Impact of Nigeria’s industrial sector on level of inefficiency for energy consumption: Fisher Ideal index decomposition analysis

Abdulrasheed Zakari, Jurij Toplak, Missaoui Ibtissim, Vishal Dagar, Muhammad Kamran Khan

ABSTRACT

This paper tries to evaluate the impact of manufacturing-industry sector on the level of inefficient consumption of energy in Nigeria. The Fisher Ideal index decomposition analysis and the VEC model are used for results for the time period from 1991 to 2014. The examined findings indicate that energy efficiency in Nigeria is linked with the per capita income from overall country’s economic growth, emissions of component of CO2, consumption of energy and investment for industrial production. In Nigeria, however, systemic reform indicates negative impact on energy production. Furthermore, for the short span of time interval, all variables have concluded with a negative relation with the production of efficient energy. According to the findings of this paper, economic growth, low carbon emissions, and industrial investment are all essential for Nigeria’s energy efficiency policies to be intensified. As a result, policymakers and the government should take steps to resolve these issues.

1. Introduction

Nigeria’s externality issues are exacerbated by energy consumption and economic development (Onakoya et al., 2013). As a result, understanding how to conserve the resources to boost the macroeconomic indicators is critical for a Nigeria’s economy. Energy demand is complex, meaning it varies over time due to a variety of factors such as increased economic output, expansion of the manufacturing base, productivity improvements, and infrastructure investments (Sineviiciene et al., 2017). Only by using data envelopment analysis (DEA) can these variables be fully understood in terms of energy demand transition (Tajudeen et al., 2018).

While assessing the effectiveness for the determinant of efficient energy, it has been played out, most of the previous studies utilize an accepted intermediary to increase the productivity of energy. In this paper, data envelopment analysis is utilized to reduce the level of inefficient consumption of energy for industrial units and subsequently withdraw the impact of a fundamental change in monetary action. Index decomposition or disintegration offers a solid proportion of level of efficiency for energy consumption that reveals more insight into the attributes and drivers of expanded energy intensity (Liu and Ang, 2007).

Moreover, notwithstanding contrasts in subtleties, a specific cycle, degree, and area in the various deterioration considers, the total energy intensity is driven by energy productivity instead of changes in its base for level of energy production (Mulder, 2015). In spite of the fact that decomposition or disintegration case-studies are as yet significant for understanding the pattern in the energy use, previous studies, particularly in Nigeria, have neglected to give information on the impact of level of efficiency for energy consumption on country’s economic growth. Second, the consequences of the currently available literature for the same are opposing the recommendations of the previous studies.

Due to its replicating impact in the industrial sector, one set of studies described economic growth as a major element of the energy efficiency. These researchers reported that economic growth leads to the highest levels of energy efficiency (Yao et al., 2012; Go et al., 2019; Voigt et al., 2014; and Yemelyanov et al., 2019). Other research used emissions of CO2 as a catalyst of energy efficiency and indicates positive impact on the energy efficiency. Tian, Yang, Zhang, and Liu (2016) found that energy...
efficiency causes low emissions of CO2 in the commercial truck market. Vieira et al. (2018); Khoshrroo et al. (2018); and Tajudeen et al. (2018) indicated that energy efficiency helps to reduce the carbon dioxide emissions.

Renewable energy, on the other side, is the best-identified determinant of energy production, according to Dhakouani et al. (2019); Rey-Hernández et al. (2018); and Akram et al. (2019). This has shown that previous experiments might not have yielded acceptable results as a result of study flaws. Aside from Tajudeen et al. (2018), no research has attempted to discover the exact measurements for the energy efficiency.

Second, previous research on the determinants of energy efficiency has mostly focused on the developed countries of the world i.e. United States, Europe, and Asia, while little attention paid to Nigeria. In light of this, we are inspired to use the Index Decomposition Analysis (IDA) method to investigate the determinants of energy efficiency in Nigeria for the first time. The aim of this study is to examine the impact of economic growth, carbon emissions, energy use, structural change, and industrial investment in Nigeria on the energy efficiency. To find an actual measure of energy efficiency, the paper employs the Fisher Ideal index decomposition technique.

The paper has involved an econometric approach to analyses the relationship among energy efficiency, economic development, carbon emissions, structural change, and industrial investment using the Vector Error Correction (VEC) model. We discover a long-run positive impact of the economic growth, CO2 emissions, industrial investment on the energy efficiency, implying that economic growth, carbon emissions, structural change, and industrial investment are all linked to increased energy efficiency in Nigeria. To put it another way, as the country’s manufacturing capacity grows, so does interest in energy efficiency.

Similarly, growing environmental destruction, that harmful to the humanity's wellbeing and causes environmental degradations, has compelled businesses and individuals to adopt the use of green or clean energy. In the same way, industrial investment in green machines may help to achieve the energy efficiency. However, we discover a long-run negative relationship between structural change and the energy efficiency, implying that structural change in Nigeria is linked to the lower energy efficiency. Indiscriminate systemic change, that is, changes that impair energy quality, usage, and efficiency, could be one significant contributor to this reduction in energy efficiency.

Further investigation reveals a short-run relationship between economic growth, CO2 emissions, economic growth, industrial investment, and energy efficiency, implying that economic growth, CO2 emissions, economic growth, industrial investment, and energy efficiency are all connected in the short term. To look at it another way, population change, CO2 output, economic growth, and industrial investment all work on reducing energy efficiency. Granger causality demonstrates a unidirectional relationship between variables without exhibiting a feedback relationship.

This paper adds to the existing literature in a number of respects. First, by focusing on Nigeria, this study adds to the literature on the impact of energy efficiency on the economic growth, CO2 emissions, energy use, industrial investment, and structural change. The majority of the current studies related to the energy efficiency are dominated by multi-country studies. The government provides and regulates the energy market in Africa, allowing businesses to access and afford the energy. Since the government has the power and incentive to affect the energy efficiency improvement, the energy efficiency climate at the national level is critical. Second, using the Fisher Ideal index decomposition, we provide novel evidence from a prospective data envelopment study.

Section one is the brief introduction and the research GAP; Section two is related to the literature review; Section three explains the analysis methodology; Section four presents the findings of empirical results and Section five contains the discussion and conclusions.

2. Literature review

2.1. Energy efficiency and economic growth

Energy issues have been on the frontline of academic discussions for a decade due to their predictive influence in our day-to-day life, environment and the economy. Hence, researchers have pointed out their interest in that area, particularly on the nexus between energy efficiency and economic growth. For example, Yao et al. (2012) examined the sudden surge in the Chinese economy and its impact on the energy efficiency. The authors concluded that energy efficiency in China divergence is bred-in-the-bone from the transformed Chinese economy constitution. However, the movement of the heavy industries from coastal cities and the cost of transport energy to the consuming coastal towns have caused inefficiency in energy use in China.

On the other hand, energy efficiency helps to push the technology that drives economic growth. In essence, not the procurement of the new technology drives the economic growth, but the improved regulation or the deregulation of the power sector that pave the way for the economic growth (Ayre et al., 2007). Chris and Noel (2017) argue that Canadian energy efficiency improvement has caused a surge in GDP growth rate about 2.0%. This changes the economic structure from capital intensive energy supply to a slightly labor-intensive manufacturing and services provision one.

In any case, Go et al. (2019) utilized the ARDL bound test across the data of time series in nature, which had been spreading over 1971–2013 for Malaysia. That paper found that the level of energy efficiency improves the level of growth of the economy for almost all sectors however fizzle at essential primary, auxiliary (secondary) and tertiary areas of the economy. Then again, proficiency for consumption of energy in industrial or secondary sector shows U-relationship with the growth of the economy, recommending that the productivity of energy will decrease from the start however recapture its force as increment in economic exercises (Pan et al., 2020). The support, Yemelyanov et al. (2019) can be track down that a decrease in flammable gas utilization could expand the level of productivity for the consumption of energy for certain industries as well enterprises with buying power for this type of energy. Voigt, De Cian, Schymura, and Verdolini (2014) gathered information as well as valuable data sets for 40 economies to evaluate the determinant of energy efficiency. These studies find that intensity of energy had been diminishing by around 10 per cent because of the stagnation in new innovation in the research studies of the nations.

In Nigeria, Yusuf (2014) collected data on energy consumption and carbon emission to examine the links to the economy. The author used the VAR model across the data spanning from 1981-2011, the author found that electricity serves as an essential element of the economic growth driver. The granger causality test indicates a two-way direction between electricity consumption and economic growth; while a further the examined result shows that energy use directly influences the increase in emissions of carbon. Olumuyiwa (2012) reported similar results using the ordinary least square method for multiple regressions. Inimically, it shows that the Nigerian economy depends on the petroleum and electricity, while coal and gas have a limited impact on the economy growth of the Nigerian economy. Oyedepo (2012) states that energy efficiency contributes to the economic development, access to energy, creation of jobs, and saved personal income.

2.2. Energy efficiency and CO2 emissions

We reviewed the nexus between the energy efficiency and the carbon emission to clear our perception. For instance, Tian et al. (2016) tested the energy intensity within the commercial truck market in China. The authors found that there is a set of commercial trucks with low emissions and high energy efficiency. Also, low carbon emissions policies are likely to reduce the carbon emissions and regain the energy efficiency (Vieira et al., 2018). Khoshrroo et al. (2018) further stress that maintaining the
energy-saving production through the proper power, size, and farm machinery are likely to improve energy efficiency within the farm and reduce 7% of carbon emissions.

However, Tajudeen et al. (2018) use STSM and LSDVC models to examine the degree to which the energy efficiency reduces or not on the carbon emissions growth. Their findings show that energy efficiency serves as the primary driver that decreases the carbon emission. More so, clean energy consumption is found to reduce the carbon emission, but the impact is insignificant compared to the energy efficiency. Similarly, Hao et al. (2019) used the Logarithmic Mean Divisia Index (LMDI) decomposition method and concludes that end-users of electricity and the fuel used in electricity generation are likely to emit more carbon emissions than the end-use energy efficiency and supply of electricity efficiency, which reduces the growth of carbon emissions. Hu, Li and Zhang (2019) argue that provinces’ carbon emissions are related to GDP growth, but on the contrary, low carbon emissions promote energy efficiency. However, Li et al. (2020a) confirm energy consumption spurs environmental degradation. The consumption of energy and CO₂ emissions may affect one another, and indicates bidirectional relationships.

2.3. Energy efficiency and energy consumption

Energy consumption is increasing because of its predictive value to reduce the carbon emissions and improve energy efficiency. We reviewed some selected literature to determine what researchers reported about the nexus between energy efficiency and energy consumption. For instance, Moezzi (2000) argues that promoting energy efficiency to save energy and reduce the carbon emission is not always obtainable; however, a surge in the economic growth is positively predicted to the impact on energy efficiency. Also, renewable energy sources are likely to maintain the highest power optimization, supporting the energy efficiency action target (Dhakouani et al., 2019). This shows that renewable energy is better off maintaining energy efficiency, reducing the carbon emissions to over 90 quartiles (Akram et al., 2019).

However, Adam & Fuerst (2016) confirmed a decrease in the energy consumption due to the upgrade in the power generating facilities such as cavity wall installations, loft installation and new efficient boilers. Also, energy intensity can be govern by primary effects instead of positive changes (Reddy and Ray, 2010). Furthermore, reducing the energy consumption will help to achieve the maximum energy efficiency level (D’Agostino et al., 2017). Kusumadewi and Limneechookhai (2017) argue that renewable energy sources from biogas have the upper mitigation strength, with an average reduction in carbon dioxide emission at 11.42%. Similarly, Leal Filho et al. (2019) found that building and equipment/machinery are the significant source of renewable energy sources employed by these institutions that are considered the key to energy efficiency.

More or less, there are broad studies are available on the nexus between energy productivity, financial development, CO₂ outflows, energy utilization, modern speculation and primary change in structure. However, the previous studies have neglected the factors such as the structural changes and technological innovation adopted by various industries to strengthen the environment and production capacities. Moreover, early studies did not pay attention to the sectorial economy concerning energy efficiency in Nigeria. Most of the research done in Nigeria only highlights the determinants of energy efficiency in the whole economy. Against this background, we will highlight energy efficiency determinants by employing Fisher Ideal index decomposition, which considers the sectorial energy efficiency, reflecting actual energy efficiency in the economy.

3. Methodology

3.1. Data and sampling

The main objective of this research is to examine the determinants of energy efficiency in Nigeria by using data from 1991 to 2014 with Fisher Ideal Index Decomposition analysis. We collected the balanced time-series data from the World Development Indicators (WDI) following the work of Sineviciene et al. (2017) and Li et al. (2020b). Table 1 provides details and the source of the variables.

3.2. Fisher Ideal index

Previous studies failed to provide the essential interpretation of the energy efficiency, with some defining the energy efficiency as the average energy consumption in a country as a given share of GDP, while some proxy for the energy intensity used the energy efficiency. These assumptions may be misleading and the root cause of the unreliable results and findings so far. Against this background, we adopted the Fisher Ideal index decomposition analysis (Tajudeen et al., 2018) based on the input-output approach.

Inside the analysis of index decomposition approach, the Fisher Ideal list (Fisher, 1921) and Logarithmic Average Divisia Index can give amazing deterioration, consistency in the accumulation and it also, hold the fundamental list of hypotheses with appropriate properties as the time-inversion and proportionality (Tajudeen et al., 2018). Accordingly, this paper follows the designs which was crafted by Tajudeen et al. (2018) to disintegrate or decomposition of the intensity of energy for utilizing the IDA approach, explicitly the ideal file (FIID). In the Fisher Ideal list, we indicate Et as the all-energy utilization; Yt as the absolute utilization, including taxes and subtracting subsidies. WDI

| Variable                        | Symbols | Unit of measurement | Definition                                                                 | Source                        |
|---------------------------------|---------|---------------------|---------------------------------------------------------------------------|-------------------------------|
| Energy efficiency               | EF      | Input-out approach  | Energy efficiency is the estimated energy saving with time as a result of improvement in energy intensity. | Fisher ideal index decomposition analysis |
| Economic growth                 | GDP     | Current US$         | Gross value added by all domestic manufacturers within the boundary, including taxes and subtracting subsidies. | WDI                           |
| CO₂ emissions                   | CO₂     | Metric tons per capita | Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. | WDI                           |
| Energy consumption              | EC      | Fossil fuel energy consumption (% of total) | Fossil fuel comprises coal, oil, petroleum, and natural gas products. | WDI                           |
| Gross fixed capital formation   | FCF     | Current $US$        | Land improvements, machinery, purchase of equipment, industrial and commercial road construction, institutions, buildings, etc. | WDI                           |
| Structural change               | IVA     | In constant price   | Value added of the industrial sectors                                       | WDI                           |

Table 1. Description of variables.
composed as the weighted normal of sectoral energy force, where loads are the yield portion of the areas. As follows:

\[ e_i = \frac{E_i}{Y_i} = \sum_i \left( \frac{E_i}{Y_i} \right) = \sum_i e_i \]

(1)

Eq. (1) shows the absolute energy force is the small amount of the results of the intensity for energy consumption inside a given area \((e_o)\) and the primary changes in the economy \((\sigma_o)\) across different areas. At a point, the energy force record \((I_i)\) by separating the energy in year \(t\) \((e_t)\) from efficient energy usages in a beginning or base year \((e_0)\) as \(I_i = e_i/\sigma_o = \sum_j e_j B_j \sum_j e_j B_j_o\).

Following Dievert (2001), we separate the areas that represent the entirety of the energy use in the economy without cover. Subsequently, financial exercises \((Y_i)\) are measures with area energy power \((\sigma_0)\). Further, we decayed the energy power list \((I_i)\) into an effectiveness record \((D_{iFF})\) and action file \((D_{iACT})\). Henceforth, the efficiency load can be properties for improving the intensity of energy and proficiency change by consistently holding the financial movement, while the action list ascribes energy power to underlying changes in monetary exercises by holding productivity inside an area steady. Mathematically written as:

\[ I_i = e_i = D_{iFF} \times D_{iACT} \]

(2)

To obtain the decomposed intensity index in Eq. (2), we employ Laspeyres and Paasche indexes, which assume the application of a base variable has a fixed weight and last time variable also has a fixed weight, respectively. Mathematically written as follows:

\[ E_t = \sqrt{\text{Laspeyres} \times \text{Paasche} \times 100} \]

(3)

Laspeyres = \[\sum E_i Y_0 \times 100 \]

\[ \sum E_i Y_0 \]

(4)

Paasche = \[\sum E_i Y_t \times 100 \]

\[ \sum E_i Y_t \]

(5)

where \(E_t\) refers to the intensity of energy for a given time frame, \(E_1\) represents the energy consumption at current and base years, respectively, \(Y_1\) means the output at present and the beginning (base) year respectively, then subscribers, it deals with economic factor and periodically changes.

We express the energy efficiency index using Fisher Ideal index (Fisher, 1921) and the Log mean divisia index (Ang, 2004) to overcome the setback observed in energy intensity by decomposition energy intensity as energy efficiency and activity indexes respectively with explained residuals as follows:

\[ EFl = (\text{Laspeyres} \times \text{Paasche})^{1/2} \text{ACI} = (\text{Laspeyres} \times \text{Paasche})^{1/2} \]

(6)

Nonetheless, the intensity for energy consumption has been listed and is indexed as the result of the efficiency for energy usages, which is includes different actions as follows:

\[ E_t = EFl \times \text{ACI} \]

(7)

Using Eq. (7), we estimated energy saving \((\Delta E_s)\) with time due to the progress in intensity of energy. This assessment can be communicated as follows: \(\Delta E_s = E_t - \bar{E}_t\). Therefore, we can estimate the enhancement in consumption of energy with efficient measures in an economy as

\[ EF_t = \Delta E_s = \frac{EFl}{E_t} + \frac{ACI}{E_t} \]

(8)

here \(E_t\) is the real use of energy and \(\bar{E}_t\) is the energy that would have been used if intensity of the real energy use remained at the level of beginning of studied years or the considered base year.

3.3. Unit root test

Testing the stationary with unit root is essential to enable the prediction of the state of the data set; data that are not stationary are associated with biased results; hence we have to check for a unit root test. The paper has applied Dicky-Fuller (1997) augmented Dickey-Fuller test, Phillips and Perron (1988) Phillips-Perron test, standard Dicky-Fuller (1997) ADF as:

\[ \Delta y_t = \alpha y_{t-1} + \sum_{j=1}^{k} \delta_j \Delta y_{t-j} + \epsilon_t \]

(9)

\[ \Delta y_t = \alpha y_{t-1} + \beta_t + \sum_{j=1}^{k} \delta_j \Delta y_{t-j} + \epsilon_t \]

(10)

where \(\Delta y_t\) is the time series, and \(\Delta y_{t-j}\) is the lagged first-difference to accommodate serial correlation among the errors.

3.4. Cointegration test

We apply the cointegration test to ascertain the long span of time for a better equilibrium among the variables. This study maintains the cointegration approach by Johansen (1991, 1995), which considers every one of the factors as internal factors, and it allows two or more relationships. Johansen’s trial of co-reconciliation builds up whether at least three time-arrangement are cointegrated utilizing the standard cointegrating condition:

\[ y_t = A_1 y_{t-1} + \ldots A_p y_{t-p} + \beta X_t + \epsilon_t \]

(11)

here, \(y_t\) is considered as k-vector which is of non-stationary in nature I(1) repressors, \(\beta X_t\) is the vector of deterministic variables, and \(\epsilon_t\) is a residual vector.

3.5. VECM analysis

The vector autoregressive model (VAR) and vector error correction model (VECM) explain the rationale between the economic variables in the conventional econometric procedure. For example, the VAR model (Sim, 1980) is established, so the endogenous variable is the lagged value of the entire endogenous variable in the model. Often time, this is used when testing the dynamic analysis of economic variables.

However, a model called the vector error correction model (VECM) had been developed in which short-run relationships between the variables are analyzed, taking account of the cointegration. Thus, if two variables are cointegrated, a dynamic error correction model is constructed to consider the variables underlying cointegration properties. Pesaran et al. (2020) applied the two-stage technique by principal estimating residuals from the long-run equilibrium relationship model. The second step includes the description of residuals lagged. The equations of the Dynamic Error Correction model are explained as below:

\[ \Delta E_i = \phi_1 + \sum_{k=1}^{m} \theta_{1k} \Delta E_{p_{-k}} + \sum_{k=1}^{m} \theta_{2k} \Delta GDP_{p_{-k}} + \sum_{k=1}^{m} \theta_{3k} \Delta CO2_{p_{-k}} + \sum_{k=1}^{m} \theta_{4k} \Delta IVA_{p_{-k}} + \sum_{k=1}^{m} \theta_{5k} \Delta EC_{p_{-k}} + \sum_{k=1}^{m} \theta_{6k} \Delta FCF_{p_{-k}} + \lambda_{1} ECT_{t-1} + \mu_{1t} \]

(12)

\[ \Delta GDP = \phi_2 + \sum_{k=1}^{m} \theta_{21} \Delta E_{p_{-k}} + \sum_{k=1}^{m} \theta_{22} \Delta GDP_{p_{-k}} + \sum_{k=1}^{m} \theta_{23} \Delta CO2_{p_{-k}} + \sum_{k=1}^{m} \theta_{24} \Delta IVA_{p_{-k}} + \sum_{k=1}^{m} \theta_{25} \Delta EC_{p_{-k}} + \sum_{k=1}^{m} \theta_{26} \Delta FCF_{p_{-k}} + \lambda_{2} ECT_{t-1} + \mu_{2t} \]

(13)
\[ \Delta \text{CO}_2 = \phi_y + \sum_{k=1}^{m} \theta_{318} \Delta \text{EF}_{it-k} + \sum_{k=1}^{m} \theta_{358} \Delta \text{GDP}_{it-k} + \sum_{k=1}^{m} \theta_{538} \Delta \text{CO}_2_{it-k} + \mu_{30} \]

\[ \Delta \text{IVA} = \phi_y + \sum_{k=1}^{m} \theta_{418} \Delta \text{EF}_{it-k} + \sum_{k=1}^{m} \theta_{438} \Delta \text{GDP}_{it-k} + \sum_{k=1}^{m} \theta_{638} \Delta \text{CO}_2_{it-k} + \mu_{40} \]

\[ \Delta \text{EC} = \phi_y + \sum_{k=1}^{m} \theta_{518} \Delta \text{EF}_{it-k} + \sum_{k=1}^{m} \theta_{538} \Delta \text{GDP}_{it-k} + \sum_{k=1}^{m} \theta_{738} \Delta \text{CO}_2_{it-k} + \mu_{50} \]

\[ \Delta \text{FCF} = \phi_y + \sum_{k=1}^{m} \theta_{618} \Delta \text{EF}_{it-k} + \sum_{k=1}^{m} \theta_{638} \Delta \text{GDP}_{it-k} + \sum_{k=1}^{m} \theta_{838} \Delta \text{CO}_2_{it-k} + \mu_{60} \]

where \( \Delta \) is an administrator for difference; \( k \) is ideal slack length, \( \mu \) is considered as error term which is accepted not to associate with zero methods, \( \phi \) addresses steady of the individual impact, and ECT addresses the error rectification or correction term resultant from the since quite a while ago run cointegrating condition.

4. Empirical results

4.1. Econometric analysis

Table 2 presents the consequences of ADF and PP tests for the factors at their level qualities. The ADF and PP unit root test results show that each factor are not fixed in their level qualities, even at a degree of significance of 5\%, proposing the elective theory that expresses an arrangement of variables which have a value for unit root. Notwithstanding, the test outcomes demonstrate that each of the factors are fixed in their first lag differences have been estimated at a significant level of 1\% with a certain level of degree of freedom, as demonstrated in Table 3. This recommends that the acknowledgment of the invalid theory expresses that there is no unit root in the pre-owned factors i.e., the pre-owned arrangement is fixed from the initial distinction. The aftereffects of the tests suggest that the factors are incorporated into the main contrast. As per Eagle and Granger (1987), all factors should be coordinated in a similar request to direct a co-integration investigation. Thus, this gives us space for a co-integration test.

We test for optimal lags to be included in Johansen tests, and the results are reported in Table 4. From the results, three (3) of the criteria (FPE, HQ, and AIC) favor the inclusion of two lags in the co-integration regression, while two (2) (LR and SC) out of five of them suggest one lag. Therefore, two lags have been included for the co-integration regression since most of the criteria suggested the inclusion of two lags.

The Johansen test show results for the number of co-integrating ranks presented in Tables 5 and 6. The results in Table 5 shows the trace statistic co-integrating ranks, and the results show that the rejection of the null hypothesis, the examined result states that there is no co-integrating vector since out of five (5) panels, four (4) panels confirm co-integration vector at a 1\% and 5\% level of significance respectively. Similarly, our results in Table 6 show the Maximum Eigenvalue co-integration ranks. The results show that the rejection of the null hypothesis, which states there is no co-integrating vector since out of five (5) panels, four (4) panels confirm co-integration vector at a 1\% and 5\% level of significance, respectively. The overall findings reveal that the variables, EF, GDP, CO2, IVA, EC, and FCF, are co-integrated. Thus, all the factors have since quite a while ago moves upward simultaneously from 1991 to 2014. Therefore, we run for VEC regression to get the normalized co-integrating coefficients.

The result of normalized co-integrating coefficients is reported in Table 7. The result of the normalized co-integrating coefficients is shown below:

\[ \text{EF} = 4.9409 + 0.2477 \text{GDP} + 0.1259 \text{CO}_2 - 0.6978 \text{IVA} + 0.0029 \text{FCF} + 0.7643 \text{EC} \]

The above equation shows a significant for a longer time span with positive relationship between GDP, CO2, EC, and FCF and energy.

| Variable | ADF | PP |
|----------|-----|----|
| Level    | t-statistic | Prob | Level | t-statistic | Prob |
| EF       | 1.2629 | 0.9975 | 1.0464 | 0.9956 |
| GDP      | -1.3797 | 0.5741 | 0.8788 | 0.9932 |
| CO2      | -1.3797 | 0.5741 | -1.3797 | 0.5741 |
| IVA      | -2.5797 | 0.1114 | -2.5797 | 0.1114 |
| EI       | 0.4052 | 0.9782 | -0.9791 | 0.7430 |
| FCF      | -0.4721 | 0.8785 | -3.2449 | 0.0301 |

Note: * and ** indicate levels of significance at 10\%, 5\% and 1\% respectively.
efficiency in Nigeria, suggesting that economic growth, CO2 emissions, energy consumption, and industrial investment are associated with improved energy efficiency. This is expected because increasing economic growth means more production of goods and services, resulting in less energy consumed to attain a high productivity level. This is consistent with the work of Yao et al. (2012), who explained that economic growth positively affects energy efficiency but contradicts Yao et al. (2012) find a reduction in consumption of natural gas to improve efficient use of energy.

However, structural change (IVA) has a significant long-run negative relationship with energy efficiency. The negative sign of the IVA coefficient (0.6978) and t ratio of 0.1229 indicates that structural changes are associated with reduced energy efficiency. This is maybe caused by neglecting the energy source of the firms in the structure. One will expect firms that do not employ the latest energy generating sets to fail in attaining energy efficiency. This study contradicts with the results of Farla and Blok (2008), who found a positive relationship between structural change and energy efficiency.

The VAR model outcomes are introduced in Table 8; the outcomes show that there is a short-run connection between the reliant variable, EF, and free factors containing the GDP, CO2, EC, IVA, and FCF, suggesting that GDP, CO2, EC, IVA, and FCF are associated with downturn of energy efficiency; one possible reason for the adverse effects on the energy efficiency for a short span of time frame. Energy efficiency is a long-term project; hence, economic growth, low CO2 emissions, energy consumption, structural change, and industrial investment exhibit negative effects in the short run. This is inconsistent with the work of Dhakouni et al. (2019), who confirm the positive relationship between economic growth and energy efficiency.

Further, we test for robustness, and the results are shown in Table 9. The results show that the VEC model is fitted since the R-square value is more significant than 0.5, AIC, and S.C. measures esteem generally a very little, showing that model assessment is sensible. The zero normal lines address a steady and long-haul balance esteem generally a very little, showing that model assessment is sensible.
In the granger causality test, this paper observes that the relationship between the selected variables become causal. For instance, variable A can be said to be Granger cause B variable regarding A and B past value. This paper additionally tracks down the unidirectional causality from energy efficiency to energy utilization, energy utilization to mechanical venture.

5. Conclusions remarks

It is beneficial to the environment and to the individual's wallet to use less energy by opting for the efficiency steps. The process of reducing over energy consumption makes complex activities necessary to apply in terms of objectives like achieving a higher level of energy efficiency, which is beneficial to the environment. It has the potential to minimize environmental degradation i.e. air and water pollution caused by some forms of energy generation while also avoiding negative consequences for sensitive habitats, such as the impediments that a new hydroelectric dam could pose to migrating salmon. In addition, it helps to relieve strain on the power grid. This research paper uses a VECM structure and Granger causality to examine the determinants of energy efficiency in Nigeria.

The determinants of energy efficiency differ, implying that only a few factors influence Nigeria's energy efficiency. For example, we discovered in Nigeria, economic growth, low CO2 emissions, energy consumption, and industrial investment are all likely to boost energy efficiency. Structure transition, other side it has a negative or negligible impact on the energy production. To put it another way, the systemic reform lowers Nigeria's energy production.

Furthermore, we discovered that in the short run, economic growth, CO2 pollution, energy demand, industrial investment, and structural change degrade the energy efficiency.

5.1. Policy recommendations

First, the results indicate that economic growth has a positive impact on the energy efficiency, implying that the economic growth attracts energy efficiency in Nigeria. To keep Nigeria's energy consumption low while maintaining high efficiency, the government and policymakers prioritize the economic growth by lowering interest rates, rising real wages, increasing export devaluation, and increasing wealth. This would undoubtedly lead to a rise in consumer spending and investment, pushing the economy forward.

Second, we discovered that increasing energy consumption would result in increased energy efficiency. The advancement of the modern technologies may be one explanation for this increased energy production. Productivity would most likely be aided by the introduction of new technologies, such as steam power and telegrams. More recently, it has been found that technological advances such as the Internet, artificial intelligence, and computers improve efficiency. As a result, lawmakers and the government should implement policies that promote research and development. Offering grants and support for technology-based research both at home and abroad is one way to accomplish this.

Third, increased industrial investment boosts energy efficiency. As a result, the government should assist industries and businesses in increasing their output capacities. Industries and businesses will increase their production capacities with government loans and tax breaks, which is likely to boost energy efficiency.

We recognize that our sample size appears to be limited, but given the lack of data at the sector level, this is not a major limitation. We believe our current sample size is sufficient to provide insight into Nigeria's energy efficiency situation. Future research may draw on a wealth of data accumulated over time to strengthen the nexus.

Declinations

Author contribution statement

Abdurasheed Zakari: Conceived and designed the experiments; Performed the experiments; Wrote the paper.
Jurij Toplak: Performed the experiments; Wrote the paper.
Missaoui: Contributed reagents, materials, analysis tools or data.

Table 10. Granger causality test results.

| Dependent variable: E.F. | Variable | F-statistic | Prob. |
|--------------------------|----------|-------------|-------|
| GDP                      | 0.87050  | 0.3619      | Refuse|
| CO2                      | 0.14710  | 0.7054      | Refuse|
| IVA                      | 0.22608  | 0.6396      | Refuse|
| EC                       | 8.15208  | 0.0098***   | Accepted|
| FCF                      | 9.52603  | 0.0058***   | Accepted|

| Dependent variable: GDP  | Variable | F-statistic | Prob. |
|--------------------------|----------|-------------|-------|
| EF                       | 7.53169  | 0.0125**    | Accepted|
| GDP                      | 10.4113  | 0.0042***   | Accepted|
| IVA                      | 1.58999  | 0.2218      | Refuse|
| EC                       | 2.14245  | 0.1588*     | Accepted|
| FCF                      | 9.43178  | 0.0060***   | Accepted|

| Dependent variable: G.D.P | Variable | F-statistic | Prob. |
|---------------------------|----------|-------------|-------|
| EF                        | 9.70702  | 0.0054***   | Accepted|
| GDP                       | 10.4113  | 0.0042***   | Accepted|
| IVA                       | 1.58999  | 0.2218      | Refuse|
| EC                        | 2.14245  | 0.1588*     | Accepted|
| FCF                       | 9.43178  | 0.0060***   | Accepted|

Note: *, **, and *** indicate levels of significance at 10%, 5% and 1% respectively.
Vishal Dagar: Analyzed and interpreted the data. 
Muhammad Kamran Khan: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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The authors declare no conflict of interest.

Additional information
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