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Energy Intensity of Use and Socioeconomic Development in the GCC Countries: Trends and Impacts before the Pandemic

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ABSTRACT

It is anticipated that energy intensities will continue to decline, leading to a more effective distribution of energy resources that can produce wealth and a good standard of living for countries. This paper's goal is to evaluate this trend and use a linear regression model to examine the energy intensity and how it affects growth in two of the GCC countries: Saudi Arabia and the United Arab Emirates. Initially, we examined the connection between economic growth and energy consumption, and the two countries had better results, pointing to the rise in economic activities. We then examined the connection between GDPs per capita and energy intensity of use. For the two countries, the effect of GDP per capita on intensity of use was found to be negative, indicating a reduced cost or price of transforming energy into output. Put differently, a dollar's worth of production requires less amount of energy to be used, which will result in a more efficient use of energy. The analysis concludes that higher cost savings through more effective energy regulations will lead to more economic growth and better standard of living.

Keywords: Energy Intensity, Growth, Economic Analysis, Estimation, Forecast
JEL Classification: Q43

1. INTRODUCTION

Energy has played and will continue to play a vital role in development and in forming all global economies since its discovery phases throughout history. Energy is the essential component for such development as nations transition from labour-intensive agriculture to more energy-capital and energy-demanding industries. When the economy goes toward industrialization in its early stages, energy use tends to increase, and when it moves toward information-intensive services in its later stages, it tends to decrease. Our everyday needs for energy have increased, particularly during the past 50 years. Among other things, we utilize energy to cook, power a range of gadgets, run machines and industrial equipment, and illuminate our homes. On the other hand, excessive energy use is expensive and necessitates unique conservation techniques to maximize its use and improve efficiency.

A trend toward economies with lower energy intensities has been observed in the second half of the 20th century; it is anticipated that this tendency will continue, resulting in a more efficient allocation of energy resources that should provide prosperity and a high quality of living for nations. This article seeks to assess this tendency and investigate, between 1990 and 2020, the relationship between the energy intensity of use and economic growth in two different GCC nations: the Kingdom of Saudia Arabia and the United Arab Emirates, using a linear regression model.

We first look at the relationship between energy consumption and growth to measure the effect of economic growth on energy consumption. Next, we investigate the relationship between GDP and energy intensity to understand how intensity of use varies with income and how this relationship changes over time. High energy intensities indicate high prices or expenses related to converting energy into output, whereas low energy intensities indicate low prices or costs related to the same (Paul, 2007). The section that follows provides a summary of energy consumption and energy intensity in the tested countries as well as globally. A review of the literature and earlier studies on energy intensity will be included in the third section. Research methodology, analysis, and estimation will be covered in the fourth section. Part five will examine the forecasting strategy and methodologies. In part six, the study's findings will be presented and discussed.

2. OVERVIEW

2.1. Energy Consumption

Over time, the world's energy consumption has typically increased, with the biggest increases coming from the use of coal, oil, and natural gas. Global energy and climate statistics indicate that the world's energy consumption increased by 58% between 1990 and 2019 (from 8556 Mtoe to 13,995 Mtoe), with most of the increase occurring in the Middle East, Asia, and Africa. Nonetheless, the Covid-19 pandemic caused a 3.5% decrease in worldwide energy usage in 2020 compared to 2019. In the preceding thirty years, this represents the second-largest decline in world consumption. The demand for energy in Saudi Arabia and the United Arab Emirates has increased over the last 30 years from 78 Mtoe in 1990 to 290 Mtoe in 2020 (an increase of 272%) (Figure 1).

The world's energy consumption rose by 58% between 1990 and 2019 (from 8556 Mtoe to 13,995 Mtoe), according to global energy and climate statistics, with the Middle East, Asia, and Africa accounting for most of the rise. However, global energy consumption fell 3.5% in 2020 because of the Covid-19 pandemic compared to 2019. This represents the second-largest fall in global consumption in the previous thirty years.

2.2. Energy Intensity

Energy efficiency is gauged by a nation's energy intensity, which is expressed in energy units per GDP unit. It is the amount of energy needed to produce one dollar of goods and services. An individual country's energy intensity decreases with decreasing energy intensity ratios. Depending on a nation's degree of industrialization, the proportion of manufacturing and services in its economy, and the importance it places on energy efficiency, this number varies significantly between nations.

Enhancing energy efficiency is the most economical way to lower the energy intensity of the economy and promote a low-carbon future. Energy efficiency contributes to the mitigation of climate change and its aftereffects by lowering emissions brought on by wasteful and inefficient energy use. Energy-saving measures can save governments, corporations, and people billions of dollars in energy costs. To achieve quicker results and long-term energy sustainability, several nations, especially those in the region, are passing new laws, rules, and regulations aimed at saving energy (RCREEE, 2019).

Global energy intensity has generally been declining over time. Global energy and climate statistics show that, between 1990 and 2020, the world's energy intensity fell by 18.6%, from 0.177 koe/$15p to 0.144 koe/$15p. But during the past three decades, the two nations in our analysis have seen fluctuations in their energy intensity. As depicted in Figure 2, the energy intensity in Saudi Arabia and the United Arab Emirates decreased from 0.000493 and 0.000394 tone/US$ in 1990 to 0.000298 and 0.000225 in 2020 (a decrease of 39.6% and 42.9% respectively) (Figure 2).

3. PREVIOUS STUDIES

3.1. Energy Intensity of Use and Economic Growth

As the importance of energy intensity reduction grows as a global strategic aim, numerous studies have attempted to identify the systems of energy intensity change using a variety of informational and analytical approaches. Energy intensity is an issue that has received little quantitative study attention, despite its relevance. It is preferable to consider global differences in energy intensity as the outcome of different technologies used by different countries. If a variety of energy intensities are depicted as the results of various technological choices, they can be efficiently broken down. Research on the changing energy market have demonstrated the value of this methodology (Messner and Strubegger, 1995).

A point-by-point database of energy-shifting technologies and additional information on engineering artifacts are included in some energy models. The system that keeps an eye on those technologies is defined by these energy models, and the model arrangement yields the resulting energy intensity. All other industrial divisions find it challenging to include such accurate depictions of technology into models because of their massive information requirements. For these kinds of organizations,

Figure 1: The demand for energy in Saudi Arabia and the United Arab Emirates 1990-2020

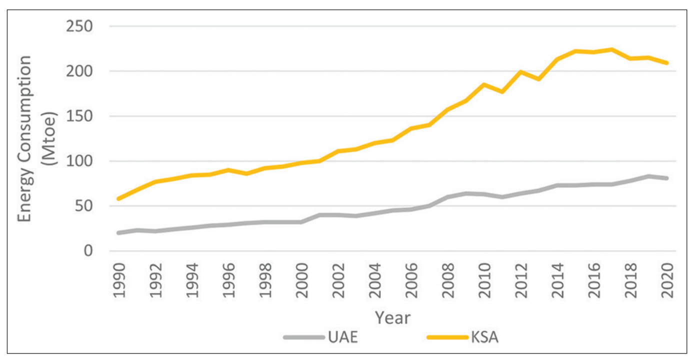
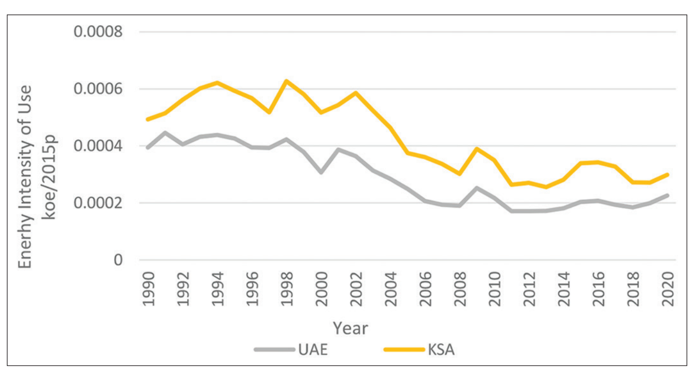


Figure 2: Energy intensity of use in Saudi Arabia and United Arab Emirates 1990-2020



traditional economic techniques like proving improvements in reduced structures (such compounding energy intensity) are still applicable (Hogan and Jorgenson, 1991). This kind of approach seeks to create a clear connection between energy intensity and other economic factors. These kinds of correlations are sometimes quantified using economic assumptions, and occasionally the outcomes are refined by the application of econometric findings. This is particularly true in non-OECD nations or at the level of sub-aggregated industries (Pesaran et al., 1998).

Countries gradually change their output toward the production of high-quality goods and services as they grow toward development and post-modern improvement (which commonly indicates decrease in weight, measurement, or on the other hand energy use). Furthermore, in the manufacturing sector, large-scale conventional machinery has been replaced by gadgets and data processing equipment. Ultimately, there is no denying the importance of recycling and reusing. Although not always for specific materials, this is likely to lead to a decrease in the total intensity of energy and materials consumed (Galli, 1999).

Energy has been essential to human development and advancement throughout history (Wu, 2010). In recent decades, governments and certain international organizations have shown a persistent interest in and focus on studies related to energy intensity, which is the ratio of energy use to GDP (Ang, 2006). Energy intensity, or the ratio of energy consumption to income, does not seem to be consistent between nations. Energy intensity increases as income rises from low dimensions but subsequently decreases as income rises above a fundamental dimension, as shown by (Wang, 2013).

Mulder and De Groot (2012) evaluated energy intensity and found that most manufacturing sectors had declining levels of energy intensity across national boundaries. The service sector experiences a somewhat moderate drop in energy intensity, with different sub-sectors seeing different patterns. They also found evidence, with average convergence rates greater in leading countries, supporting the idea that lagging countries are catching up to leading countries across sectors.

Dahan (2013) studied the relationship between energy consumption and economic growth in Saudia Arabia and the United Arab Emirates between 1990 and 2010. His findings revealed that, for Saudi Arabia, the influence of GDP on intensity of usage is positive, indicating a high cost or price of converting energy into GDP, whereas, for the United Arab Emirates, the effect is negative, showing a lower cost or price of converting energy into GDP. These findings suggest that Saudi Arabia needs to improve its energy efficiency if it is to experience longer-term, more steady growth.

Aydin and Esen (2018) looked at whether the degree of energy intensity affected how much energy was consumed and how much economic growth it produced. To determine the "threshold" level of energy intensity that has an unequal energy consumption influence on economic development, they used an advanced dynamic panel threshold regression model. The model's output indicates that 0.44% is the energy intensity threshold. Over this level, energy consumption has a statistically significant negative impact on economic growth; below this threshold, energy consumption has a statistically significant positive impact.

Díaz et al. (2019) examined the ways in which shifting to renewable energy sources and adjusting energy intensity can boost growth. The technique they employed was dynamic panel data on a sample of 134 countries. They made use of a collection of control variables that have been extensively utilized in studies on economic growth, including human and physical capital, socioeconomic circumstances, policies, and institutions. They found that both raising energy intensity and moving from fossil fuels to emerging renewables accelerate global development.

González-Álvarez et al. (2020) divided energy intensity into three categories: total, non-renewable, and clean, and examined the global evolution of energy intensity for a large sample of nations from 1990 to 2015. Their results disprove the global convergence theory for all energy intensity categories based on recent evidence. When nations are categorized by wealth or geography, the evidence against this theory is still overwhelming, with very few exceptions.

Shokoohi et al. (2022) used ecological footprint (EF) and carbon dioxide (CO_2) emissions to test the Environmental Kuznets Curve (EKC) theory and investigate how energy intensity and economic growth affect environmental quality in Iran, Iraq, and Turkey. The EKC was supported by the study's finding that income and environmental degradation in Turkey had an inverted U-shaped relationship for both variables. The EKC was supported in Iraq and Iran when EF was used, but not when CO_2 emissions were. All three nations showed a strong positive association between energy intensity and environmental deterioration, suggesting that excessive energy use is a major cause of environmental issues in the Middle East.

A study by Namahoro et al. (2021) examined the long-term impacts of economic growth, energy intensity, and renewable energy use on CO_2 emissions in 50 African countries between 1980 and 2018. The study discovered that while higher energy intensity resulted in higher emissions across all areas and income levels, higher consumption of renewable energy helped to lower CO_2 emissions. At the continental level, economic growth reduced CO_2 emissions, although the effects differed by location and income level.

The effect of energy intensity and CO_2 emissions on economic growth in the six Gulf Cooperation Council (GCC) nations between 1990 and 2023 was examined by Abid et al. (2024). They adjusted for trade openness, population, unemployment, urbanization, foreign direct investment, and other variables using fixed effects, random effects, and pooled regression models. Higher energy intensity has a detrimental impact on GDP growth, according to the study. On the other hand, there is a positive correlation between CO_2 emissions and economic growth. In order to lower energy intensity, boost economic growth, and combat climate change, the authors advise GCC nations to implement sustainable energy policies.

In their study of South Asian economies, Mahmood et al. (2021) questioned the widely held belief that there is a positive association between economic growth and energy intensity (the energy/GDP ratio) in developing countries. The study discovered a significant correlation between de-trended energy intensity and economic growth across the panel of developing South Asian economies after eliminating trend effects from energy intensity data. These findings imply that there are little prospects for energy conservation in the area and that it is expensive for these developing countries to turn energy into GDP.

The relationship between food security, CO_2 emissions, energy intensity, foreign direct investment (FDI), and per capita income in 32 rising economies between 1980 and 2018 was examined by Hasan and Adnan (2023). Their research demonstrated the environmental impact of improved food security by showing that an average 32% increase in CO_2 emissions accompanied by a 1% improvement in food security. The study also demonstrated a positive relationship between GDP and CO_2 emissions, supporting the Environmental Kuznets Curve (EKC) theory. The Food Security Index (FSI), energy intensity level (EIL), exchange rate (EXR), and CO_2 emissions were all shown to have a strong association with one another, suggesting that they all significantly affect environmental performance.

3.2. Factors Affecting Energy Intensity

Some important factors that significantly affect energy intensity have not been studied by many academics. For instance, raising the price of energy ought to reduce energy demand and, consequently, energy intensity over time. (Fisher-Vanden and Jefferson, 2004) econometrically identify commitments from energy price, R&D action, ownership, and geography using a firm-level informational index from 1997 to 1999. Following a thorough assessment of numerous research and an investigation into their effects, Hu (2007) identified the key factors that influence energy intensity variations as well as the pathways by which those effects are produced. He identified three categories of determinants: policy variables, natural endowment variables, and socioeconomic variables. The significant regional variations in economic development, structure, and technological advancement were highlighted by (Ang, 1995). According to Liu and Ang (2007), econometric analysis distinguishes between a number of contributing variables and determinants of energy intensity that vary over time, as well as the differences across provinces and the pathways via which they operate. They found that whereas energy costs have no effect on energy intensity, higher income significantly contributes to it. According to Zha et al. (2009), the substitution relationship will play a crucial role in the decline of energy intensity as local economies continue to build up their capital stock. Reducing energy intensity may be more difficult in provinces with higher rates of urbanization and plentiful energy resources.

Madlener (2011) talked about several factors that could affect energy intensity, including industrialization and urbanization. It is challenging to forecast how urbanization would affect energy intensity because it boosts economic activity by centralizing production and consumption, creates economies of scale, and may improve energy efficiency. He concluded that industrialization—the introduction of new machinery and contemporary methods for manufacturing both old and new ideas—increases modern action, which consumes more energy than conventional farming or assembly, suggesting that industrialization has a beneficial effect on energy intensity.

Voigt et al. (2014) examined the patterns and variables affecting energy intensity in 40 major economies. For the country research, they used a two-factor index decomposition approach; for the global analysis, which takes into account regional structural changes in the global economy, they used a three-factor decomposition. They found that most country-level gains in energy intensity are due to technology advancements, with structural change playing a modest influence in most countries.

To determine the factors influencing energy intensity in EU-28 member states, Filipović et al. (2015) employed a panel data technique in their work "Determinants of energy intensity in the European Union." Gross inland consumption and final energy consumption per capita had a positive effect on energy intensity, while energy prices, energy taxes, and GDP per capita had a negative effect, according to the estimated model.

(Sadorsky, 2013) created heterogeneous panel regression techniques, including mean group estimators and common correlated effects estimators, for a panel of 76 developing nations to model the impacts of income, urbanization, and industrialization on energy intensity. He concluded that, over time, a 1% increase in income lowers energy intensity by 0.45-0.35%. With long-term industrialization elasticities ranging from 0.07 to 0.12, urbanization has a mixed effect on energy intensity.

Ma et al. (2022) used a dynamic panel model with the Generalized Method of Moments (sys-GMM) system to examine the effects of financial development on energy intensity in 67 developing nations between 1995 and 2018. According to the study, energy intensity was considerably decreased by enhancements to the depth, accessibility, and effectiveness of markets and financial institutions. Modernizing industrial buildings also contributed to this decrease. These results held up well across different country groups. The study provides insightful information for policymakers seeking to support sustainable growth in developing countries by highlighting the significance of industrial upgrading and financial development in reducing energy intensity.

Through an analysis of 3918 papers from the Web of Science, Zaidi et al. (2024) carried out a thorough bibliometric evaluation of research on energy intensity drivers in emerging economies during the previous three decades. Technological developments, industrial structure, economic expansion, urbanization, financial development, trade, and environmental restrictions are some of the major elements that impact energy intensity, according to their results. The study highlights how crucial it is to comprehend and deal with these factors in order to create practical plans for lowering energy intensity and encouraging sustainable growth in developing nations.

Liu et al. (2023) used a difference-in-differences model and firm-level data from the National Tax Survey Database to evaluate the effect of China's New Energy Demonstration City (NEDC) pilot policy on enterprises' energy consumption intensity (ECI). After controlling for endogeneity, the analysis discovered that the NEDC policy had a significant impact on lowering ECI in pilot cities. Increased tax incentives and improved technology innovation among businesses were the main drivers of the drop, according to mechanism analysis.

Shahadat et al. (2022) examined how, in 30 rising economies between 1995 and 2018, utilizing the demographic dividend, digital economy, and energy efficiency might support sustainable economic development. The study, which used sophisticated panel econometrics, discovered that digitalization and the demographic dividend both favourably influence sustainable economic growth across all quantiles. On the other hand, urbanization, capital formation, and industrialization demonstrated favourable associations with sustainable economic growth, whereas energy intensity and economic sustainability revealed negative associations.

4. ANALYSIS AND FINDINGS

4.1. Data and Descriptive Analysis

A set of data spanning the energy demand from 1990 to 2020 serves as the basis for the analysis of long-term changes in energy intensity that have been noted in this study. The Kingdom of Saudi Arabia, and the United Arab Emirates are the two countries discussed in this part. The data was gathered from the Yearbook Global Energy Statistics and World Bank (WDI).

The use of factors such as population, GDP, energy intensity, and energy consumption is the focus of this research. Predicting energy intensity, or the ratio of energy consumption to GDP, is the goal. The explanatory variable will be per capita GDP, while the dependent variable will be energy intensity.

The figures for GDP per capita, energy consumption, and energy intensity from 1990 to 2020, along with the growth rate for the two countries, are displayed in Table 1 below. The Kingdom of Saudi Arabia has the highest GDP growth rate of roughly 5.1% and of 0.92% for the United Arab Emirates, respectively. The table also, shows that the United Arab Emirates has the high energy consumption growth rate of 4.6% whereas the Kingdom of Saudia Arabi has a rate of 4.2%, demonstrating that GDP is seen as a key driver of economic growth for both nations. However, several specific linked features, including the distribution of income and the level of efficiency, differ between the two countries. Energy intensity's outcomes have likewise varied over time; initially high, they have decreased over the past three decades. The largest decline is recorded in the United Arab Emirates, where it hit −1.7%, followed by the Kingdom of Saudia Arabia at −1.59%, respectively.

4.2. Econometric Model

To investigate the relationship between energy consumption, energy intensity of use, and economic growth, the following basic linear model: $Yi = \alpha + \beta Xi + \varepsilon i$ will be used, which can be transformed to a *log-log* model as: *Log* $EIit = \alpha + \beta$ *log* $GDPit$, where $EIit$ is *log* energy intensity of country *i* in year *t*, $GDPit$ is *log* GDP per capita. The purpose of using the *log-log* format is that the logarithm format makes an exponential shape linear and allows correlation and regression analysis of the data.

Table 2 provides an overview of the regression's output. With predicted values for t-statistics and P-values, each variable is statistically significant and exhibits the expected signals proposed by economic theory. The values of R^2 for both countries are quite high, which is to be expected given that the results only measure the correlation between GDPs per capita and energy consumption when other factors are taken out of the equations.

The dependent variable in the first section of the table is energy consumption, while the independent variable is GDP per capita.

Table 1: Descriptive data for gross domestic product, energy consumption, and energy intensity of use

County	Gross Domestic Product			Energy Consumption			Energy Intensity		
	1990	2020	Growth% 1990-2020	1990	2020	Growth% 1990-2020	1990	2020	Growth% 1990-2020
UAE	27256	36284	0.92	20	81	4.6	0.000394	0.00022	−1.78
KSA	7204	20110	3.4	58	209	4.2	0.000493	0.00029	−1.59

Table 2: The regression's output

The dependent variable is the energy consumption							
Country	Correlation coefficient	Intercept	GDP coefficient	t-Statistic	P-value	R^2	n
KSA	+95	4.7	0.83	16	1.62E-16	0.91	31
UAE	+87	−1.2	1.95	9.5	1.77E-10	0.76	31
The dependent variable is energy intensity: Consumption/GDP							
KSA	−97	−0.77	−0.64	−24	4.46E-21	0.95	31
UAE	−96	4.183	−1.71	−18	9.41E-18	0.92	31
The dependent variable is log GDP/capita and independent variable is log energy intensity (Consumption/GDP)							
Country	Correlation coefficient	Intercept	Intensity Coefficient	t-Statistic	P-value	R^2	n
KSA	−97	−0.97	−1.5	−24	4.46E-21	0.95	31
UAE	−96	2.61	−0.54	−18	9.41E-18	0.92	31

Figure 3: Energy intensity, GDP per capita and trend equations

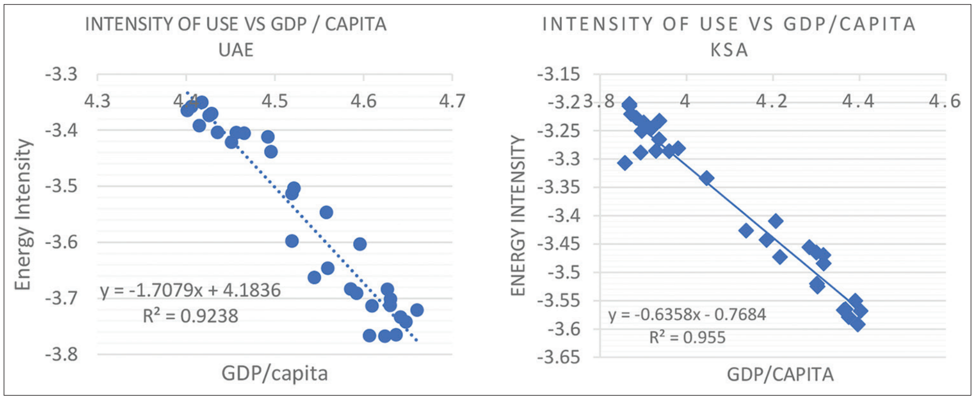


Figure 4: Predicted energy intensity of use 2021-2025

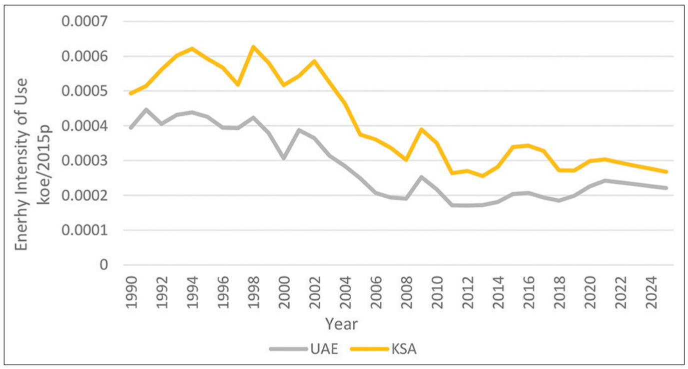


Table 3: The estimated GDP per capita and energy intensity of use 2021-2025

Projected GDP per capita, 2021-2025, US$		
Year	Kingdom of Saudia Arabia (KSA)	United Arab Emirates (UAE)
2021	21115.84	36861.46
2022	22171.63	37359.09
2023	23280.21	37863.43
2024	24444.22	38374.59
2025	25666.43	38892.65
Projected energy intensity of use, 2021-2025		
Year	KSA	UAE
2021	0.000303389	0.000242103
2022	0.000293765	0.000237137
2023	0.000285102	0.000231739
2024	0.000276694	0.000226464
2025	0.000267917	0.0002208

Energy consumption and the two GDP per capita variables are positively correlated; as GDP per capita rises, so does the demand for energy. The GDP per capita is the independent variable and the energy intensity of use is the dependent variable in the second section of the table. As anticipated, there is a negative correlation between both GDP per capita coefficients and energy intensity; that is, as GDP per capita rises, so does the energy intensity of use. Energy intensity is the independent variable and GDP per capita is the dependent variable in the third section of the table. GDP per capita is negatively correlated with both energy intensity coefficients; when energy intensity declines, GDP per capita rises. In other words, less energy is needed to generate a dollar's worth of output, which will result in more efficient energy use, particularly in nations that are in the latter phases of their development.

(Figure 3) presents energy intensity and GDP per capita and their trend equations for the two countries from 1990 to 2020.

4.3. Elasticity Calculations

More evidence for the aforesaid finding comes from calculating the elasticity of energy intensity in proportion to the growth in GDP per capita. Even though both nations' energy intensity of use is decreasing as GDP per capita rises, the United Arab Emirates has the lowest. This suggests that, in comparison to the Kingdom of Saudi Arabia, the United Arab Emirates is using its energy more efficiently. A 1% increase in its GDP per capita leads to a decrease of 1.93% in energy use in the United Arab Emirates, whereas a 1% increase in GDP per capita for the Kingdom of Saudia Arabia leads to a decrease of 0.52%

5. FORECASTING TECHNIQUES AND METHODOLOGY

To predict the energy intensity of use, it is necessary to first assess the GDP per capita for the two countries and project their future trends. The calculated regression equations will be the basis for these projections, which will be based on historical data from 1990 to 2020. The energy intensity of use for the years 2021-2025 will be predicted using the forecast of individual variables. The projection methodology employed is that projections are basically driven by the assumption that GDP per capita for each of the two countries will continue to grow to the year 2025 at the 2000-2020 average annual growth rates.

Following the computation of the anticipated GDP per capita growth rates, which come out to be 5% for Saudi Arabia and 1.35% for the United Arab Emirates, the estimated GDP per capita and energy intensity of use are displayed in Table 3 and Figure 4, respectively.

6. CONCLUSION

The findings of this research conclude that the overall outcome of the regression for the two tested countries is either a significant positive correlation between energy consumption and GDP per capita (economic growth) or a strong negative correlation between energy intensity of use and GDP per capita.

Calculations of elasticity reveal that as more efficient energy is used, the two countries experience more economic growth. In comparison, the United Arab Emirates has a more elastic demand, indicating that it is making better use of its energy. In other words, the United Arab Emirates requires less energy to generate one dollar of economic output compared to the Kingdom of Saudia Arabi.

The analysis's findings also imply that energy intensity for both economies will continue to drop over the coming years, leading to more economical energy use. This implies that by creating and implementing more effective energy efficiency policies, offering reliable funding sources for energy efficiency projects, and taking decisive action to eradicate energy waste, the two tested nations can further increase their energy efficiency and lower their energy intensities. These initiatives will undoubtedly help save a considerable amount of money on energy, which can be reflected in stronger economic growth. Over time, this will lead to a higher standard of living, greater prosperity, and an improved quality of life.

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