JOURNAL OF BUSINESS AND SOCIAL SCIENCES
Vol.2024:05

Oil Price and Energy Intensity Dynamics in Nigeria: Does Technical Change Matter?

Olusegun Felix Ayadi[1], Johnnie Williams[2], Babatunde Olufemi Oke[3]

[1,2]Texas Southern University, Houston, USA
[3]University of Lagos, Lagos, Nigeria

***Email:** Olusegun.ayadi@tsu.edu[1], Johnnie.williams@tsu.edu[2], boke@unilag.edu.ng[3]

Abstract

It is critical to understand the mechanism needed to control energy intensity especially in an oil-exporting country like Nigeria, because of its consequential effect on carbon dioxide emissions and environmental pollution. Increases in energy prices can lead to promotion of better technology and consequently, a reduction in energy intensity through a reduction in energy demand (consumption). This paper explores the dynamics between energy price and energy intensity to reveal the role of technical change in the equation. The study utilizes an autoregressive distributed lag (ARDL) and Toda-Yamamoto approaches. The study sample covers the period 1980 through 2021. The key contribution of this study to the literature is rooted in an understanding of the dynamics of energy intensity and its interplay with technical change in a country study as a critical piece of information for policymakers. The results indicate a change in oil price significantly affects technical innovation. However, there is no link between technical innovation and energy intensity. The plausible justification for the results is the enormity of oil subsidy policy of the Nigerian government.

Keywords

Economic development, Energy consumption**,** Energy efficiency, Sustainable development, Nigeria, Technical change

Introduction

The energy sector is a critical segment of any economy because it is an essential input in economic production. According to Sharma *et al*. (2019), there is a significant link between energy consumption and economic growth. The authors note that since the Industrial Revolution, if an economy grows, the demand for energy also grows and vice versa. As an economy grows, energy consumption tends to increase because in most cases, the economy shifts from labor-intensive

---

Submission: 30 July 2024; **Acceptance:** 27 September 2024

agrarian production system to capital and energy-intensive system (Deichmann *et al*., 2018). Lloyd (2017) sees a contradiction in the sense that an improvement in economic development is associated with an increase in energy consumption. The author notes that energy use is intersected with almost all aspects of development including health, nutrition, education, wealth and life expectancy. The implication is that a desire to achieve economic development conflicts with the goal of reducing energy emission given the dominant position of fossil fuels in the energy portfolio. This assertion is emphasized by Cornillie and Fankhauser (2004) who report that in transition economies, energy intensity is much higher than in industrialized economies.

In 2015, the United Nations developed a series of targets under its 2030 Agenda for Sustainable Development to end poverty while providing a guarantee for prosperity for all people. These targets are collectively referred to as Sustainable Development Goals (SDGs). Some of the critical ones relating to energy use include, SDG 7 (Affordable and clean energy), SDG 9 (Industry, innovation, and infrastructure which contains CO_2 per unit value as an indicator) and SDG 13 (Climate action). According to Amin et al. (2022), and Zakari et al. (2022), the projected surge in energy use will have a significant effect on economic activity, society and the environment. Thus, governments and policymakers around the world should pay attention to clean energy policies. The pursuance of sustainable development is more pronounced today than ever before. Energy is indeed a key component for achieving sustainable development.

McDade (2015) notes that energy is indeed a significant part of the current international debate and acknowledges the existence of divergent views on the subject. Mr. Ban Ki-moon, the former Secretary-General of the United Nations, once remarked: “Energy is the golden thread that connects economic growth, increased social equity and an environment that allows the world to thrive.” Oyedepo (2014), argues that the strategies for sustainable energy development are rested on three technological changes, namely:

(1) Energy savings on the demand side;
(2) Efficiency improvements in the production of energy; and,
(3) The use of renewable energy to replace fossil fuels.

Policymakers are interested in setting energy prices at levels needed to promote higher energy efficiency (Hang and Tu, 2007). Birol and Keppler (2000) note that economic growth can receive a critical boost from energy efficiency. A lower energy intensity is interpreted as a higher level of energy efficiency. To achieve higher energy efficiency, policymakers have two options. The first option is an increase in the price of energy through economic instruments. The second option requires more investment in modern technologies to increase the productivity of each unit of energy.

The United Nations projects the population of Africa and South Asia to rise significantly by 2050 with important repercussions for energy demand and use. The increase in demand for energy is needed to support increased economic activities because of population growth. Given that economic activities consume energy, ways must be designed to reduce energy intensity to ensure that energy resources are efficiently utilized. The result will be a minimization of environmental costs' adverse effects in terms of greenhouse gas emissions. The forecast of energy consumption growth within OECD countries is estimated to be 14 percent, while the rate is 84 percent within non-OECD countries (OECD 2012 and Wolfram et al., 2012).

Voigt et al. (2014) and IEA (2014) report that the issue of energy efficiency improvement driven either by technology or structural change is country specific. Moreover, it neither depends on the initial energy intensity nor the level of economic development. Therefore, this paper's objective is to explore the dynamics between energy price and energy intensity to reveal the role of technical change in the equation. The case of Nigeria presents a unique one because it is a major exporter of crude oil. The energy consumption in Nigeria is made up of petroleum products, hydrocarbon gas liquids, natural gas and coal. The dominant source of commercial energy is crude oil which accounts for over 70 percent of its commercial energy consumption (Chinedu et al., 2019). The key contribution of this study to the literature is rooted in an understanding of the dynamics of energy intensity and its interplay with technical change in a country-study as a critical piece of information for policymakers. There are several studies on the relationship between energy demand and economic growth based on Nigerian data analysis. This study is the first country study of the role of energy price and its interplay with technical change. It is important to explore the potential policy factors required to influence energy intensity by policymakers. The knowledge gained is useful in terms of a decoupling policy between economic output and energy use. More importantly, policymakers will rely on their knowledge in negotiating international agreements on energy use and the environment.

The remainder of this paper is organized as follows: The profile of energy in Nigeria is revealed in the second section. The third section gives an overview of the inter-relationships among energy price, innovation, energy intensity and rebound effects, while the fourth section explores the model framework. In section five, data and study methodology are discussed. Section six focuses on the empirical analysis and discussion of results while the final section contains the paper conclusion.

Nigeria’s Energy Profile

Nigeria is a country that is well-endowed with energy resources comprising of hydrocarbon and renewables. Olabisi (2021) dichotomizes the energy resources in Nigeria into conventional and renewables. Nigeria, a member of the Organization of Petroleum Exporting Countries (OPEC), is one of the largest producers of oil and natural gas in the world. The oil and gas reserves are found in different parts of the country. The discovery of oil in commercial quantities at Oloibiri, in Nigeria’s Niger Delta region occurred in 1956, however, production did not start until 1958. The relative significance of the petroleum sector has overshadowed the other sectors of the economy especially since 2000. The production of oil has been relatively stable over time, especially since 2006. Aenert.com (2022) reports production levels of 2015, 1989, 2020 and 1798 barrels per day for the years 2017, 2018, 2019 and 2020 respectively. Therefore, the significant growth rate experienced in the petroleum sector did not transfer to the industrial sector (Ayadi & Boyd 2006). In 2003, the seventh largest producer of oil and the fifth-largest supplier of crude oil to the US was Nigeria. With over 91 per cent of its export revenue and over 90 per cent of foreign exchange earnings from oil, Nigeria depends heavily on the oil sector. The government revenue from the sector is over 82 per cent (Oyelami, 2018). Aenert.com (2022) report indicates that the main energy resources in Nigeria are oil and gas made up of traditional oil, oil sands, extra heavy oil, natural gas and associated petroleum gas. According to the 2022 OPEC Annual Statistical

Bulletin, the country possesses about 37,050 million barrels of proven crude oil reserves and 5,848 billion cubic meters of proven natural gas reserves.

Coal is another conventional energy resource that is abundant in Nigeria. According to Olabisi (2021), coal was discovered in Nigeria in 1909 and by 1956, a sizable portion of energy generation was based on coal. Aenert.com (2022) reports Nigeria's coal reserves in 2016 at 379 million short tons. The renewable energy resources identified by Olabisi (2021) include biomass, solar, hydro, biogas and geothermal. Even though renewable energy resources exist in abundance in Nigeria, the efforts to utilize them in electricity generation is poor (Oniemola, 2016; Sa'ad, 2010).

Oyelami (2018) reports that because the Nigerian economy is import-dependent, the economy depends largely on oil proceeds to finance its huge imports of consumer and intermediate products. The implication of this is that the supply of and demand for these products are affected by changes in the price of oil.

Energy Price, Innovation, Energy Intensity and Rebound Effects

If energy prices increase, technological innovation is expected to occur and consequently lead to a reduction in energy intensity. In other words, if energy prices rise, innovative technology that will reduce energy demand will be developed and used. This will then lead to a reduction in energy intensity (Tang, 2020). The mechanism may not hold because of the so-called rebound effect. The reduction in the demand for energy may not materialize as expected. According to Bessec and Meritet (2007), an improvement in energy efficiency via technological innovation could reduce the demand for energy. The decrease in energy demand makes energy cheaper. Cheaper energy creates an incentive for increased demand and use. This indeed is the genesis of the rebound effect. Freeman (2018) revisits the rebound effect as a paradox in energy economics, referring to a smaller than expected reduction in energy use in the face of improvements in energy efficiency. In some cases, the net effect is an increase in energy use.

According to Bessec and Meritet (2007), energy intensity can change because of several factors such as:

(a) Structural effect due to the proportion of industries that are energy intensive.
(b) Fuel substitution effect arising from the use of inputs requiring high-quality energy.
(c) Technical effect from a combination of energy/labor and energy/capital substitutions resulting in energy efficiency improvements.

The authors argue that price-driven changes in demand, income-driven changes in demand and autonomous efficiency improvements are possible causes of changes in energy intensity. Literature identifies the difficulty of separating the sources. More importantly, the role played by technology is not clear-cut.

According to Chen *et al*. (2020), the International Energy Agency (IEA) defines energy efficiency in terms of generating increased output with the same level or less of energy input. The initial equation is denoted as:

$$ECEI = \frac{Y}{E} \tag{1}$$

Where, ECEI is the energy consumption efficiency index, Y is the total efficacy produced (such as total output quantity) after energy consumption and E is actual energy input consumption.

$$ECEI = \frac{Y_t - Y_{t-1}}{E_t - E_{t-1}} = \frac{\Delta Y}{\Delta E} = \frac{\frac{Y_t}{E_t}}{\frac{Y_{t-1}}{E_{t-1}}} \tag{2}$$

In view of the symmetry between production and cost, Chen *et al.* (2020) re-expressed ECEI as the inverse of Equation (1) with TC defined as total energy cost of output and EC as energy input cost in Equation (3).

$$ECEI = \frac{EC}{TC} \tag{3}$$

Chen et al. (2020) identified two components of energy efficiency as (a) a comparison between input and out denoted as (ECEI) and (b) a comparison between output for a given level of input or a caparison between input for a given level of output, denoted as (EEEE). EEEE is defined as energy-economic-efficiency-estimate as expressed as:

$$EEEE = \frac{E^*}{E} \tag{4}$$

E* is the target or optimal energy input. However, E* is a subjectively chosen level and this leaves ECEI as a series to be evaluated over time to detect whether or not it is growing. Energy efficiency is often defined as the inverse of energy intensity (Sorrell, 2014). Bessec and Meritet (2007) note that energy efficiency definition considers the specific output as well as the efficiency of the process generating the output.

Model Framework

The research approach in this paper is the theory of production and growth from the point of view of natural scientists and ecological economists as documented in Stern (2004). Romer (1990) defines the stock of ideas within the production function as total factor productivity. Jones (1995, 2002) converts Romer's analysis into a technical progress function and Myro et al. (2008) estimate Jones' specification and conclude that the sources of total factor productivity are fully captured. Colina et al. (2014) also reach the same conclusion as Myro et al. The researchers ascribe a huge role to energy in economic production. Sorrell (2014) notes that within the neoclassical theory of production, energy productivity (efficiency) relies on two sources of improvements, namely, technical change and substitution of energy with other production inputs. The production model is expressed as:

$$Y = f(K, L, E, M, t) \tag{5}$$

Where:
Y = Economic output

K = Capital input
L = Labor input
E = Energy input
M = Materials
t = Current state of technology

Equation (5) shows that output depends primarily on capital and labor and secondarily on intermediate inputs such as energy and materials given a level of technology. According to Sorrell (2014, a dual cost function under standard assumptions, yields the following expression:

$$C = g(P_1K, P_2L, P_3E, P_4M, Y, t) \tag{6}$$

The dual cost function defines the minimum possible cost (C) of producing Y output given P_i as price of each input at the current level of technology (t). The output associated with a given number of inputs increases as technology improves over time. Therefore, the rate of total factor productivity is given by:

$$\varepsilon_{it} = \frac{\partial LnY}{\partial t} \tag{7}$$

Energy efficiency can be re-expressed as:

$$\frac{Y}{E} = \frac{f(K,L,E,M,t)}{E} \tag{8}$$

Thus, energy efficiency is determined by the level of each input, how inputs are measured and aggregated in the face of current state of technology, and the level of output. Sorrell (2014) applies Shephard's Lemma to derive an expression for energy intensity as the inverse of energy efficiency, expressed as (Equation 9):

$$\frac{\partial C}{\partial P_E} = \frac{E}{Y} \tag{9}$$

P_E is the price of energy. The author argues that energy price increases lead to a substitution of other inputs for energy. The substitution results in an improvement in energy productivity. However, the effect is a reduction in output. On the other hand, only a technical change is needed to improve energy productivity without a reduction in output. Sorrell (2014) reports that the technical change is captured by total factor productivity (TFP). Gamtessa (2014) reports that TFP captures technical efficiency changes, technical changes and factors accounting for the effect of input growth.

Data and Methodology

The data employed in this study are annual time series of the Nigerian light crude, Forcados oil price series, energy consumption, gross domestic product (GDP), and total factor productivity (TFP) spanning 1980 through 2021. The time series data are collected from the World Development Indicators database, CEIC Data, and the Central Bank of Nigeria. The energy intensity indicator is defined as the ratio energy consumption to GDP. A higher ratio reflects a greater amount of energy used to generate a unit of GDP and a lower ratio reflects energy efficiency.

In Equation (10), Y_1 represents oil price, Y_2 is total factor productivity and Y_3 is energy intensity. The autoregressive distributed lag (ARDL) bounds cointegration and Toda-Yamamoto causality approaches are employed in this analysis. The VAR model employed is of the form:

$$[Y_{1t}\ Y_{2t}\ Y_{3t}\ ] = [\partial_{10}\ \partial_{20}\ \partial_{30}\ ] + \\ \sum_{i=1}^{k} \square\, [\partial_{11,i}\ \dots\ \partial_{13,i}\ \partial_{21,i}\ \cdots\ \partial_{23,i}\ \partial_{31,i}\ \dots\ \partial_{33,i}\ ][Y_{1,t-i}\ Y_{2,t-i}\ Y_{3,t-i}\ ] + \\ \sum_{j=1}^{dmax} \square\, [\partial_{11,k+j}\ \dots\ \partial_{13,k+j}\ \partial_{21,k+j}\ \cdots\ \partial_{23,k+j}\ \partial_{31,k+j}\ \dots\ \partial_{33,k+j}\ ][Y_{1,t-k-j}\ Y_{2,t-k-j}\ Y_{3,t-ik-j}\ ] + \\ [e_1\ e_2\ e_3\ ]\ (10)$$

The ARDL method is judged to be more reliable for small samples as compared to other methods. It involves a simultaneous estimation of short-run and long-run effects and the ability to test hypotheses on the estimated coefficients (Pesaran *et al*., 2001). According to Rahman and Kashem (2017), the interpretation of the ARDL test and its implementation is straightforward. The first step in ARDL estimation is to examine the stationarity of the variables. Next, the VAR model is estimated given that an appropriate lag is chosen that removes autocorrelation and makes the residual to become normally distributed. Then, the existence of a long-run relationship among the variables is explored using the ARDL bounds test and the dynamics (short-run and long-run) of the model are investigated. If the system exhibits a long-run relationship, one process is to examine the error correction mechanism, otherwise, the ARDL model is employed for research interpretation.

Three variables are tested within the causality model. The three time series variables are oil price (Y_{1t}), total factor productivity (Y_{2t}), and energy intensity (Y_{3t}). For example, oil price Granger-causes total factor productivity if total factor productivity can be better predicted using past data on oil price and total factor productivity rather than past data on total factor productivity only. Within the VAR model specified in Equation10, the null hypothesis that causality runs from Y_{1t} to Y_{2t} means a test of $\partial_{21,1} = \partial_{21,2} = \partial_{21,3} = 0$. The same logic can be applied to testing causality among all other variables within the model.

The Toda-Yamamoto methodology involves three steps. The first step requires the determination of the maximum order of variable integration, denoted as d_{max}. This variable can be found by undertaking a stationarity test on all the variables in the model. The unit root of the variable with the highest integration is denoted as d_{max}. The next step involves the determination of an optimal lag (k) for a vector autoregressive (VAR(k)) estimation of the variables that is specified in levels. In this case, the Akaike information criterion (AIC) and/or the Schwarz information criterion (SIC) is employed. The last step involves the application of the Modified Wald procedure to test for causality using a VAR($k + d_{max}$). The usual robustness checks are performed on the chosen VAR model. A rejection of the null hypothesis means the causality exists.

Empirical Results and Discussion

The summary statistics of the sample data are presented in Table 1. The most significant characteristic of the data is the probability distribution. The Jarque-Bera test indicates that energy intensity and oil prices are not distributed normally. However, the probability distribution of TFP is the closest to normal of the three variables.

Table 1: Data Summary Statistics

Statistic	Intensity	Oil Price	TFP
Mean	2.98E-09	44.07550	0.804870
Median	2.66E-09	29.10000	0.764850
Maximum	9.79E-09	114.2100	1.092105
Minimum	6.10E-10	12.62000	0.622001
Std. Dev.	2.22E-09	31.04652	0.148726
Skewness	0.939976	1.051351	0.566388
Kurtosis	3.482143	2.886893	1.914065
Jarque-Bera (JB)	6.277796	7.390254	4.104058
JB Probability	0.043331	0.024844	0.128474
Observations	42	42	42

The first step is the implementation of unit root test on the variables. Three versions (models) of the Philip-Perron tests are employed. The first model does not include intercept and trend, while the second only includes intercept. The last model includes both intercept and trend. The results are reported in Table 2.

The results reported in Table 2 indicate that the three variables, energy intensity, oil price, and total factor productivity, possess unit roots. To make the three variables stationary, one must convert them by differencing them once. An ARDL(2,0,5) model is then setup based on an optimal lag and with no serial correlation in the residuals. The lag length chosen is based on Akaike information criterion (AIC).

The ARDL(2,0,5) that is employed is stable. The figures of CUSUM and CUSSUM of squares show that the modeled process stays within the 5 percent significance range. Both the CUSUM and CUSUM of squares test indicate the dynamic stability of the ARDL model.

Table 2: Philip-Perron Unit Root Test Results

Variable	Model	PP t-Statistic	Probability	Remarks
Intensity	A	-0.8962	0.3217	Unit Root Present
	B	-1.1458	0.6877	Unit Root Present
	C	-1.7800	0.6951	Unit Root Present
1st Diff Intensity	A	-6.9487	0.0000*	Stationary
	B	-6.8520	0.0000*	Stationary
	C	-7.0265	0.0000*	Stationary
Oil Price	A	-0.5089	0.4895	Unit Root Present
	B	-1.3290	0.6064	Unit Root Present
	C	-2.2119	0.4957	Unit Root Present
1st Diff Oil Price	A	-5.6948	0.0000*	Stationary
	B	-5.6262	0.0000*	Stationary
	C	-5.5460	0.0003*	Stationary
TFP	A	0.4100	0.7968	Unit Root Present
	B	-0.6774	0.8407	Unit Root Present
	C	-2.5538	0.3023	Unit Root Present
1st Diff TFP	A	-3.4300	0.0011*	Stationary
	B	-3.4234	0.0162**	Stationary
	C	-3.3325	0.0764***	Stationary

Notes: Model A does not include intercept and trend. Model B includes only intercept. Model C includes both intercept and trend. H_0: Series possess unit root. H_1: Series is stationary.
* Refers to statistical significance at 1percent level, ** at 5 percent level, and *** at 10 percent level.

Table 3: Serial Correlation Test

Breusch-Godfrey Serial Correlation LM Test:			
Null hypothesis: No serial correlation at up to 5 lags			
F-statistic	0.823974	Prob. F(5,20)	0.5473
Obs*R-squared	5.978283	Prob. Chi-Square (5)	0.3083

Table 3 shows that the chosen ARDL(2,0,5) model is also free of serial correlation because the null hypothesis of the Breusch-Godfrey no serial correlation test is not rejected at the usual conventional statistical significance levels.

The results reported in Table 4 show the short-term dynamics of the optimal ARDL model. Energy intensity is affected by its own one-period lag and the two-period, three-period and four-period lags of total factor productivity. These results are statistically significant at the conventional ten percent level. If the one-period lagged value of total factor productivity is increased by 1 percent, energy intensity will rise by 0.0000000185 percent in the short-run. However, while the relationship between the one-period lagged and three-period lagged total factor productivity and energy intensity is positive, the inverse is the case with two-period and four-period lagged total factor productivity.

Table 4: ARDL (2, 0, 5) Model Results - Short Run Dynamics

Dependent Variable: **INTENSITY**				
Selected Model: **ARDL (2, 0, 5)**				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
INTENSITY(-1)	1.047236	0.195349	5.360832	0.0000
INTENSITY(-2)	-0.243000	0.179434	-1.354263	0.1878
OIL PRICE	-8.25E-12	9.46E-12	-0.871658	0.3917
TFP	-8.77E-09	7.20E-09	-1.218368	0.2345
TFP(-1)	1.85E-08	1.01E-08	1.837712	0.0780
TFP(-2)	-2.22E-08	9.74E-09	-2.280686	0.0314
TFP(-3)	2.80E-08	1.01E-08	2.774811	0.0103
TFP(-4)	-2.45E-08	1.03E-08	-2.372666	0.0257
TFP(-5)	8.45E-09	6.43E-09	1.314336	0.2007
C	1.37E-09	2.09E-09	0.654979	0.5185
R-squared	0.904649	Akaike info criterion		-38.72345
Adj. R-squared	0.870323	Schwarz criterion		-38.27906
		Hannan-Quinn criterion		-38.57005

Table 5 shows the long-run relationship among the variables. The F-statistic is lower than the lower critical value at all levels of significance. This is an indication that there is no long-run equilibrium relationship among the variables. With a probability of 0.3977, the results show that there is no long-run relationship between energy intensity and oil price. Moreover, with a probability of 0.8206, there is no long-run relationship between energy intensity and total factor productivity.

The results reported in Table 6 show that the null hypothesis that oil price does not granger-cause total factor productivity is rejected at the statistical significance level of 5 percent. This means oil price is a significant explanatory variable for total factor productivity. In other words, increases in oil prices lead to improvement in technical innovation. However, the improvement in technical innovation does not affect energy intensity.

Table 5: Results of ARDL Long Run F-Bounds Test

Dependent Variable: D(INTENSITY)				
Selected Model: ARDL(2, 0, 5)				
Case 2: Restricted Constant and No Trend		**Sample: 1980 - 2021**		
Levels Equation: Case 2: Restricted Constant and No Trend				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
OIL PRICE	-4.21E-11	4.90E-11	-0.860564	0.3977

TFP	-2.50E-09	1.09E-08	-0.229222	0.8206
C	7.00E-09	7.31E-09	0.956701	0.3479
F-Bounds Test		**Null Hypothesis: No levels relationship**		
Test Statistic	**Value**	**Signif.**	**I(0)**	**I(1)**
Asymptotic: =1000				
F-statistic	0.674858	10%	2.63	3.35
k	2	5%	3.1	3.87
		2.5%	3.55	4.38
		1%	4.13	5

Table 6: Toda-Yamamoto Causality (modified Wald) Test Results

Null Hypothesis	Chi-Square	Probability	Remarks
OIL PRICE does not granger-cause INTENSITY	1.040963	0.3076	Cannot Reject Null
TFP does not granger-cause INTENSITY	0.413654	0.5201	Cannot Reject Null
INTENSITY does not granger-cause OIL PRICE	0.578773	0.4468	Cannot Reject Null
TFP does not granger-cause OIL PRICE	0.186190	0.6661	Cannot Reject Null
INTENSITY does not granger-cause TFP	0.745175	0.3880	Cannot Reject Null
OIL PRICE does not granger-cause TFP	6.597225	0.0102	Reject Null
OIL PRICE and TFP do not granger-cause INTENSITY	1.244945	0.5366	Cannot Reject Null
INTENSITY and TFP do not granger-cause OIL PRICE	0.872432	0.6465	Cannot Reject Null

Conclusion and Policy Recommendations

The United Nations has identified energy efficiency as one of the cardinal pillars of its Sustainable Development Goals. However, de la Rue du Can et al. (2022) observe that only a handful of African countries have indeed implemented the required energy efficiency standards labeling (EESL). Understanding the mechanism needed to control energy intensity, especially in an oil-exporting country, is critical because of its consequential effect on carbon dioxide emissions and environmental pollution. Increases in energy prices can lead to the promotion of better technology and, consequently, a reduction in energy intensity through a reduction in energy demand (consumption). The rebound effect with the manifestation of a less-than-expected reduction in energy demand can neutralize the effect. Therefore, the savings from energy resources recorded due to improved efficiency can be lost through increased energy consumption. The results reported in this study indicate a change in oil price significantly affects technical innovation. A plausible explanation is that increasing oil prices provides additional revenue to an oil-exporting nation to acquire innovative technologies. However, there is no link between technical innovation and energy intensity. In other words, changes in technical innovation do not affect energy consumption changes.

The results reported in this paper are consistent with Gencsu et al. (2022), who report that the Nigerian government has been devoting huge resources to fossil fuel production and consumption. According to the authors, about $1.7 billion was expended on oil consumption subsidies in 2019. In a simulation performed by Rentschler (2016), Nigeria could achieve a 1% reduction in its poverty level if the funds expended in a year are made available to citizens through direct cash transfers. McCulloch et al. (2021) describe the enormity of fuel subsidies in Nigeria. According to the authors, the almost USD 4 billion annual subsidy is double the annual health expenditure. Unfortunately, a significant portion of the oil subsidy goes to the wealthiest Nigerians. The resultant effect of cheaper premium motor spirits (petrol) is increased pollution and environmental damage.

This research effort has provided a policy direction for policymakers in Nigeria. They should pursue an agenda that builds trust in governance. Nigerians should be able to trust the ruling class regarding service delivery. A key policy goal to achieve this is substantial control over corruption. If corruption is tamed, Nigerians will respond positively to subsidy removal and its replacement with an acceptable social benefit program and the pursuit of alternative renewable sources of energy.

Research Data

The data employed in this research are sourced from: World Development Indicators Databank, CEIC Data (Global Economic Data, Indicators, Charts & Forecasts) and Central Bank of Nigeria.

References

Adenikinju, A.F. (1998). Productivity growth and energy consumption in the Nigerian manufacturing sector: A panel data analysis. Energy Policy, 26 (3), 199-205. https://doi.org/10.1016/S0301-4215(97)00098-0

Aenert.com (2022). Energy Industry in Nigeria. May 29, 2022. Schwertgasse 2/14, 1010 Vienna, Austria. www.aenert.com

Amin, S. B., Taghizadeh-Hesary, F., Al Kabir, F., & Khan, F. (2022). Nexus between energy intensity and capital-output ratio: A holistic approach. Energy & Environment, Forthcoming https://doi.org/10.1177/0958305X221115489

Antonietti, R., & Fontini, F. (2019). Does energy price affect energy efficiency? Cross-country panel evidence. Energy Policy, 129, 896-906.https://doi.org/10.1016/j.enpol.2019.02.069

Asafu-Adjaye, J. (2000). The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries, Energy Economics, 22 (6), 615-625.https://doi.org/10.1016/S0140-9883(00)00050-5

Ayadi, O.F., & Boyd, J.L. (2006). The political economy of petrodollars in a mono-product economy. International Energy Journal, 7(3), 227-231.

Bessec, M. & Meritet, S. (2007). The causality link between energy prices, technology and energy intensity, in Keppler, J.H and Girod, J. (eds). The Econometrics of Energy Systems, Palgrave-MacMillan, New York, NY. https://doi.org/10.1057/9780230626317_6

Biesebroeck, J.V. (2007). Robustness of productivity estimates. The Journal of Industrial Economics, 55, No. 3, pp. 529-569.https://doi.org/10.1111/j.1467-6451.2007.00322.x

Birol, F., & Keppler, J.H. (2000). Prices, technology development and the rebound effect. Energy Policy, 28, 457-469.https://doi.org/10.1016/S0301-4215(00)00020-3

Boyd, G.A., & Pang, J.X. (2000). Estimating the linkage between energy efficiency and productivity. Energy Policy, 28 (5), 289-296.https://doi.org/10.1016/S0301-4215(00)00016-1

Cantore, N., Calı, M. & te Velde, D.W. (2016). Does energy efficiency improve technological change and economic growth in developing countries? Energy Policy, 92, 279-285. https://doi.org/10.1016/j.enpol.2016.01.040

Chinedu, U. A., Daniel, O. C., & Ezekwe, U. C. (2019). Impact of energy consumption on economic growth in Nigeria: An approach of time series econometric model. International Journal of Academic Research in Economics and Management and Sciences, 8(2), 65-77.

Colino, A., Benito-Osorio, D., & Rueda-Armengot, C. (2014). Entrepreneurship culture, total factor productivity growth and technical progress: Patterns of convergence towards the technological frontier. Technological Forecasting and Social Change, 88, 349-359. https://doi.org/10.1016/j.techfore.2013.10.007

Cornillie, J., & Fankhauser, S. (2004). The energy intensity of transition countries. Energy Economics, 26, 283-295. https://doi.org/10.1016/j.eneco.2004.04.015

Damette, O., & Seghir, M. (2013). Energy as a driver of growth in oil exporting countries? Energy Economics, 37, 193-199. https://doi.org/10.1016/j.eneco.2012.12.011

Deichmann, U., Reuter, A., Vollmer, S. and Zhang, F. (2018). Relationship between energy intensity and economic growth: New evidence from a multi-country multi-sector data set. World Bank Policy Research Working Paper No. 8322, Available at https://ssrn.com/abstract=3113873
https://doi.org/10.1596/1813-9450-8322

de la Rue du Can, S., Letschert, V., Agarwal, S., Park, W. Y., & Kaggwa, U. (2022). Energy efficiency improves energy access affordability. Energy for Sustainable Development, 70, 560-568. https://doi.org/10.1016/j.esd.2022.09.003

Farrell, M.J. (1957). The measurement of productive efficiency. Journal of the Royal Statistical Society. Series A (General), 120(3), 253-290. https://doi.org/10.2307/2343100

Freeman, R. (2018). A theory on the future of the rebound effect in a resource-constrained world. Frontiers in Energy Research, 6, Article 81. Doi: 10.3389/fenrg.2018.00081 https://doi.org/10.3389/fenrg.2018.00081

Gamtessa, S. (2014). Technical efficiency and technical change in Canadian manufacturing industries. Economics Research International, 376486, 1-8. https://doi.org/10.1155/2014/376486

Gencsu, I., Walls, G., Picciariello, A., & Alasia, J. (2022). Nigeria's energy transition: Reforming fossil fuel subsidies and other financing opportunities. Working Paper, ODI: London. www.odi.org

Gillingham, K., Newell, R. G., & Palmer, K. (2009). Energy efficiency economics and policy. Annual Review of Resource Economics, 1, 597-620. https://doi.org/10.1146/annurev.resource.102308.124234

Grosskopf, S. (1986). The Role of the Reference Technology in Measuring Productive Efficiency. The Economic Journal, 96(382), 499-513.https://doi.org/10.2307/2233129

Hang, L. and Tu, M. (2007). The impacts of energy prices on energy intensity: Evidence from China. Energy Policy, 35, 2978-2988. https://doi.org/10.1016/j.enpol.2006.10.022

IEA (2014). Energy Efficiency Indicators: Fundamentals on Statistics, OECD/IEA: Paris, France. https://iea.blob.core.windows.net/assets/6862080c-8614-494e-a8aa-52c3c0d4291b/IEA_EnergyEfficiencyIndicatorsFundamentalsonStatistics.pdf

Jayasuriya, R., & Wodon, Q. (2005). Measuring and explaining the impact of productive efficiency on economic development. The World Bank Economic Review, 19(1), 121-140. https://doi.org/10.1093/wber/lhi006

Jimenez, R. & Mercado, J. (2013). Energy intensity: A decomposition and counterfactual exercise for Latin American countries. IDB Working Paper Series No. IDB-WP-441. 2013. Available at: http://www.iadb.org, https://doi.org/10.18235/0011485

Jo, S., Karnizova, L., & Reza, A. (2019). Industry effects of oil price shocks: a re-examination. Energy Economics, 82, 179-190. https://doi.org/10.1016/j.eneco.2018.12.010

Jones, C. I. (1995). R&D Based Models of Economic Growth. Journal of Political Economy, 103, 759-784. https://doi.org/10.1086/262002

Jones, C. I. (2002). Sources of U.S. economic growth in a world of ideas. American Economic Review, 92 (1), 220-239. https://doi.org/10.1257/000282802760015685

Lloyd, P.J. (2017). The role of energy in development. Journal of Energy in Southern Africa, 28(1), 54-62. https://doi.org/10.17159/2413-3051/2017/v28i1a1498

Malik, A. (2019). Dynamics and determinants of energy intensity: Evidence from Pakistan. Journal of Academic Research in Economics, 11, 2, 249-275.

McCulloch, N., Moerenhout, T., & Yang, J. (2021). Fuel subsidy reform and the social contract in Nigeria: A micro-economic analysis. Energy Policy. Sep;156: None. https://doi.org/10.1016/j.enpol.2021.112336

McDade, S. (2015). SDG 7 and sustainable energy development in Latin America and the Caribbean. UN Chronicle, 3, 26-29.

Mirza, F. M., & Fatima, N. (2016). Drivers of energy intensity in Pakistan: An assessment using index decomposition methods. Pakistan Business Review, 17, 781-804.

Mulder, P., de Groot, H. L.F., & Pfeiffer, B. (2014). Dynamics and determinants of energy intensity in the service sector: A cross-country analysis, 1980-2005. Ecological Economics, 100, 1-15. https://doi.org/10.1016/j.ecolecon.2014.01.016

Myro, R., Pérez, P., & Colino, A. (2008). Economic growth in a world of ideas: U.S. and the leading European countries. Applied Economics, 40 (22), 2901-2909. https://doi.org/10.1080/00036840600993957

Nasreen, S. & Anwar, S. (2020). Energy efficiency and the role of financial development, trade openness and technological innovation: Exploring the dynamic linkages for Pakistan. Retrieved from https://www.sciencegate.app/app/document/download/10.21203/rs.3.rs-84180/v1 https://doi.org/10.21203/rs.3.rs-84180/v1

Noah, A., & Ichoku, H. E. (2015). Total factor productivity dynamics in Sub-Saharan Africa: Malmquist index approach. International Business and Management, 10 (3), 54-73.

OECD (2012). OECD Environmental Outlook to 2050, OECD Publishing. https://doi.org/10.1787/9789264122246-en

Olabisi, O. (2021). Forecasting Nigeria's Electricity Demand and Energy Efficiency Potential Under Climate Uncertainty. PhD diss., University of Tennessee, 2021. https://trace.tennessee.edu/utk_graddiss/7012

Oniemola, P.K. (2016). Why should oil rich Nigeria make a law for the promotion of renewable energy in the power sector? Journal of African Law, 60(1), 29-55. https://doi.org/10.1017/S0021855315000212

Osunmuyiwa, O., & Kalfagianni, A. (2017). The oil climax: Can Nigeria's fuel subsidy reforms propel energy transitions? Energy Research & Social Science, 27, 96-105. https://doi.org/10.1016/j.erss.2017.03.003

Ouedraogo, N.S. (2013). Energy consumption and economic growth: Evidence from the economic community of West African States (ECOWAS). Energy Economics, 36, 637-647. https://doi.org/10.1016/j.eneco.2012.11.011

Oyedepo, S.O. (2014). Towards achieving energy for sustainable development in Nigeria. Renewable and Sustainable Energy Reviews, 34, 255-272. https://doi.org/10.1016/j.rser.2014.03.019

Oyelami, L.O. (2018). Effects of oil price movement on Nigerian macroeconomic variables: Evidence from linear, near and nonlinear ARDL modelling. Iran Economic Review, 22(4), 908-933.

Pan, X., Wei, Z., Han, B., & Shahbaz, M. (2021). The heterogenous impacts of interregional green technology spillover on energy intensity in China. Energy Economics, 96, 105-133. https://doi.org/10.1016/j.eneco.2021.105133

Pesaran, M. H., Shin, Y., & Smith, R.J. (2001). Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics, 16, 289-326. https://doi.org/10.1002/jae.616

Rahman, M.M., & Kashem, M.A. (2017). Carbon emissions, energy consumption and industrial growth in Bangladesh: Empirical evidence from ARDL cointegration and Granger causality analysis. Energy Policy, 110, 600-608. https://doi.org/10.1016/j.enpol.2017.09.006

Rentschler, J. (2016). Incidence and impact: The regional variation of poverty effects due to fossil fuel subsidy reform. Energy Policy, 96, 491-503. https://doi.org/10.1016/j.enpol.2016.06.025

Roche, M.Y., Verolme, H., Agbaegbu, C., Binnington, T., Fischedick, M., & Oladipo, E.O. (2020). Achieving sustainable development goals in Nigeria's power sector: Assessment of transition pathways, Climate Policy, 20(7), 846-865. https://doi.org/10.1080/14693062.2019.1661818

Romer, P.M. (1990). Endogenous technological change. Journal of Political Economy, 98(5), 71-102. https://doi.org/10.1086/261725

Sa'ad, S. (2010). Energy consumption and economic growth: Causality relationship for Nigeria. OPEC Energy Review, 34(1), 15-24. https://doi.org/10.1111/j.1753-0237.2010.00173.x

Sadorsky, P. (2013). Do urbanization and industrialization affect energy intensity in developing countries? Energy Economics, 37, 52-59. https://doi.org/10.1016/j.eneco.2013.01.009

Shanker, A. & Stern, D. (2018). Energy intensity, growth and technical change. SSRN Electronic Journal. 10.2139/ssrn.3256574.https://doi.org/10.2139/ssrn.3256574

Saudi, M. H. M., Sinaga, O., Roespinoedji, D., & Ghani, E. K. (2019). The impact of technological innovation on energy intensity: Evidence from Indonesia. International Journal of Energy Economics and Policy, 9(3), 11-17. https://doi.org/10.32479/ijeep.7731

Sengupta, J.K. (1995). Technical Change and Efficiency. In: Dynamics of Data Envelopment Analysis. Springer, Dordrecht. https://doi.org/10.1007/978-94-015-8506-4_3

Sharma, N., Smeets, B., & Tryggestad, C. (2019). The decoupling of GDP and energy growth: A CEO guide. McKinsey Quarterly, April, 1-11.

Sorrell, S. (2014). Energy substitution, technical change, and rebound effects. Energies, 7, 2850-2873. https://doi.org/10.3390/en7052850

Sorrell, S. (2015). Reducing energy demand: A review of issues, challenges and approaches. Renewable and Sustainable Energy Reviews, 47(C), 74-82. https://doi.org/10.1016/j.rser.2015.03.002

Stern, D.I. (2004). Economic growth and energy. Encyclopedia of Energy, 2, 35-51. https://doi.org/10.1016/B0-12-176480-X/00147-9

Stern, D.I. (2010). The Role of Energy in Economic Growth, CCEP working paper 3.10, Centre for Climate Economics & Policy, Crawford School of Economics and Government, The Australian National University, Canberra.

Stern, D. I. (2012). Modeling international trends in energy efficiency. Energy Economics, 34(6), 2200-2208. https://doi.org/10.1016/j.eneco.2012.03.009

Tang, L. (2020). Energy prices and investment in energy efficiency: Evidence from Chinese industry 1997-2004. Asian Pacific Economic Literature, 34(2), 93-105. https://doi.org/10.1111/apel.12301

Toda, H.Y. & Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. Journal of Econometrics, 66, 225-250. https://doi.org/10.1016/0304-4076(94)01616-8

Troster, V., Shahbaz, M. & Uddin, G.S. (2018). Renewable energy, oil prices, and economic activity: A Granger-causality in quantiles analysis, Energy Economics, 70, 440-452. https://doi.org/10.1016/j.eneco.2018.01.029

Tugcu, C.T. & Tiwari, A.K. (2016). Does renewable and/or non-renewable energy consumption matter for total factor productivity (TFP) growth? Evidence from the BRICS. Renewable and Sustainable Energy Reviews, 65, 610-616.

Umeh, A.C., Ochuba, C.D., & Ugwo, C.E. (2019). Impact of energy consumption on economic growth in Nigeria: An approach of time series econometric model. International Journal of Academic Research in Economics and Management Sciences, 8(2), 65-77. https://doi.org/10.6007/IJAREMS/v8-i2/6203

Voigt, S., DeCian, E., Schymura, M., & Verdolini, E. (2014). Energy intensity developments in 40 major economies: Structural change or technology improvement? Energy Economics, $1(1), 47-62. https://doi.org/10.1016/j.eneco.2013.10.015

Wolfram, C., Shelef, O., & Gertler, P. (2012). How will energy demand develop in the developing world? Journal of Economic Perspectives, 26(1), 119-138. https://doi.org/10.1257/jep.26.1.119

Worrell, E., Laitner, J.A., Ruth, M., & Finman, H. (2003). Productivity benefits of industrial energy efficiency measures. Energy, 28(11), 1081-1098.

Zakari, A., Khan, I., Tan, D., Alvarado, R., & Dagar, V. (2022). Energy efficiency and sustainable development goals (SDGs). Energy, 239, 122365. https://doi.org/10.1016/j.energy.2021.122365