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Determinants of Energy Intensity in Bahrain: An Econometric Analysis Using Canonical and Cointegrating Regression Approaches

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ABSTRACT

Background: Energy intensity, the ratio of energy consumption to economic output, is a key measure of energy productivity and efficiency. Bahrain remains heavily dependent on fossil fuels, with energy-intensive industries driving high consumption despite diversification efforts. As economies grow rapidly, understanding energy intensity is essential for developing policies that enhance energy efficiency without hampering economic growth. Hence, this study examines the determinants of energy intensity in Bahrain, assessing the impact of economic growth, industrial value-added, foreign direct investment (FDI), trade openness, energy prices, and government policies on energy consumption trends.

Methods: The study covers data from 1980 to 2024, employing Canonical Regression Approach (CRA), Fully Modified Ordinary Least Squares (FMOLS), and Canonical Cointegration Regression (CCR) to analyze statistical relationships between energy intensity and key economic factors.

Result: Canonical and cointegrating regression estimates indicate that economic growth increases energy intensity (e.g., a 1% GDP rise leads to a 0.6% increase in energy use via CCR), and FDI raises it due to investments in energy-intensive sectors. Conversely, industrial value-added (-0.68%) and trade openness (-0.64%) reduce energy intensity, reflecting efficiency gains, while government policies show minimal impact due to subsidies.

Conclusion: To mitigate high energy intensity, Bahrain must strengthen energy policies, reform energy pricing, promote renewable energy investments, and encourage energy-efficient technologies. Enhanced regulatory oversight and stricter enforcement of existing policies are crucial for balancing economic growth and sustainability, providing insights relevant to Bahrain and other Gulf economies.

Keywords: Energy Intensity, Fully Modified Ordinary Least Squares, Canonical Cointegration

1.Introduction

Energy intensity, or the amount of energy consumed per unit of GDP, serves as an indication of the level of economic activity and its sustainability (IEA, 2021). It marks the grade a country or a certain sector achieves in converting value from energy resources. Nothing is more encouraging than a low energy intensity where an economy's output is large in relation to the input of energy resources. On the other hand, this circumstance could suggest a greater dependency on energy-intensive industries or ineffective patterns during production and consumption, particularly in highly powered economies (Ang & Su, 2016). Most importantly, energy intensity offers an enumeration for a country seeking to continuously grow and balance energy use against economic output. It is also a significant term for policy makers when evaluating different policies made within different times regarding the spectacular shift in the energy intensive industry of fossil fuels to not only endeavor conservation but improvement of the conservation measures and machinery (Csereklyei et al., 2016). In an expanding economy, industrial growth together with the overconsumption of fossil fuels is often correlated with greater energy intensity and therefore, more severe environmental issues (Sadorsky, 2020). Developed economies tend to shift towards less energy intensive efficient and structural fueled serviceoriented economy. The UN SDGs, like many global schemes, focus on energy efficiency as an integral part of any economically viable development strategy that seeks to minimize harm to the environment (UNEP 2022). Governments throughout the world, especially in the context of climate change and sustainable development, give preference to reducing energy intensity as a principal policy goal and an urgent need for action in development.

The disparity observed in energy intensity across different sectors and nations can range greatly; this is due to the structure of an economy, the advancement of technology, as well as the region's policies (Stern, 2017). Developing economies that heavily rely on manufacturing and mining services tend to exhibit greater energy intensity; however, this is not the case for industrialized nations that have incorporated the use of energy-efficient technologies and robust policies (Pérez-Lombard et al., 2013). The use of energy-efficient machinery and smart grid systems qualifies as technological advancement, which in turn reduces energy intensity (Ürge-Vorsatz et al., 2018). Moreover, economies that are shifting towards a greater reliance on service-based industries relative to manufacturing industries tend to benefit from lower energy intensity due to auxiliary service sector possessing a lower demand for energy (Sharma et al., 2019).

Additionally, changes in industrial policies also intake the management of energy intensity. These changes include reforms in energy prices, enhancement of renewable energy, and standard policies for industrial production (Bhattacharya et al., 2016). On the other hand, the rapid economic growth and urbanization experienced by developing economies serves as a larger hindrance in achieving energy efficiency targets due to heightened energy demand (Sadorsky, 2021). The International Energy Agency and World Bank are among the international bodies that advocate the adoption of energy policies focusing on efficiency due to their access to information on the positive effects of such policies on economic productivity and strain on the environment (IEA, 2021). Countries that heavily depend on energy, on the contrary, tend to have low energy security and therefore are more susceptible to the volatility of energy prices and the supply of goods (Apergis & Payne, 2010). Greater reliance on the efficient use of energy, then, puts the economy and the environment at an ideal harmonious state.

The determinants of energy intensity rest on complex, multi-dimensional factors which include economic, technological, and policy dimensions (Wang et al., 2019). Energy intensity is affected by economic growth, as rapid energy consumption tends to follow industrialization (Karanfil & Li, 2015). Yet, there exists an inverse relationship as well, where increased development of an economy accompanied by the setting up of high-tech industries and services leads to greater efficiency and innovation, therefore lowering energy intensity (Stern, 2017). Another vital factor is urbanization, where increasing city population needs a lot of energy for transportation, infrastructure, and residential consumption (Lin & Du, 2015). Government policies, such as carbon taxation and energy efficiency mandates, lean towards lowering energy intensity greatly by encouraging the responsible use of energy (Bhattacharya et al., 2016). The energy mix of a country also matters greatly, since economies that depend heavily on fossil fuels are usually more energy intensive than those that rely on a wide variety of sources including renewable energy (Csereklyei et al., 2016). The level of energy and process automation and use of modern technology significantly determines (Ang & Su, 2016). Also, trade and globalization influence energy intensity because the adoption of more efficient technologies and practices tends to occur more often with economies that are part of global supply chains (Sharma et al., 2019). As for climate and geography, areas with extreme temperatures have an increased need for energy to heat or cool the buildings, which adds to the energy intensity (Ürge-Vorsatz et al., 2018). To these, one adds the rest of the determinants, and one helps governments target specific energy efficiency goals paired with economic growth.

Considering the role that energy intensity plays in the economy and the environment, many nations have set optimistic goals to reduce their energy intensity levels (IEA, 2021). The international Paris Agreement, alongside the United Nations Sustainable Development Goals (SDG 7) underscores the integration of energy efficiency in the global fight against climate change (UNEP, 2022). Sadorsky (2021) claims that businesses and households are able to save money on energy costs which, in turn, fuels economic growth and lowers the emission of greenhouse gasses. There have been numerous efforts, like advertising, monetary incentivization, and set benchmarks regarding energy efficiency, which aim to aid in the conservation of energy. Such steps have also been taken by the private sector.

Businesses are adopting advanced technologies to remain competitive and sustainable or fuel further investment (Bhattacharya et al., 2016). For developing economies trying to achieve equilibrium on growth and sustainability, international collaboration and sharing knowledge regarding best practices focused on energy efficiency is vital (Lin & Du, 2015). Stern (2017) stated that research on energy intensity is still dynamic with incorporation of machine learning and big data analytics in predicting policies and their programs. Lowering energy intensity is likely to be crucial for a nation's economic vitality and ecological sustainability considering the constant rise in global energy usage. For that reason, ongoing research and

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policy development is necessary to enable countries to achieve their energy efficiency targets alongside economic development.

Bahrain is interesting for studying energy intensity because of its unique economic structure and patterns of energy use. Unlike other high-income countries, energy consumption of Bahrain is determined by its industries, particularly aluminium smelting, construction, and petrochemical and petrochemical industries (World Bank, 2021). Even though the economy is striving to diversify under Bahrain's Economic Vision 2030, there is a strong dependency on fossil fuels for economic growth and for the hydrocarbon energy needs of the country (Bahrain Economic Development Board, 2022). Subsequently, the industrial sector, with its large investment into manufacturing and oil refining, constitutes an important part in Bahraini total energy use (IEA, 2021). Al-Mulali and Ozturk (2015) argue that Bahrain, being a Gulf Cooperation Council (GCC) member, will continue facing energy efficiency challenges stemming from low historical energy prices combined with high energy use per capita (Al-Mulali & Ozturk, 2015). While still inadequate in scale, reforms meant to cut down the unsustainable subsidies have been introduced by the authorities recently (Oxford Business Group, 2020). The unprecedented growth in population and development of the infrastructures in Bahrain lead to increase energy consumption which further requires the formulation of sustainable economic policies to cope with the rapid economic growth and energy efficiency (Sbia et al., 2017). Considering the recent attention around the globe towards energy sustainability, this knowledge makes Bahrain's energy intensity important for formulating effective policy interventions. Due to the specific features of its economy, the structure of her energy intensive industries, and the political constellation, a case study of the country offers a good example for analyzing determinants of energy intensity (Sadorsky, 2021).

Aluminium Bahrain (Alba), located in Bahrain, is one of the leading aluminium smelters across the globe and is a major consumer of energy (IEA, 2021). All the industries that operate in the region consume around 35% of the total electricity in Bahrain which signals a huge consumption of energy resources within the heavy industries (Bahrain Electricity and Water Authority, 2022). There are also significant auctions of Fossil Fuel Subsidies, which affects them critical as well. Bahrain's energy consumption patterns will be especially interesting in the context of its transition toward more knowledge-focused and sustainable economy. Efforts towards oil me Economics Diversification Efforts: The government is gradually consuming energy have been assumed through the revisions in the economic subsystems policies but there has yet to show demonstrable positive results (IEA, 2019).

Bahrain Economic Development Board expects focus on tourism and technology also aid in energy alleviation (Alkhateeb & Sultan 2021). Soon, these investments are forecasted to limit dependency on the economy that relies heavily on energy intake. This shift towards sustainability does, however, run contrary to their claims through the NEEAP and carbon emissions of oil producing nations. Bahrain's commitment to improve its carbon footprint does refocus its policies towards energy efficiency, but the motivations are purely economic, aiming to boast their global reputation, to remain compliant will all potentially prove to be ineffective (UNEP, 2022). Further compounded by the existing policies laid down by Bahrain as well as rich themes results in the Paradise Paradox, where underlying complexities are to be dug deeper into, especially when examining the youth and economic growth. Policymakers need to pay special attention to these underlying tenets of energy intensiveness to smoothen the transition towards a satisfied framework for reduction of energy use increase economic growth.

The main aim of this research is to establish the significant factors which influence energy intensity in Bahrain. This study seeks to: Explore the correlation between economic development and energy intensity in Bahrain, considering the effects of GDP changes on energy consumption patterns. It will evaluate the effects of industrialness, urban growth, and technological change on energy intensity by considering, the construction development and modernization of industries. Further, it examines how government measures such as energy pricing including certain subsidizations affect energy consumption, focusing on recent changes and their impacts on energy consumption. It applies canonical regression to capture the energy intensity variability influences and enhance the understanding of its economic, industrial, and policy dimensions. The result of this study will be critical in formulating strategies to enhance energy efficiency, minimize fossil fuel dependency, and promote economic development in a sustainable manner in Bahrain. This is especially important for Bahrain as it attempts to further diversify its economy to help enhance understanding of the causes of energy intensity for formulating energy policies in a manner that would be favorable both nationally and internationally in terms of sustainability. This study will also add to the discussion on energy efficiency in the Gulf region, which will help in other oil-based economies that struggle with similar issues. This study proceeds in 5 sections. Having discussed section 1, section 2 examines literature review. The methodology is done in 3 while the presentation of result in 4. Finally, summary and conclusions are in 5.

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2.0 Literature Review

2.1 Theoretical Review

Energy intensity, measured as the ratio of energy consumption to economic output, is a critical indicator of an economy's energy efficiency and sustainability. One of the most popular theories is the Kuznets Curve Hypothesis for Energy Intensity which argues that the relationship between energy intensity and economic growth follows an inverted U-shaped curve (Sadorsky, 2021). While a country is undergoing industrialization, industrial and heavy power manufacturing energy GDP ratios are relatively high (Wang et al., 2019). However, in the later stages of industrialization where economies become service dominated, energy efficiency increases and thus energy intensity declines (Stern, 2014). This theory is immensely important for Bahrain which is seeking to diversify away from its oil reliant industrial economy as outlined in Economic Vision 2030 (Bahrain Economic Development Board, 2021).

Following this theory, Grossman and Krueger (1993) introduced the decomposition effects which is now widely used in trade and environment literature. He decomposed the effects of economic activity and trade on pollution into scale, a composition and a technique effect. Antweiler et al. (2001) supported with a formal postulation and was furthered by Copeland and Taylor (2003) considering total economic activity as a divide between two sectors having different energy intensities: industry and non-industry. Let energy use in the non-industry sector relative to its output value be defined by e(A) with the properties e(A) > 0 or e(A) < 0, where A is a proxy for the average technology in use. Assuming that the energy intensity in the industry sector is always μ times higher than e(A), total output be GDP and the share of industrial value added be (VA), then total energy use can be written as:

$Ei = GDP. (\mu .VA + 1\text{-}VA). e(A)$ .... eqn 1

It follows from eqn(1) that total energy use in a country can be decomposed into three effects: the scale of overall economic activity (GDP), the relative importance of energy-intensive sectors in economic activity (VA), and the energy intensity of the technology in use e(A)

The Scale Effect:

The scale effect captures the marginal returns on output as a result of changes in the factors of production. These returns could be increasing, constant or diminishing (Jhingan, 1997). Relating this concept to energy consumption as examined by (Akinlo, 2008; Ajmi et al 2013), an expansion in economic activity means increase energy consumption (Destais; Fouquau; Hurlin; 2007). In this context, the scale effect represents an increase in energy consumption (Elliot, Sun and Chen, 2012). Antweiler et al. (2001) argues that the scale effect reflects the impact of increasing or decreasing economic activity on total energy use when holding constant the mix of sectoral changes as well as the technology. Following Antweiler et al (2001), energy intensity defined as energy use per Gross Domestic Product (GDP) could either increase owing to improved economic investment, remains constant over a large range of expanded activity as a result of the counterbalance by internal and external diseconomies or experience a diminishing return. Furthermore, (Song and Zheng, 2012; Suri and Chapman, 1998; Dinda 2004) documented that a rising economic level induces people to enhance their awareness for environmental quality. This induces the adoption of stricter environmental regulation. Firms react to regulations by acquiring improved inputs. With this in view, output increases but with lesser amount of energy consumed. This fits the concept of a diminishing returns to scale. If economic activity is expressed by GDP, then the scale effect on energy intensity could be expressed thus:

$E(i) = E/GDP = f(GDP)$............................ eqn 2

Where E(i) which is energy intensity is defined E/GDP (by energy consumption per GDP) and the Gross Domestic Product which represent s economic activity.

The Composition Effect:

Holding scale and technology constant, the production of relatively more energy intensive goods due to a sectoral shift will increase energy intensity and will decrease if less energy intensive goods are produced (Moroney, 1988). This effect explains the changes in the industry structure and its influence on intensity. A movement from the production of energy intensive goods to less intensive ones which is determine by changes in the sectoral structure of an economy. Dunkerley et al., (1981) posited that in the early stages of a country's development, economic activity shifts from the agricultural to the industry and then to tertiary. Smil (1990) and Kambara (1992) observed that later in the development process, activity moves typically from the industry to the service sector or from the heavy to the lighter industry. This implies a negative composition effect in this stage. Since the service sector and the light industry are less energy intensive, energy intensity will fall. (Stern, 2004). If we examine industrial structure by value addition, energy intensive structure will create less value than the less intensive industry. We can then represent energy intensity as a function of the industrial structure captured by value addition.

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Ei = f (VA)……………………………… eqn 3

The Technique Effect:

The technique effect covers the impact of using new technologies on energy use. New technologies with a higher level of knowledge are more productive and hence more energy efficient than old technologies. (Rivera and Oh, 2013; Saikawa, 2013; Ahlquist and Prakash, 2010) supported earlier studies by (Mielnik and Goldemberg, 2002; King and Shaver, 2001) that imported investments through FDI in developing countries have a stronger energy reducing effect than domestic investments. An indirect link is also established between openness to trade and the technique effect. Earlier study by Grossman and Krueger (1993) laid emphasis on trade as a measure of the technique effect in their work on trade liberalization. Their argument was later confirmed theoretically by a model which was developed by Antweiler et al. (2001). Keller, (2004) also confirmed the technology transfer potential of trade on energy intensity. (Grossman and Helpman, 1991) earlier identified the role of trade openness to be in two parts: the "pull" and the "push" effects. Their study argued that imitating and learning from outsiders as a result of trade openness is the pull effect. The push effect argues that a well-integrated economy creates competitive environments which affect local firm's adoption of energy efficient technologies and make them imitate and learn from the international market. This argument was supported by a study by (Holmes and Schmitz, 2001). This induced competition translates into energy use reductions in host economies Hubler (2011) and Sbia et al. (2014) Corcos et al. (2007). From the above, the study infers that energy intensity of a country e(A) can be represented as.
e(A) = f (FDI, TO, TEC) ……………………………. eqn 4
Where FDI = Foreign investment, TO =Trade openness, TEC = technology.

2.2 Empirical Review

Quite a few studies of results on the determinants of energy intensity have been documented in energy literature. There is no unanimous conclusion on the impact of some variables. This may stem from the different economic structures analyzed by these studies. Chief among these determinants include Gross domestic product, price of energy, foreign direct investment inflow, trade openness and changes in industrial structure. One clear observation from studies is that the result remains mixed for trade openness, FDI, and industry structure, but there is unanimous conclusion on the effects of price of energy and GDP.
For instance, (Birol and Keppler 2000; Vanden and Quan 2002) confirmed energy prices to be negatively significant to energy intensity. They concluded that higher energy prices will force the adoption of higher energy efficient technologies, but lower prices will force the adoption of lower energy efficient technologies. This confirmed earlier findings by Greening et al. (1998) who found out that energy intensity changes in OECD countries were related to the cost of energy. (Fisher-Vanden et al. 2004; Kaufmann, 2004; Miketa; 2001; Verbruggen, 2003) show the effect of energy prices on energy intensity to be negatively significant. A significant relationship has been established between GDP and energy intensity. Higher income brought about by increase economic activity raises expenses more on environmental research and the adoption of clean and efficient technologies (Sten 2004), Komen (1997). Wu (2012) and Narayan (2016) also indicated that energy efficiency generally improves as an economy develops in China hence, concluded that growing per capita GDP can reduce energy intensity

The ambiguity surrounding the effects of trade openness on energy intensity has attracted much attention in the literature. Hubler (2011) and Sbia et al. (2014) in their study posited that trade openness promotes energy efficiency. However, results by (Adom and Kwakwa, 2014; Su-yun and Zhen-yu 2010) are counteractive as they show that international trade increases energy intensity. Fisher-Vanden et al. (2004) acknowledged this ambiguity and in their work opined that the effect of trade openness on energy intensity can be positive or negative. (Cole 2006; Zheng et. al 2011) supported earlier view by Keller (2000) that the overall impact of trade openness on energy intensity depends on the relative weights of the energy saved by imports and the energy consumed by exports.
Energy intensity patterns have also been linked to industrial and economic structure. Poumanyvong and Kaneko, (2010); Su-yun and Zhen-yu, (2010) found a positive relationship between industrial activities and energy intensity. Adom and Kwakwa (2014) revealed that manufacturing activity increased energy intensity in Ghana. He furthered that the changing technical and composition aspects of the manufacturing sector post reforms contributed to the decline in energy intensity in Ghana.
Inglesi-Lotz and Pouris, (2012); Lin and Moubarak, (2014) also found out that changing economic structure in favour of less energy intensive sectors contributes to energy intensity reduction. On the contrary, Yu (2012)

show that, the ratio of heavy industries to total industries, and the ratio of coal consumption to energy consumption significantly increased energy intensity in China. Voigt et al. (2014), however, could not establish the energy reducing effect of structural changes in 40 major countries. Lin and Moubarak (2014) have analyzed energy intensity determinants for China and concluded that changes in industrial structure are negatively related to energy intensity in China. Lin and Moubarak's finding confirmed the result by Voigt et al. (2014), on the subject.

The importance of technological change in reducing energy requirement has also been documented in literature. Ma and Stern (2008) confirmed the result of earlier studies by (Garbaccio and Ho, 1999; Smil 1990; Kambara 1992) who reported a negative relationship between technology and energy intensity. In a recent study, Lin and Moubarak (2014) has establish a negative relationship between technology and energy intensity while Voigt et al. (2014) reported strong evidence of improvement in energy intensity in 40 major economies. Other studies with similar findings incudes (Cui, Kuang, Wu, Li, 2014; Inglesi-lotz et al 2012).

Empirically, strong evidence of foreign direct investment on energy intensity has also been documented. Studies by Su-yun and Zhen –yu (2010) and Ting et al. (2011) revealed that FDI reduces energy intensity by composition effect and technique effect confirming earlier finding by Hubler and Keller (2009) that foreign capital and technology transfer from FDI induces energy intensity reduction. Mielnik and Goldemberg (2002), Eskeland and Harrison (2003) and Cole et al. (2008), Zhang and Chen (2009), Yuan-yuan and Li (2010), Hubler (2011), Kretschner and Hubler (2013) and Sbia et al, (2001) all confirmed a negative relationship between energy intensity and foreign direct investment. However, Antweiler et, al (2001) provided a different opinion to the subject matter. Their results showed that foreign direct investment affects host country's output but not energy intensity. While Adom and Kwakwa (2014) had a mixed result.

For government policies, earlier study by Xing, (1998) showed Government policies to influence intensity. (Copeland, 2003; Tony, 2012) later confirmed this views that there exist a significant relationship between energy intensity and government policies. In a related study, Enerdata (2013) also established the effect of government policies on energy intensity. The study posited that government policies in developed countries was responsible for a decreasing energy intensity. The present study is an extension of previous research to determine the determinants of energy intensity in Bahrain.

2.3 Energy Consumption in Bahrain

There have been investigations done on energy consumption in Bahrain and other economies in the Gulf Cooperation Council (GCC) region. Since the International Energy Agency IEA (2021) states, which the GCC economies have done in the past, Bahrain has extensively consumed energy due to the use of fossil fuels for economic development. Unlike the World Bank estimates, the country's energy consumption activities are influenced by economic growth, industrial development, and government funding ([IMF], 2020). Sbia et al. (2017) explored the interrelationship among energy consumption, foreign direct investments (FDI), and economic activities of Bahrain and noted that imports of FDI increased the energy demand in industrial sectors of Bahrain. As noted by Al-Mulali and Ozturk (2015), this pattern also holds for other countries with considerable energy endowment and developed industries.

Analyzing the trends in energy consumption is critical in understanding Bahrain's economic diversification considering the nation's continued reliance on energy intensive industries like aluminum smelting and petrochemicals (Bahrain Economic Development Board, 2021). Additionally, Sadorsky (2021) pointed out that Bahrain's economic structure requires specific policies for achieving development alongside energy conservation. The energy intensity of a country is higher than the global benchmarks which suggests room for improvement on efficiency measures (IEA, 2021). Considering all this, exploring the factors that drive energy consumption in Bahrain is crucial for grasping regional energy patterns.

The GCC region helps understand the context of shifts on energy consumption in Bahrain through its research on energy subsidy reforms. As part of the IMF's (2020) review of Bahrain and its regional partners, the energy subsidy offered was assessed within the context of a shift towards more rationed fuel consumption. One of the cornerstones of the Bahraini economy, cheap energy, has always contributed to overuse and wasteful activities within the country's consumption patterns, especially amongst the industry and population (IEA, 2021). Sharma and Kumar (2020) on their research on the GCC nations noted that with time and cut down subsidies, the per head energy usage started coming down across all other GCC nations. At the same time, these policies will only work if alternatives exist and people accept pricing equations for energy that are higher than what is currently used (Sadorsky, 2021). Bahrain's actions put forth extreme national energy efficiency action plan (NEEAP policies) which seeks to integrate renewables and add efficiency looking at the energy intensity quotient (Bahrain Supreme Council for Environment, 2021). The effectiveness of these policies in consumption still remains a question that needs further examination (Alkhateeb & Sultan, 2021). Thus, as subsidy reforms are undertaken, it remains critical to the understanding how Bahrain moves towards meeting its objectives in a shifted economy.

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Comparative studies help provide a context for understanding Bahrain's energy intensity within a global framework which requires examining sectoral insights in regard to a country's energy consumption policy. According to the IEA (2021), Bahrain's economy distinguishes itself from other economies in the world through important patterns observed in the region's energy consumption. The aluminum industry dominated by Aluminum Bahrain is one of the key contributors for high energy usage alongside the industrial sector who are the largest consumers of fuel and electricity. As Wang et al. (2019) highlight, the high level of energy intensity is a characteristic mainly common among economies that utilize energy driven industries.

In comparison, The UAE, much like Bahrain, has less diversified economic structures but is able to lower their energy intensity when investing in renewable energy (IMF, 2020). Energy measurement while utilizing different fuels in the form of oil barrels shows that wide variety of Bahrain's industrial policy impacts the country's prospect in the energy sector (Bahrain Economic Development Board, 2021). These patterns and policies are currently watched closely to see the impact marked urbanization and infrastructure development will have on energy efficiency (Sharma & Kumar, 2020). Overall, this fosters energy policies that are directed towards the Bahrian economy.

Al-Mulali and Ozturk (2015) studied the concentration ratios of energy use for oil-proficient economies and discovered that there exist energy price distortions and economic diversifications which affects energy efficiency. As a small economy with plentiful resources, Bahrain faces industrial challenges at the same time as Kuwait, Qatar, and Saudi Arabia (IEA, 2021). Sadorsky (2021) contended that investing in energy efficient technologies as well as adopting policies that consume an appropriate quantity of energy can deal with increased energy consumption. Nations which do not affect the necessary reforms, however, position themselves to continue relying on inefficient patterns of energy use for an extended period (IMF, 2020). This case of Bahrain shows the lack of need for specific approach which takes sectoral energy consumption while fostering economic resilience (Bahrain Supreme Council for Environment, 2021).

3.0 Methodology

3.1 Model Framework

Total energy use in a country can be decomposed into three effects: the scale of overall economic activity (GDP), the relative importance of energy-intensive sectors in economic activity (VA), and the energy intensity of the technology in use e(A). The technique effect is what our data can capture. The technique effect covers the impact of using new technologies on energy use. New technologies with a higher level of knowledge are more productive and hence more energy efficient than old technologies. (Rivera and Oh, 2013; Saikawa, 2013; Ahlquist and Prakash, 2010) supported earlier studies by (Mielnik and Goldemberg, 2002; King and Shaver, 2001) that imported investments through FDI in developing countries have a stronger energy reducing effect than domestic investments.

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Their study argued that imitating and learning from outsiders because of trade openness is the pull effect. The push effect argues that a well-integrated economy creates competitive environments which affect local firm's adoption of energy efficient technologies and make them imitate and learn from the international market. This argument was supported by a study by (Holmes and Schmitz, 2001). This induced competition translates into energy use reductions in host economies Hubler (2011) and Sbia et al. (2014) Corcos et al. (2007). From the above, energy intensity of a country e(A) can be represented as:

e(A) = f (FDI, TO, TEC) .... eqn (5)

Where FDI = Foreign investment, TO =Trade openness, TEC = technology

Following the empirical literature and the specifications by Hubler and Keller (2010), Fisher-Vanden et al. (2004) and Adom and Kwakwa (2014), a model specification which expresses energy intensity as a function of energy prices, foreign direct investment, and industry value added.

$Eit = F (PE_t, FDI_t, IVA_t)$.......................... eqn (6)

To capture the effect of government policy and economic activity which is the thrust of this study. A baseline regression is specified as stated below

$Eit = F (PE_t, FDI_t, GDP_t, IVA_t, GOP_t)$........................... eqn(7)

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$Ei_t = \beta_0 + \beta_1 PE_t + \beta_2 FDI_t + \beta_3 GDP_t + \beta_4 IVAt + \beta_5 TO_t + \beta_6 GOP_t + Ui_t$ .... eqn(8)
Where the dependent variable is energy intensity (EI_t) and the independent variables are price of energy (PE_t), foreign direct investment ($FDI_{t,}$), industry value added (IVA_t) and government policy (GOP_t)

3.2 Variables Used

This study uses yearly data with the sample period from 1980 to 2024. The effect of five variables on energy intensity will be assessed. These variables include Foreign Direct Investment (FDI, Price of Energy (PE), Industry value added (IVA), Economic activity (GDP), and Government policy (GOP). Energy Intensity (Ei) is the dependent variable in this study. It is the level of primary energy is the ratio between energy supply and gross domestic product measured at purchasing power parity. Energy intensity is an indication of how much energy is used to produce one unit of economic output. Lower ratio indicates that less energy is used to produce one unit of output.
Price of energy (PE); Energy prices and subsidies significantly impact energy intensity by influencing consumption behavior (Sadorsky, 2021). In Bahrain, historically low energy prices due to government subsidies have contributed to high energy consumption and inefficiencies (IEA, 2021). Recent subsidy reforms aim to encourage more responsible energy use and promote efficiency measures (IMF, 2020). However, balancing affordability with efficiency remains a challenge for policymakers (Bahrain Supreme Council for Environment, 2021). Price is measured in this study as crude prices in $/bbl. It is used to capture the effect of energy prices on energy intensity.
Foreign direct inflows (FDI): FDI plays a dual role in shaping energy intensity, depending on the type of industries receiving investment (Ozturk, 2010). In Bahrain, FDI has historically been concentrated in energy-intensive sectors, such as refining and manufacturing (Alkhateeb & Sultan, 2021). However, recent efforts to attract investment in knowledge-based and service industries could lead to lower energy intensity over time (Bahrain Economic Development Board, 2021). In this study, it is captured as the net inflows of investment in an economy. The FDI is measured as the net inflow of FDI in current US$. It has been used widely by researchers as an independent variable in the study of energy intensity. In this study, the FDI is used to capture the effect of technology transfer otherwise called the technique effect on energy intensity.
Industry Value Added (IVA): The level of industrialization is another key factor influencing energy intensity, as countries with large-scale manufacturing and resource extraction industries tend to consume more energy per unit of GDP (Sharma & Kumar, 2020). Bahrain's economy is characterized by significant industrial activity, including oil refining, petrochemicals, and aluminum smelting (IEA, 2021). The presence of energy-intensive industries such as Alba contributes to high overall energy consumption (Sbia et al., 2017). Efforts to improve energy efficiency in these industries through technological advancements and policy incentives could help reduce Bahrain's energy intensity (IMF, 2020). This variable is measured as a percent of GDP. Industry value-added comprises value added in mining, manufacturing, and construction. Its addition in the model will show how efficient (energy intensive or less intensive) the Bahrain industry.
Gross Domestic Product (GDP): GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. Higher economic activity typically leads to increased energy consumption (Sadorsky, 2021). However, in advanced economies, improvements in energy efficiency and structural changes can reduce energy intensity over time (IEA, 2021). In Bahrain, GDP growth has been closely linked to energy consumption, particularly in the industrial and transportation sectors (Bahrain Economic Development Board, 2021). Understanding this relationship is crucial for developing policies that balance economic expansion with sustainable energy use. In this study, GDP is used to capture the extent to which economic activity affects energy intensity. Higher income brought about by increase economic activity raises expenses more on environmental research and the adoption of clean and efficient technologies.

Government policy (GOP): GOP is included as an explanatory variable to analyze how efficient the existing policy on energy intensity is to the Bahrain economy. Policy regulations play a critical role in shaping energy intensity trends (Wang et al., 2019). Policies in investment in energy-efficient technologies, smart grids, and renewable energy sources can significantly reduce energy intensity (Sharma & Kumar, 2020). Bahrain's commitment to sustainability through initiatives such as the National Energy Efficiency Action Plan (NEEAP) is a step toward lowering energy intensity (Bahrain Supreme Council for Environment, 2021). The effectiveness of these initiatives depends on their implementation and industry compliance (IMF, 2020). To capture the effect policy on energy intensity, this variable is measured as dummy with 1 assigned to years with energy intensity policies and zero to the years without such policies.
Trade Openness: Theoretical relationships between trade openness and energy intensity are often related to scale, composition, and technique effects. The scale effect hypothesizes that energy use increases with industrial output and infrastructure investment expansion that occur as trade liberalization stimulates

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economic growth (Sbia et al., 2017). This is particularly true for Bahrain, a country where trade-driven industries such as aluminum smelting and petrochemicals use a lot of energy (IEA, 2021). Trade openness is measured by the indicator which captures the proportion of international trade activity of a country in relation to its total economic output. In this paper, trade openness is captured by the trade to GDP ratio.

3.3 Data Source

For the purpose of this study, data on Energy Intensity (EI) measured in kilograms of oil equivalent per capita, Gross Domestic Production (GDP) measured in current US dollars, Industry Value added (IV) measured in current US dollars, Foreign Direct Inflows (FDI) measured in current US dollars are sourced from the World Development Indicators while data on Crude Oil Price which is used as proxy for Price of Energy (PE) is obtained from the BP Statistical Review of World Energy.

3.4 Estimation Techniques

3.4.1 Unit Root

When dealing with time series data, it is important to investigate whether the series are stationary or not, because the regression of non-stationary series on another may yield spurious results. It is the According to Engle and Granger, (1987), the parameter estimates from such a regression may be biased and inconsistent. The standard approach for testing stationary of time series data is the unit root test. The most commonly used is the Augmented Dickey-Fuller (ADF) test proposed by Dickey and Fuller (1981), which is also employed in this study. This study therefore adopted the Augmented Dickey-Fuller (ADF) to test for stationarity on all variables in the model for the period 1980 to 2024. The test will be conducted with intercept and no trend (t) or intercept and trend. This decision is made upon graphing the series. Each of the series as stated by the equation below.

$$\Delta Y_t = \alpha + \beta_t + \delta Y_{t-1} + \sum_{t-1}^{m} \Delta Y + \varepsilon_t \quad \text{......} \quad (9)$$

$$\Delta Y_t = \alpha + \delta Y_{t-1} + \sum_{t-1}^{m} \Delta Y + \varepsilon_t \quad \text{......} \quad (10)$$

Equation 9 above represents intercept and trend, while equation 10 represents intercept and no trend in series, α represents the drift, t represents deterministic trend and m is a lag length large enough to ensure that ε is a white noise process. The coefficient of interest in both equations above is δ. If δ is less than one (1) i.e $\delta<1$, the series does not have unit root. $\delta >1$ will suggest the presence of a unit root. The estimated t-statistic of the variable of interest is compared with the Dickey and Fuller critical values to determine if the null hypothesis is valid.

3.4.2 Cointegration Technique

Having confirmed the stationarity of the variables, this study proceeds to examine the existence of co-integration among the variables. The variables are integrated of order one (1), then there is the possibility of a co-integrated relationship. The econometric frame work used for this analysis is the Johnsen-Juselius (Maximum-Likelihood) co-integration technique, which test both the existence and the number of co-integrating vectors. The Johansen multivariate co-integration technique was adopted rather than the Engel-Granger technique. This is based on the fact that the variables for analysis are I(1) series, which is a pre-condition for the adoption of the Johansen technique. The multivariate co-integration test by Johnsen (1988) can be expressed as:

$$Y_t = X_0 + X_1\Delta\beta_{t-1} + X_2\Delta \beta_{t-2} + X_3\Delta\beta_{t-3} + X_4\Delta\beta t_{-4} + X_5\Delta \beta_{t-5} + X_6\Delta \beta_{t-6} + \varepsilon_t \qquad \text{Eqn (11)}$$

3.4.3 Econometric Technique

The Determinants of energy intensity would be examine using the Fully Modified Ordinary Least Square and the Canonical Cointegration Regression. In a situation, where the series are co-integrated at first difference 'I(1)', Fully modified ordinary least squares (FMOLS) is suitable for estimation. FMOLS is attributed to Phillips and Hansen (1990) to provide optimal estimates of cointegrating regressions. FMOLS modifies least squares to explicate serial correlation effects and for the endogeneity in the regressors that arise from the existence of a cointegrating relationship. Like the FMOLS, the CCR transforms the data and then selects a canonical regression from the class of models representing the same cointegration relationship. The first step is to obtain estimates and then long-run covariance matrices. The method then uses the transformation to obtain consistent and efficient estimate of beta. Park (1999) has shown that CCR transformation asymptotically eliminates the endogeneity and cancels for asymptotic bias resulting from contemporaneous

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correlation between the regression and stochastic regressors error. Thus, the CCR are fully efficient and have the same unbiased mixture normal distribution as FMOLS. The current study uses both techniques for robustness purposes.

$$\Delta Y_t = \alpha_o + \sum_{t-1}^{n} \beta_i \Delta X_{t-1} + \varepsilon_t \quad (12)$$

Canonical Regression Analysis (CRA) extends the capabilities of CCA by explicitly modeling how economic and policy-related factors collectively shape energy intensity trends (Sharma & Kumar, 2020). By accounting for multiple dependent and independent variables, CRA provides a more robust analytical framework than conventional regression methods (Sadorsky, 2021). In energy economics, this technique helps assess the impact of industrial structure, government regulations, and technological progress on national energy consumption (IEA, 2021). In Bahrain, where diverse economic sectors contribute to energy demand, CRA enables policymakers to identify key drivers of energy efficiency (IMF, 2020). The method also facilitates the evaluation of long-term policy impacts, such as subsidy reforms and renewable energy integration, on overall energy consumption trends (Bahrain Supreme Council for Environment, 2021).
Compared to ordinary least squares (OLS) regression, which estimates the relationship between a single dependent variable and one or more independent variables, canonical regression provides a more holistic perspective (Hardoon et al., 2004). OLS regression often overlooks interdependencies among predictor variables, whereas canonical regression accounts for multiple variable relationships simultaneously (Wang et al., 2019). This makes it particularly useful for studying energy intensity, where economic, policy, and technological factors interact dynamically (Sharma & Kumar, 2020). The ability of CRA to uncover latent relationships in energy consumption data enhances its applicability in energy policy research (Sadorsky, 2021).
The application of canonical methods in energy economics has grown in recent years due to the increasing complexity of global energy systems (IEA, 2021). Bahrain's energy sector, characterized by industrial growth, subsidy reforms, and economic diversification, presents an ideal case for applying these advanced statistical techniques (IMF, 2020). Future research should explore how CRA can be used alongside machine learning and big data analytics to improve energy policy formulation (Sharma & Kumar, 2

4.0 Result and Discussion

Table 1: Descriptive Analysis of Variables

	ENI	ENP	FDI	GDP	LGOP	LTRO	INV
Mean	1.697143	41.97143	2.54E+09	3.715481	0.142857	1.32E+10	3.72E+10
Median	1.900000	28.00000	1.35E+09	4.279277	0.000000	5.71E+09	1.67E+10
Maximum	4.700000	114.0000	8.84E+09	33.73578	1.000000	4.59E+10	1.36E+11
Minimum	0.200000	13.00000	-7.39E+08	-13.12788	0.000000	-2.72E+09	5.20E+09
Std. Dev.	1.077166	32.53006	2.72E+09	7.670147	0.355036	1.44E+10	3.95E+10
Skewness	0.577931	1.208558	1.096520	1.162254	2.041241	0.968068	1.323820
Kurtosis	3.197894	3.018323	2.856315	8.568055	5.166667	2.492287	3.446932
Jarque-Bera	2.005468	8.520732	7.043856	53.09293	31.15162	5.842654	10.51422
Probability	0.366875	0.014117	0.029542	0.000000	0.000000	0.053862	0.005210
Observations	35	35	35	35	35	35	35

Note: LENI stands for energy intensity; LENP is the energy price; LFDI is foreign direct investment; LGDP is gross domestic product; LGOP is government policy and LINV is industry value added.

In the period under consideration, energy intensity averages 1.7 kilograms of energy per capita. It ranges between 0.2 and 4.7 kilograms per capita with a standard deviation of 1.0 kilograms of energy per capita. The mean energy price is 41.9 dollars per barrel. It varies from a minimum of 13 dollars per barrel to a maximum of 114 dollars per barrel. Foreign direct investment averages 2.5 billion dollars. Its all-time low is 7.3 million dollars and a maximum of 8.8 billion dollars. Between 1980 and 2014, Bahrain's economic activity grew by 3.71 percent. It ranges between a minimum of -13.12 percent and a maximum of 33.7 percent with a mean departure of 7.69 percent. While the industry value added ranges between 5.2 billion and 136 billion dollars with a mean value of 3.7 billion dollars, trade openness averaged 13 billion dollars, ranging from -2.7 billion dollars to 45 billion having a standard deviation of 14 billion dollars. The value for the Kurtosis varies among variables. The lowest is 2.8 and the highest is 5.1. This indicates that the data set is leptokurtic. The distribution is normally distributed as indicated by Jarque-bera. This is confirmed by the probability ranges of the variable which reveals a significant position. The skewness which shows the asymmetry of the observation indicates a positive skewness (right skew) and has a relative high value for the variables

Table 2: Correlation Matrix, 1980-2024

	LENI	**LENP**	**LFDI**	**LGOP**	**LTRO**	**LINV**	**LGDP**
ENI	1.0000	-0.4720	-0.087	0.0416	-0.4438	-0.1525	0.6012
LENP	-0.4720	1.0000	0.3546	-0.3534	0.6694	-0.0847	0.1041
LFDI	-0.0087	0.3546	1.0000	-0.0064	0.3543	-0.0483	-0.1729
LGOP	0.0416	-0.3534	-0.0064	1.0000	-0.1974	0.2028	0.0110
LTRO	-0.4438	0.6694	0.3543	-0.1974	1.0000	-0.1010	0.2923
LINV	-0.1525	-0.0847	-0.0483	0.2028	-0.1010	1.0000	-0.0902
LGDP	0.6012	0.1041	-0.1729	0.0110	0.2923	-0.0902	1.0000

Note: Variables are as defined in table 5.0

The correlation matrix shows a negative relationship between energy intensity with the variables except government policy and economic growth. The degree of association to price of energy is 0.47. Foreign direct investment 0.008. It is 0.60 for gross domestic product, 0.04 for government policies and 0.15 for industry value added and 0.44 for trade openness (TRO). This result suggests an adverse association between the dependent variable, energy intensity (LENI) and the independent variables, foreign direct investment (LFDI), and industry structure (LINV) except government policy government policy (LGOP) and gross domestic product (LGDP) which is positively correlated with energy intensity.

Table 3: Result of Stationarity Test

Variables	**Symbol**	**Level**	**I (1)**
Energy Intensity	LENI	-2.3909	-5.9906 ***
Energy Price	LENP	-1.9988	-5.1631 ***
Gross Domestic Product	LGDP	-1.9743	-6.8057 ***
Government Policy	LGOP	-1.4715	-5.9141 ***
Foreign Direct Investment	LFDI	-4.2090	-4.9545 ***
Industry Value Added	LINV	-3.3817	-5.0693 ***
Trade Openness	LTRO	-2.8569	-7.5117 ***
Critical Value	1%	-4.2528	-4.2627

Note: Test statistics indicate stationarity at 1% level (***)

Using the Augmented Dickey Fuller (ADF) test, based on Akaike Info Criterion (AIC), the results of the test are presented in table 5.3. Evidently based on their critical values, all variables are not stationary at their levels of ADF while the first order differences of the variables are stationary.

Table 4: Johnsen Cointegration Test

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.824088	205.6130	125.6154	0.0000
At most 1 *	0.766607	151.7420	95.75366	0.0000
At most 2 *	0.755502	106.6360	69.81889	0.0000
At most 3 *	0.585941	62.97105	47.85613	0.0010
At most 4 *	0.470274	35.63691	29.79707	0.0095
At most 5 *	0.289270	15.93964	15.49471	0.0428
At most 6 *	0.158626	5.354291	3.841466	0.0207

Trace test indicates 7 cointegrating eqn(s) at the 0.05 level
Note (*) denotes rejection of the hypothesis at the 0.05 level

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

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Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.824088	53.87094	46.23142	0.0064
At most 1 *	0.766607	45.10602	40.07757	0.0125
At most 2 *	0.755502	43.66494	33.87687	0.0025
At most 3	0.585941	27.33414	27.58434	0.0538
At most 4	0.470274	19.69727	21.13162	0.0784
At most 5	0.289270	10.58535	14.26460	0.1763
At most 6 *	0.158626	5.354291	3.841466	0.0207

Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level
Note: (*) denotes rejection of the hypothesis at the 0.05 level

The study proceeds to examine whether the series exhibit a common deterministic trend. The study uses the Johansen multivariate test. Table 5.3 below shows the result for the Trace and Maximum eigenvalue test. The Trace test indicates that there is two cointegrating equation. This is confirmed by the Maximum eigenvalue test, which also shows two cointegrating equation. By implication, the short-term path of these variables may diverge, but in the long run there is convergence in their path. In other words, there is a common deterministic trend in these variables

Determinants of Energy Intensity in Bahrain

The drivers of energy intensity are examining in this section. For robustness purpose, the result is based on the fully modified least squares and the canonical cointegration regression. This study adopts specific to general modelling techniques to arrive at consistent estimates, and to explain the explanatory power of variables. The result is shown in table 5.4 and 5.5

Table 5: Determinants of Energy Intensity (Period: 1980-2024)

	Fully Modified Least Squares Estimates				
Variable	m1	m2	m3	m4	m5
Economic Growth	0.074*	0.043	0.023*	0.010*	0.006*
	(0.985)	(1.642)	(1.307)	(1.081)	(0.656)
Industry Value Added 0.689***	-	-0.972***	-0.160	-0.768***	
		(-4.776)	(-0.573)	(-4.332)	(-3.770)
Trade Openness	-	-	-0.961***	-0.972***	0.645***
			(-3855)	(-7.260)	(-2.844)
Government Policy	-	-	0.025	-0.178	0.090
			(0.055)	(-0.723)	(0.311)
Foreign Direct Investment	-	-	-	0.755***	0.704***
				(6.074)	(5.534)
Energy Price	-	-	-	-	-0.568
					(-1.693)
Constant	1.987***	24.769***	27.554***	26.394***	20.005***
	(3.079)	(5.140)	(6.096)	(10.977)	(4.760)
R-square	0.061	0.567	0.751	0.861	0.874
Adjusted R-square	0.094	0.539	0.717	0.836	0.846
Durbin Watson	0.561	1.234	1.081	2.155	1.988
Long-run variance	11.487	1.200	0.502	0.141	0.145

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*Cointegrating equation deterministic: Constant. Additional regressors deterministic: trend Long-run covariance estimate (prewhitening with lags = 1 from SIC maxlags = 2 Bartlett Kernel, Newey- West fixed bandwidth = 4.0000). Note: M1 = Model 1, M2 = Model 2, M3 = Model 3, M4 = Model 4, M5= Model 5 with Energy Intensity as the dependent variable it each case. * Indicates 1% significance level. ** Indicates 5%significance level. *** Indicates 10%significance level.*

Table 6: Determinants of Energy Intensity (Period: 1980 – 2024)

Canonical cointegrating regression estimates

Variable	m1	m2	m3	m4	m5
Economic Growth	0.066*	0.048	0.027	0.009*	0.007*
	(1.358)	(1.678)	(1.078)	(0.726)	(0.528)
Industry Value Added	-	-1.008***	-0.099	-0.989***	-
0.946**					
		(-4.605)	(-0.211)	(-2.785)	(-2.508)
Trade Openness	-	-	-1.037**	-0.855***	-
0.588**					
			(-2.561)	(-3.507)	(-1.706)
Government Policy	-	-	0.018	-0.070	0.167
			(0.033)	(-0.224)	(0.458)
Foreign Direct Investment	-	-	-	0.846***	
0.807***					
				(5.148)	(4.585)
Energy Price	-	-	-	-	0.441
					(-0.942)
Constant	1.987	25.583	27.822	27.03	22.207
	(5.442)	(4.938)	(5.531)	(9.851)	(3.779)
R-square	0.030	0.554	0.744	0.848	0.859
Adjusted R-square	0.062	0.525	0.709	0.821	0.827
Durbin Watson	0.502	1.306	1.154	2.330	2.251
Long-run variance	3.335	1.200	0.502	0.141	0.145

*Cointegrating equation deterministic: Constant. Additional regressors deterministic: trend Long-run covariance estimate (prewhitening with lags = 1 from SIC maxlags = 2 Bartlett Kernel, Newey- West fixed bandwidth = 4.0000) Note: M1 = Model 1, M2 = Model 2, M3 = Model 3, M4 = Model 4, M5= Model 5 with energy intensity as the dependent variable in each case. * Indicates 1% significance level. ** Indicates 5%significance level. *** Indicates 10%significance level.*

Result Comparison Between FMOS and CCR Model

In model 1, an attempt to give explanation to the variation observed in energy intensity with the inclusion of economic growth as the only explanatory variable. The result is positive and statistically significant based on the estimate from the FMOS and CCR. The diagnostic test from the Durbin Watson shows possible serial correlation but it is not of concerned since the estimates are made at levels, rather the long run variance is of more important. It is 11.48 and 3.33 respectively. Model 2: The study includes industry value added to the model as one of the regressors. With the inclusion of this variable, the value of R- square improves from 6% to 56% in FMOLS and from -3% to 55% in CCR, adjusted R-square also changes in both estimations. The long run covariance also improves. This suggest that industry value added is an important variable in explaining variation in energy intensity in Bahrain.

In model 3, Trade openness and government policy is included as explanatory variable in the model. Trade openness varies negatively with energy intensity, and it is statistically significant while government policy is not. Economic growth deceases further but its estimates still show a positive relationship with energy intensity. One striking feature is the improvement witnessed in the value of R-square; 75% in FMOLS and

74% in CCR, adjusted R-square; 71% in FMOLS and 70% in CCR, Durbin- Watson; 1.08 in FMOLS and 1.15 in CSR, Long run variance; 0.50 in FMOLS and CCR. This improvement all confirms proper modeling. The study expands further by the inclusion of foreign direct investment. Estimates for economic growth further decreases with positive relationship, industry value added is significant and varies negatively with energy intensity. Trade openness and foreign direct investment are both statistically significant. R-square is; 86% in FMOLS and 84% in CCR, adjusted R-square; 83% in FMOLS and 82% in CCR, Durbin- Watson; 2.15 in FMOLS and 2.33 in CSR and the Long run variance is 0.1 in FMOLS and CCR.
Lastly, energy price is included in Model 5. With the further improvement in diagnostic statistics, model 5 becomes the model of interest. The estimates by the fully modified least squares and canonical cointegrating regression shows that economic growth has a positive relationship with energy intensity. The effect is statistically significant. It reveals that a 1% increase in economic growth leads to 0.6% increase in energy intensity. The canonical cointegration model presents similar result. This result confirms the findings of (Sten 2004), Komen (1997) and Wu (2012). The non- establishment of energy saving role of economic activity in Bahrain means that higher per capita income leads to more and more consumption of energy intensive products like cars, air conditioners, heating system etc. Consequently, drives energy intensity up. This result suggests inefficient consumption of energy in Bahrain.

Industry Value Added (INV)
The effect of industry value-added on energy intensity is negatively and statistically significant. Based on FMOLS, an increase of one percentage point in the industrial base is expected to decrease energy intensity by 0.68%. Also the canonical cointegration regression shows that an increase of of (Poumanyvong and Kaneko, 2010; Su-yun and Zhen-yu, 2010), Adom and Kwakwa (2014) Voigt et al. (2014) who documented a positive relationship between energy intensity and the industrial structure. This result may not reflect a shift to tertiary sector which empirical literature holds, rather it implies an increase efficiency in energy use in our industries. This may be as a result of standardized equipment, switch to clean sources of energy like gas and use of renewable energy. Industry value added is a driver of energy intensity in Bahrain.

Trade openness (TRO)
The effect of trade openness is negative and significant. The baseline regression shows that as trade increase by 1%, energy intensity falls by 0.64% for according to FMOLS and 0.58% for the CCR. This finding confirms the energy saving potential importation has on the Bahrain economy. This result confirms earlier findings by Hubler (2011) and Sbia et al. (2014) and counteracts the report by Adom and Kwakwa, 2014; Su-yun and Zhen-yu 2010), Fisher-Vanden et al. (2004) and (Cole 2006; Zheng et. al 2011). In the Bahrain context, the study confirms trade openness as a source of energy saving.

Government Policy (GOP)
The inclusion of this variable is the thrust of this study. First, it positively related to energy intensity. Second, it is insignificant. Based on the FMOLS, a percent increase in government policy will cause energy intensity to rise by 0.090% while the CCR suggests a 0.167% increase in energy intensity as policies are formulated. This suggests poor design of energy efficiency policies in Bahrain.

Foreign Direct Investment (FDI)
The effect of foreign direct investment on energy intensity is positive and significant in Bahrain. FMOLS predicts a 0.704% increase in energy intensity for a percent increase in foreign direct investment. The positive relation of this variable suggests that the energy saving role of FDI in Bahrain has failed to provide the skills acquisition, labor training, and alternative management practice required to improve the existing knowledge. This result correlates the finding by Eskeland and Harrison (2003) and Cole et al. (2008) but varies Hubler and Keller's (2009).

Energy Price (ENP)
Though both technique (FMOLS and CCR) shows a negative relationship of energy prices with energy intensity in Bahrain, it is not statistically significant. The FMOLS suggest a 0.568% improvement in energy intensity as the price of energy rise, the CCR on the other hand predict 0.44% fall. This result tallies with apriori expectation and further confirms the position by (Birol and Keppler 2000; Vanden and Quan 2002) Greening et al. (1998) (Fisher-Vanden et al. 2004; Kaufmann, 2004; Miketa; 2001; Verbruggen, 2003), Mielnik and Goldemberg (2002) that high energy prices will force the adoption of higher energy efficient technologies. However, that energy price is not significant becomes the concern of this study. The immediate explanation could be because energy price is in control by the Bahrain government neglecting the energy saving role of the market.

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Table 6: Economic Growth and Energy Intensity Nexus

Pairwise Granger Causality Tests

Null Hypothesis:	Obs	F-Statistic	Prob.
DLGDP does not Granger Cause DLENI	32	1.64063	0.2126
DLENI does not Granger Cause DLGDP		0.01376	0.9863

The result by the granger causality test indicates a bi-directional causality between energy intensity and economic growth in the long run. In other words, increased energy use induces economic growth while expansion in economic activities requires increase energy use as an input in production processes. In other words, there is a nexus between the Bahrain economy and energy intensity. This result tallies with the finding by Nnaji et. al (2014)

5.0 Summary, Recommendation and Conclusion

5.1 Summary

This study theoretically confirms a nexus between energy intensity and economic growth in Bahrain. Economic growth is positively linked to energy intensity, indicating Bahrain's status as an energy-intensive country. However, contrary to expectations, growth has not reduced energy intensity due to inefficient energy consumption, including excessive lighting for advertisements, widespread use of incandescent bulbs, and reliance on substandard appliances. These behaviors contribute to the slow improvement in energy efficiency. Industry value-added has a negative and significant effect on energy intensity, suggesting efficient energy use in the industrial, mining, and manufacturing sectors due to standardized equipment, cleaner energy sources, and renewables. Trade openness also negatively impacts energy intensity, as increased trade enhances competition and knowledge transfer, leading to energy savings from imports exceeding consumption from exports.

Foreign direct investment (FDI) is positively correlated with energy intensity, indicating that foreign firms operate inefficiently in Bahrain, drawn by weak regulations and low production costs. This contradicts the expected technique effect, where FDI should improve efficiency.

Finally, energy intensity remains high in Bahrain, though its correlation with policy is weak, implying that energy efficiency policies are either ineffective or lacking.

5.2 Recommendations

The lack of clear policies and legislation on inefficient energy use hinders energy efficiency in Bahrain. It is essential to develop country-specific policies that promote responsible energy consumption. Public and private institutions should implement internal energy policies, and the government should mandate Energy Management Units in organizations.

The importation of secondhand appliances threatens energy efficiency, as many are outdated and inefficient. The government should phase out secondhand imports by imposing high tariffs while lowering tariffs on new, energy-efficient products.

To enhance accountability, the government should tax energy consumption in industries and mandate energy audits, with reports made public. These audits should be conducted by government agencies for transparency.

Energy-efficient building regulations should be enforced, requiring compliance before approval. Medium and large firms should establish Energy Management Units as a registration requirement.

Inefficient lighting should be phased out by banning the importation and production of incandescent bulbs while subsidizing energy-saving bulbs. Awareness campaigns should educate citizens on efficient lighting technologies.

Energy-saving practices should be enforced in residential, public, and private buildings, requiring security lights to be switched off during the day, with penalties for non-compliance. Energy labels must provide clear consumer information, and prepaid meters should replace estimated billing.

Trade policies should ensure imported goods meet energy efficiency standards.

A market-oriented economy will foster energy efficiency. By strengthening policies, regulating trade, and raising awareness, Bahrain can significantly reduce energy waste and promote sustainability.

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5.3 Conclusion

For decades, energy intensity has been improving in many countries of the world. This means that the value created for every unit of energy consumed is high. For Bahrain, the rate of improvement is slower compared to other countries. The study examined gross domestic products, industry value added, trade, government policy, foreign direct investment and energy price. Preliminary analysis shows evidence of long run equilibrium relationships which implies that the variables exhibit a common deterministic trend. The baseline regression showed that economic growth, industry value added, trade openness and foreign direct investment are the four important determinants of energy intensity in Bahrain in the long run. Having establish a nexus between energy intensity and economic growth, the study implored the Fully Modified Ordinary Least Squares (FMOLS) and the Canonical Cointegrating Regression (CCR) technique of analysis to empirically identify the factors that are responsible for trend. Economic growth, industry value added, foreign direct investment and trade openness are significant energy intensity determinants. In view of this, the study proposed gradual phasing out of sub-standard and second hand product from the domestic market, monitoring the activities of foreign firms, designing energy efficiency policies that addresses specific country factors, compelling the citizens to adapt efficient behaviors towards energy consumption and enhancing the effective of energy efficiency agencies at monitoring inflows of goods to meet required specifications as policy options.

5.4 Limitations of Study

The only limitation which was encountered by this study was data availability. This is one fundamental problem of research in developing countries. This consequently restricted the sample size for this study.

Declarations

Ethics approval and consent to participate

N/A

Data availability

N/A

Competing interests

None

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None

Authors' contributions

I. E. K., E.N.E. and N. B. contributed to the research design, data collection, and manuscript writing. I. E. K. and E.N.E. contributed to the data analysis, interpretation of the results, and manuscript revision. E.N.E. provided guidance on the research methodology, supervised the project, and contributed to the manuscript writing and revision.

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