significant stationarity, while Exports and Foreign Direct Investment show mixed results. In the first difference form, the rejection of the unit root hypothesis is more widespread, reinforcing the stationarity of the variables. These findings are crucial for time series analysis, suggesting that these economic indicators may follow stable patterns and allowing for more robust modeling. The outcomes of the unit root tests reveal a nuanced pattern wherein certain variables demonstrate stationarity at the level, while others exhibit stationarity at the first difference. This dichotomy in the stationarity properties of the variables leads to the conclusion that the Autoregressive Distributed Lag (ARDL) modeling approach is deemed suitable for estimating the Energy Intensity model. By leveraging the unit root results to discern the stationarity characteristics of the variables, we can make an informed decision about the appropriate econometric method for modeling. In this context, the ARDL model is favored as it accommodates variables with diverse stationarity properties, allowing for a comprehensive and accurate analysis of the Energy Intensity model. This strategic selection of the ARDL method enhances the reliability of the estimation process and contributes to a more robust understanding of the dynamic relationships within the Energy Intensity framework.

Table 2 presents the results of the ARDL bound analysis conducted to assess the long-run co-integration of determinants. The investigation aims to ascertain whether the variables are co-integrated in the long run. The bound test, applied to examine the relationship among variables in the long run, involves a null hypothesis suggesting no co-integration with upper and lower bounds at four critical values. If the statistical value falls below the lower bound at any level of significance, we do not reject the null hypothesis of no co-integration. Similarly, if the critical upper bound value is smaller than the calculated F-value, we accept the alternate hypothesis of co-integration. However, if the calculated F-value falls between the bounds, the presence of co-integration remains inconclusive. The details of the bound test are presented in the table for this specific case.

Table: 2 ARDL Bound test result

ARDL Bounds Test		
Null Hypothesis: No long-run relationships exist		
Test Statistic	Value	K
F-statistic	25.39170	4
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	1.9	3.01
5%	2.26	3.48
2.50%	2.62	3.90
1%	3.07	4.44
R-squared 0.856965	Durbin-Watson statistics 2.417828	
Adjusted Squared 0.822636		

The ARDL Bounds Test results demonstrate the presence of significant long-run relationships among the variables in the Energy Intensity model. The calculated F-statistic, with a value of 25.39170, exceeds all critical value at 1% significance levels. This leads to the rejection of the null hypothesis, indicating that there is a statistically significant long-run relationship among the variables. In other words, the economic indicators considered in the Energy Intensity model exhibit a sustained connection over time. The substantial R-squared value of 0.856965 underscores the model's ability to explain a significant portion of the variance in the dependent variable. Overall, these findings suggest that the model is robust in capturing the underlying long-run dynamics of the specified economic indicators.

Table: 3 Long and Short Run Coefficients of energy intensity index model

ARDL Long and short Run			
Long Run	**Coefficients**	**Short Run**	**Coefficients**
HD	-0.143524 (0.0009)	D(HD)	-0.081023 (0.0032)
FDI	-0.082304 (0.0824)	D(FDI)	-0.046463 (0.0756)
TRO	0.000002 (0.0574)	D(TRO)	0.000001 (0.0414)
EXP	0.187094 (0.0000)	D(EXP)	-0.529401 (0.0197)
		D(EXP(-1))	-0.532213 (0.0066)
		ECMt-1	-0.564526 (0.0000)

In table 3 the study's outcomes highlight a substantial and statistically significant negative long-and short term association between Human Development (HD) and Energy Intensity, indicating that an augmentation in Human Development is linked to a reduction in Energy Intensity. Specifically, the results suggest that a 1% raise in the educational level of a state is connected with a notable 0.14% and 0.08% decrease in energy intensity

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respectively. This suggests an elasticity in energy intensity relative to Human Development, revealing a significant responsiveness of energy intensity to fluctuations in the Human Development level. In essence, as a state advances in terms of education, there is a tendency for its energy intensity to decrease. It is noteworthy that these findings closely align with the conclusions drawn by (Santos and Sequeira,. 2018), providing additional support for the robustness and consistency of the identified negative association between Human Development and Energy Intensity. Educational Attainment is one of key aspect of Human Development often measured in such studies is the level of education within a population. As education levels increase, individuals and communities become more aware of sustainable practices and energy-efficient technologies. This heightened awareness and knowledge contribute to a more efficient utilization of energy resources.

The study's results indicate a notable and statistically significant negative relationship between Foreign Direct Investment (FDI) and Energy Intensity in long and short run. Specifically, the finding reveals that a one percent change in FDI is associated with an 8% and 4% change in the opposite direction in energy intensity respectively. This outcome aligns consistently with prior expectations and is reflective of the positive impact that FDI can have on reducing the intensity of energy consumption. The negative relationship suggests that as FDI increases, energy intensity decreases. This phenomenon can be attributed to the nature of FDI, which often involves the introduction of new and more energy-efficient technologies in the host country. The study's results are in line with the notion that foreign investors bring in advanced technologies and managerial practices that contribute to efficiency improvements in production processes. The 8% percent change in the opposite direction signifies a substantial impact of FDI on energy intensity. This implies that the infusion of foreign direct investment has a considerable influence on lowering the amount of energy required to produce one unit of output. Essentially, FDI acts as a catalyst for the adoption of energy-efficient technologies, leading to a more sustainable and environmentally friendly production environment.

Table 3 reveals a significant and statistically positive relationship between Trade Openness (TRO) and Energy Intensity (EI) in long and short run in Pakistan, with a direct impact observed at a 10% & 5% significance level. Contrary to prior expectations and established economic theories predicting a negative correlation, the empirical results show that a 1% increase in trade openness corresponds to a subtle yet measurable elevation in energy intensity by 0.000002 and 0.000001 respectively in the long and short run during a one year. This finding underscores the intricate dynamics between international trade and energy consumption, prompting a reconsideration of policy approaches. The recommendation to integrate modern technologies into production processes aligns with the broader discourse on sustainable development, emphasizing the need to balance economic gains from trade with the imperative of managing the environmental impact on energy consumption.

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The study's outcomes highlight the importance of adopting strategic measures to enhance energy efficiency, fostering a harmonious integration of international trade and sustainable energy practices in the pursuit of balanced economic growth.

In table 3 the estimation highlights a substantial and statistically significant negative relationship between exports (EXP) and Energy Intensity (EI) in the long and short run. The results indicate that a 1% increase in the export share of Pakistan corresponds to a remarkable 18% and 15% reduction in energy intensity respectively in long and short run.

This signifies a high elasticity in the energy intensity concerning export, suggesting that as the export activity of the country grows, there is a considerable decrease in energy consumption per unit of output. This finding aligns with the analysis conducted by (Deichmann et al., 2018), which also observed an inverse relationship between energy intensity and exports. The consistency in results across studies further reinforces the validity of the identified negative impact between export activities and energy intensity in the context of Pakistan. This inverse relationship emphasizes the potential for economic growth through increased exports while concurrently achieving energy efficiency objectives.

In the short-run column of Table 3, the ultimate row reveals the parameter associated with the Error Correction Mechanism (ECM) term. This term not only exhibits statistical significance at the 1% level but also carries a negative sign. This implies that all the variables included in the model ultimately converge to the equilibrium with a speed of 56%. The ECM term serves a crucial role in both short and long-run scenarios, acting as a mechanism for the adjustment speed towards equilibrium. The negative sign indicates a corrective process, suggesting that any deviations from equilibrium are rectified over time, contributing to the stability and balance of the model's variables.

Table: 4 Diagnostic Tests

Tests	**Energy Intensity Model**	
	Test-statics	**p-values**
Breusch-Godfrey Autocorrelation LM Test, F-statistic	1.415097	0.2633
Heteroskedasticity Test: White, F-statistic	1.893618	0.1152
Ramsey RESET Test, F-statistic	2.627042	0.0939

Notes: (1) Breusch-Godfrey Test H0: No serial correlation to 6 lags (2) Heteroskedasticity Test H0: NO Heteroskedasticity (3) RESETTestH0: Functional form is correct.

Table 4 presents the outcomes of diagnostic tests employed to assess the stability of the functional form and errors in the model. Specifically, the Breusch-Godfrey test was utilized to examine for potential serial correlation issues, and the results affirm the absence of such concerns in the model. The White General test indicates that the Autoregressive Distributed Lag (ARDL) coefficients exhibit homoscedasticity following the regression estimation. Finally, the Ramsey RESET test was employed to validate the correctness of the functional form. The test results support the appropriateness of the chosen functional form, as evidenced by the acceptance of the null hypothesis.

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These diagnostic tests collectively contribute to the robustness and reliability of the model by confirming the absence of serial correlation, verifying the homoscedasticity of ARDL coefficients, and ensuring the correctness of the functional form employed in the analysis.

Parameter stability test

Figures 1, and 2 express the cusum and cusum square tests and used for stability of energy intensity index model. These techniques are used to find out the stability of the estimated parameter over the time. Furthermore, this method provides the stability information about the estimated coefficients in graphical manner. The graphical analysis of these method consist of two red lines which display significance level at 5% and a blue line in the middle. If the blue line fall outside of the red lines boundary than these result indicate that the estimated coefficients are inconsistent with the passage of time after performing econometrics technique, but in our analysis all the variable are consistent over the period.

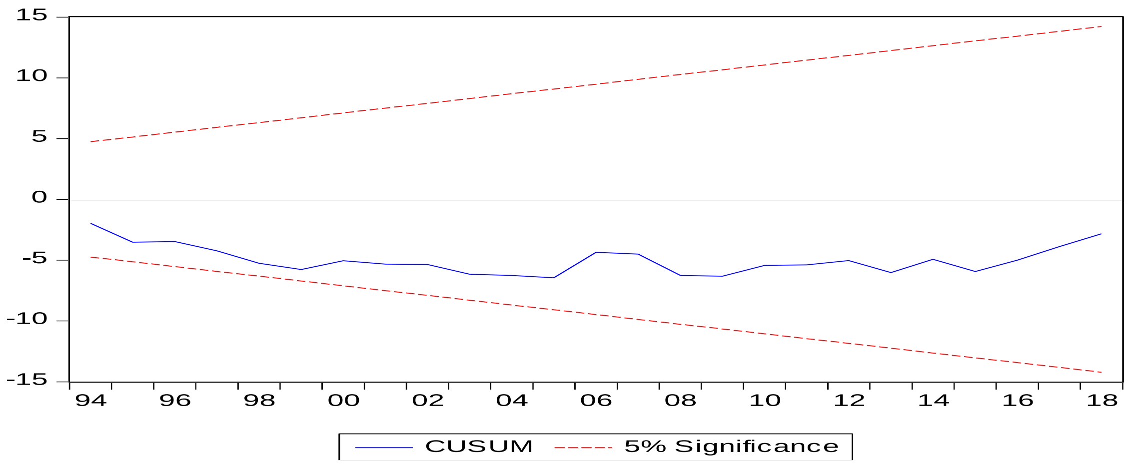

Figure 1: CUSUM of plot of energy intensity index model

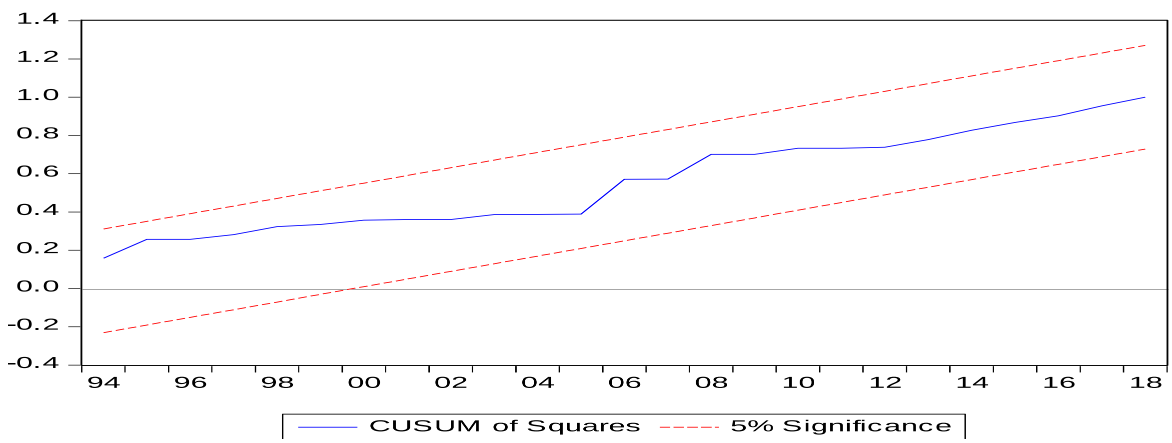

Figure 2: CUSUM of Squares Plot of energy intensity index model

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5. CONCLUSION AND POLICY RECOMMENDATIONS

The present study is an empirical investigation of energy intensity index and its determinants in Pakistan during 1985 to 2018. Awareness regarding efficient modes of production and produces more given the level of energy consumption. People get aware tends to rise in productivity for instance Global warming, environmental Hazards. Literate masses well aware of the importance of these issues and it improves the wellbeing of mankind. This awareness helps them to use energy efficiently and declines its intensity per unit.

The comprehensive analysis presented in this study and consistent findings regarding the intricate relationships between key factors and energy intensity in Pakistan. Notably, there exists a robust and statistically significant negative association between Human Development (HD) and Energy Intensity, indicating that higher educational levels are linked to a substantial reduction in energy intensity. Foreign Direct Investment (FDI) also demonstrates a noteworthy negative relationship with energy intensity, suggesting that as FDI increases, there is a significant decrease in energy consumption per unit of output.

In contrast, Trade Openness (TRO) exhibits a surprising positive correlation with Energy Intensity, challenging traditional economic expectations. However, the study underscores the need for strategic measures to enhance energy efficiency and harmonize international trade with sustainable energy practices for balanced economic growth. Additionally, the research highlights a substantial negative relationship between exports (EXP) and Energy Intensity, reinforcing the potential for economic growth through increased exports while concurrently achieving energy efficiency objectives.

Based on the findings that higher Human Development (HD) and increased Foreign Direct Investment (FDI) correlate with reduced Energy Intensity in Pakistan, policy recommendations should focus on fostering education and attracting foreign investment. Implementing initiatives to enhance educational attainment, particularly in sustainable practices and energy-efficient technologies, can contribute to a significant reduction in energy consumption. Policymakers should prioritize investments in education infrastructure and curriculum development. Additionally, recognizing the positive impact of FDI on lowering energy intensity, the government should create a conducive environment to attract foreign investors.

This includes streamlining regulations, providing incentives for investments in energy-efficient technologies, and facilitating knowledge transfer between foreign investors and local industries. While acknowledging the unexpected positive correlation between Trade Openness (TRO) and Energy Intensity, policy measures should be implemented to balance economic gains from international trade with the imperative of managing environmental impact. Moreover, the government should continue to support and promote the export sector, as indicated by the substantial negative relationship between exports (EXP) and Energy Intensity. Overall, a holistic approach that integrates education, foreign investment, and strategic trade policies is recommended to achieve balanced economic growth with reduced energy consumption in Pakistan.

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References

1) Adom, P. K., & Kwakwa, P. A. (2014). Effects of changing trade structure and technical characteristics of the manufacturing sector on energy intensity in Ghana. Renewable and Sustainable Energy Reviews, 35, 475-483.

2) Alam, S. (2002). Efficiency of electricity consumption in Pakistan’s industrial sector: an application of the multi-level decomposition model. Pacific and Asian Journal of Energy, 12(2), 167-179.

3) Alam, S., & Butt, M. S. (2001). Assessing energy consumption and energy intensity changes in Pakistan: an application of complete decomposition model. The Pakistan Development Review, 135-147.

4) Alam, S., & Butt, M. S. (2002). Causality between energy and economic growth in Pakistan: an application of cointegration and error-correction modeling techniques. Pacific and Asia Journal of Energy, 12(2), 151-165.

5) Alaydin, E., Demirel, G., Altin, S., & Altin, A. (2014). Environmental knowledge of primary school students: Zonguldak (Turkey) example. Procedia-Social and Behavioral Sciences, 141, 1150-1155.

6) Allcott, H., & Greenstone, M. (2012). Is there an energy efficiency gap?. Journal of Economic perspectives, 26(1), 3-28.

7) Aller, C., Herrerias, M. J., & Ordóñez, J. (2018). The effect of financial development on energy intensity in China. The Energy Journal, 39(Special Issue 1).

8) Ang, B. W., & Zhang, F. Q. (2000). A survey of index decomposition analysis in energy and environmental studies. Energy, 25(12), 1149-1176.

9) Baloch, Z. A., Tan, Q., Iqbal, N., Mohsin, M., Abbas, Q., Iqbal, W., & Chaudhry, I. S. (2020). Trilemma assessment of energy intensity, efficiency, and environmental index: evidence from BRICS countries. Environmental Science and Pollution Research, 27(27), 34337-34347.

ISSN: 1671-5497
E-Publication: Online Open Access
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DOI: 10.5281/zenodo.10612425

10) Bernardini, O., & Galli, R. (1993). Dematerialization: long-term trends in the intensity of use of materials and energy. Futures, 25(4), 431-448.

11) Birol, F., & Keppler, J. H. (2000). Prices, technology development and the rebound effect. Energy policy, 28(6-7), 457-469.

12) Cao, W., Chen, S., & Huang, Z. (2020). Does foreign direct investment impact energy intensity? Evidence from developing countries. Mathematical Problems in Engineering, 2020.

13) Chang, S. C. (2015). Effects of financial developments and income on energy consumption. International Review of Economics & Finance, 35, 28-44.

14) Chung, W., Zhou, G., & Yeung, I. M. (2013). A study of energy efficiency of transport sector in China from 2003 to 2009. Applied Energy, 112, 1066-1077.

15) Cole, M. A. (2006). Does trade liberalization increase national energy use?. Economics Letters, 92(1), 108-112.

16) Csereklyei, Z., Rubio-Varas, M. D. M., & Stern, D. I. (2016). Energy and economic growth: the stylized facts. The Energy Journal, 37(2).

17) Csereklyei, Z., Rubio-Varas, M. D. M., & Stern, D. I. (2016). Energy and economic growth: the stylized facts. The Energy Journal, 37(2), 1-34.

18) Elliott, R. J., Sun, P., & Chen, S. (2013). Energy intensity and foreign direct investment: A Chinese city-level study. Energy Economics, 40, 484-494.

19) Freeman, S. L., Niefer, M. J., & Roop, J. M. (1997). Measuring industrial energy intensity: practical issues and problems. Energy policy, 25(7-9), 703-714.

20) Gaede, J., & Rowlands, I. H. (2018). Visualizing social acceptance research: A bibliometric review of the social acceptance literature for energy technology and fuels. Energy research & social science, 40, 142-158.

21) Golusin, M., & Ivanović, O. M. (2009). Definition, characteristics and state of the indicators of sustainable development in countries of Southeastern Europe. Agriculture, ecosystems & environment, 130(1-2), 67-74.

22) Hoang, T. T. P., & Kato, T. (2016). Measuring the effect of environmental education for sustainable development at elementary schools: A case study in Da Nang city, Vietnam. Sustainable Environment Research, 26(6), 274-286.

23) Inglesi-Lotz, R., & Blignaut, J. N. (2011). South Africa's electricity consumption: A sectoral decomposition analysis. Applied Energy, 88(12), 4779-4784.

24) Jiménez, R., & Mercado, J. (2013). Energy intensity: a decomposition and counterfactual exercise for Latin American countries (No. IDB-WP-441). IDB Working Paper Series.

25) Kongsamut, P., Rebelo, S., & Xie, D. (2001). Beyond balanced growth. The Review of Economic Studies, 68(4), 869-882.

26) Lefkeli, S., Manolas, E., Ioannou, K., & Tsantopoulos, G. (2018). Socio-cultural impact of energy saving: Studying the behaviour of elementary school students in Greece. Sustainability, 10(3), 737.

27) Lefkeli, S., Manolas, E., Ioannou, K., & Tsantopoulos, G. (2018). Socio-cultural impact of energy saving: Studying the behaviour of elementary school students in Greece. Sustainability, 10(3), 737.

28) Mayer, A. (2017). Democratic institutions and the energy intensity of well-being: a cross-national study. Energy, Sustainability and Society, 7(1), 1-10.

29) Medlock III, K. B., & Soligo, R. (2001). Economic development and end-use energy demand. The Energy Journal, 77-105.

ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 01-2024
DOI: 10.5281/zenodo.10612425

30) Metcalf, G. E. (2008). An empirical analysis of energy intensity and its determinants at the state level. The Energy Journal, 29(3).

31) Metcalf, G. E. (2008). An empirical analysis of energy intensity and its determinants at the state level. The Energy Journal, 1-26.

32) Mingyong, L., Shuijun, P., & Qun, B. (2006). Technology spillovers, absorptive capacity and economic growth. China Economic Review, 17(3), 300-320.

33) Mulder, P., De Groot, H. L., & Pfeiffer, B. (2014). Dynamics and determinants of energy intensity in the service sector: A cross-country analysis, 1980–2005. Ecological Economics, 100, 1-15.

34) Nanduri, M. (1998). THEIR ROLE AS POLICY-MAKING TOOLS.

35) Ntanos, S., Kyriakopoulos, G. L., Arabatzis, G., Palios, V., & Chalikias, M. (2018). Environmental behavior of secondary education students: A case study at central Greece. Sustainability, 10(5), 1663.

36) Ntanos, S., Kyriakopoulos, G. L., Arabatzis, G., Palios, V., & Chalikias, M. (2018). Environmental behavior of secondary education students: A case study at central Greece. Sustainability, 10(5), 1663.

37) Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. Journal of applied econometrics, 16(3), 289-326.

38) Sahu, S., & Narayanan, K. (2010). Determinants of energy intensity in Indian manufacturing industries: a firm level analysis.

39) Samargandi, N. (2019). Energy intensity and its determinants in OPEC countries. Energy, 186, 115803.

40) Sequeira, T. N., & Santos, M. S. (2018). Renewable energy and politics: A systematic review and new evidence. Journal of Cleaner Production, 192, 553-568.

41) Sequeira, T., & Santos, M. (2018). Education and energy intensity: Simple economic modelling and preliminary empirical results. Sustainability, 10(8), 2625.

42) Shahiduzzaman, M., & Alam, K. (2013). Changes in energy efficiency in Australia: a decomposition of aggregate energy intensity using logarithmic mean Divisia approach. Energy Policy, 56, 341-351.

43) Shaista, A. L. A. M., & Butt, M. S. (2000). Aggregate energy efficiency in Pakistan: An application of decomposition approach. Pakistan Journal of Applied Economics, 16, 79-96.

44) Shi, D. (2002). The improvement of energy consumption efficiency in China's economic growth. Economic Research Journal, 9(9), 49-56.

45) Song, F., & Zheng, X. (2012). What drives the change in China's energy intensity: combining decomposition analysis and econometric analysis at the provincial level. Energy policy, 51, 445-453.

46) Streimikiene D. Monitoring of energy supply sustainability in the Baltic Sea region. Energy Policy 2007; 35:1658-74.

47) Van den Branden, K. (2015). Sustainable education: exploiting students' energy for learning as a renewable resource. Sustainability, 7(5), 5471-5487.

48) Van den Branden, K. (2015). Sustainable education: Exploiting students' energy for learning as a renewable resource. Sustainability, 7(5), 5471-5487.

49) Wachsmann, U., Wood, R., Lenzen, M., & Schaeffer, R. (2009). Structural decomposition of energy use in Brazil from 1970 to 1996. Applied Energy, 86(4), 578-587.

50) Wu, Y. (2012). Energy intensity and its determinants in China's regional economies. Energy Policy, 41, 703-711.

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DOI: 10.5281/zenodo.10612425

51) Wu, Y. (2012). Energy intensity and its determinants in China's regional economies. Energy Policy, 41, 703-711.

52) Yeh, S. C., Huang, J. Y., & Yu, H. C. (2017). Analysis of energy literacy and misconceptions of junior high students in taiwan. Sustainability, 9(3), 423.

53) Yeh, S. C., Huang, J. Y., & Yu, H. C. (2017). Analysis of energy literacy and misconceptions of junior high students in Taiwan. Sustainability, 9(3), 423.

54) Yong-Xiu, H., Wei-Jun, T., Song-Lei, Z., & Fu-Rong, L. Y. L. (2007). Factors decomposition of energy intensity: the case of Liaoning province in China. International journal of systems applications, engineering & development, 3, 56-61.

55) Ziolo, M., Jednak, S., Savić, G., & Kragulj, D. (2020). Link between Energy Efficiency and Sustainable Economic and Financial Development in OECD Countries. Energies, 13(22), 5898.