THE IMPACT OF TECHNOLOGICAL INNOVATION AND INSTITUTIONAL QUALITY ON THE ENVIRONMENT IN NIGERIA

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ABSTRACT
The study investigated the impact of technological innovation and institutional quality on the environment in Nigeria. The study spanned from 1990 to 2022. The key variables in the study were technological innovation as proxy by technological index, institutional quality as proxy by six governance indicators, and carbon emission as proxy for environment. While the control variables include energy consumption and Gross domestic product. The study first conducted a pre-estimation test using Descriptive statistics and Correlation matrix, and Augmented Dickey Fuller test for stationarity while Ordinary least was used as major estimation techniques since it does not violate classical linear regression assumption. The findings from the preliminary estimation shows that all data series are stationarity at levels. The result form the best linear unbiased estimates indicate that environmentally related technological innovation destructively affects $C0_2$ emissions while energy consumption and economic growth positively impact $C0_2$ emissions. Based on these findings, the government should raise investment in environmental technological innovation so as to improve the quality of institutional environment to achieve sustainable development targets.

Key words: Technological Innovation, Institutional Quality, Environment, Gross Domestic

1.INTRODUCTION
Past decades have witnessed a dramatic surge in the consumption of fossil fuels and other energy sources most especially in developing economies and this becomes imperative in order to achieve economic prosperity (he-man and Islam, 2023; Obobisa *et al*, 2022, Zhang *et al*, 2022).The surge in energy consumption has also increases the pace for greenhouse gas emissions (GHG) as a result of catastrophic variations in weather patterns, including tornadoes, volcanic eruptions and earth quakes. The aftermath of these myriads of problems have significantly affected human welfare, wildlife and ecosystems (Obobisa et al, 2022b).In addition to other greenhouse gas emission; $C0_2$ is considered as a major pollution in operation in both developing and developed nations. Therefore, reducing the pace of $C0_2$emission has been a subject to the discourse among world leaders. The $C0_2$ emission was actually tippled since 1960 due to the continues consumption of solid, liquid and gaseous furls (Ashamed and Saheng, 2021, Chabouni and Saidi 2017). In this regard, innovation in environmental related technology required the development of institutional as an importance factor that can mitigate the adverse effects of $C0_2$ emission on human health and the environment (Khan, 2022, Zhangatal, Ogbeide Osaretin, E.N and Efe,O,M 2022).

The world bank portal 2023, shows the average temperature and rainfall for each month from 1991 to 2020. Nigeria is pretty warm all year round, with an average annual temperature of 27.2°C. The hottest month is April, when it can get up to 30°C, and the coolest months are

December and January, when it drops to 24°C. Nigeria also gets a lot of rain, with an average annual precipitation of 1,162.8 mm. The rainy season lasts from April to October, and the dry season is from November to March. Climate change and environmental sustainability are the most urgent economic challenges of our time. The main cause of climate change and global warming is the emission of greenhouse gases, which trap heat in the atmosphere. Among the greenhouse gases, carbon dioxide (CO2) is the most prevalent and the most studied in the environmental literature. (Adams and Nsiah, 2019 According to the International Energy Agency (IEA, 2021), the world is facing a critical challenge in reducing CO2 emissions and achieving sustainable goals, as the increased use of fossil fuels has caused a sharp rise in greenhouse gas levels. The IEA warns that this trend is incompatible with the Paris Agreement and the global efforts to combat climate change, and urges a rapid shift to clean energy sources and technologies. The IEA also provides guidance and support to governments and stakeholders on how to implement effective policies and strategies for a low-carbon transition. (IEA, 2021).

Also, The UN has established SDGs 7, 8, 9, 12, and 13 to be achieved by 2030. These goals emphasize the importance of low-cost clean energy, sustainable economic growth, technological innovation, sustainable consumption, and production as key strategies to address climate change. (United Nations, 2015). Hence, Many nations worldwide are increasingly concerned about reducing carbon emissions, and they are also motivated by the emergence of green technological innovation, which plays a crucial role in facilitating the transition of the global economic development. (Du *et al*., 2019).

Green technological innovation is a novel form of innovation that seeks to minimize energy use, reduce pollution emissions, enhance environmental quality, and promote a greener economy. This type of innovation can generate new possibilities for sustainable development and environmental protection, as well as improve the competitiveness and efficiency of various sectors and industries..(Wang *et al*., 2021). Green technological innovation is a new way of innovating that reduces energy use, lowers pollution, improves environmental quality, and supports a greener economy. This innovation can create new possibilities for sustainable development and environmental protection, as well as enhance the competitiveness and efficiency of different sectors and industries. Green technological innovation also involves using technology to make green products that decrease environmental pollution and energy use. Green technological innovation can include clean energy production, alternative fuel use, and technologies that are less harmful to the environment than fossil fuels. (Sohag *et al.*, 2021). Furthermore, Green technological innovation is a key factor for the development of renewable energy sources and the improvement of countries' efficiency in using them. Renewable energy sources, such as solar, wind, hydro, and biomass, can reduce greenhouse gas emissions and enhance energy security. Green technological innovation can help overcome the challenges of integrating renewable energy sources into the grid, such as intermittency, storage, and transmission. It can also help create new markets and opportunities for green jobs and economic growth. (Wang *et Sal*., 2020) Some scholars have suggested that green technology and renewable energy can help developing nations reduce their environmental impact and achieve lasting sustainability. (Ben Youssef, Boubaker, and Omri 2018).

Therefore, Green technology can help developing nations lower their carbon footprint and enhance their sustainability. By investing in eco-friendly innovations, they can improve their production and economic performance while protecting the environment.

Besides the development of green technologies, quality institutions may also aid in the promotion of environmental protection measures to reduce CO_2 emissions and improve environmental quality (Teng et al., 2021). Countries are now setting up a robust and effective institutional framework to combat corruption, enhance funds management and improve

environmental conditions. According to Ibrahim (2020) a country's ability to combat environmental pollution is dependent on effective institutions.

However, some researchers concede that developing countries will need more effective institutions to execute policies and implement ambitious solutions to reduce greenhouse gas emissions (Hassan *et al*., 2020; Zhang *et a*l., 2021). Quality institutions are documented to have had more positive than adverse effects, particularly in terms of reducing corruption and crime in developing countries, however, studies on its environmental impact and consequences are limited. Therefore, this study aims to examine the impact of green technological innovation and institutional quality on carbon emissions in African countries.

Despite its vast potential for renewable energy, Africa faces many challenges such as low technology performance, lack of access to energy, weak governance, and climate change impacts. (Salahuddin et al., 2019). Also, there are significant technological innovation gaps, and most African member states are frequently far from technological frontiers. Inventors in Africa are, therefore, inept at patenting their inventions and due to this, they often lose the opportunity to protect their intellectual property and benefit from their creativity. the deficiency of R&D investment, the desired level of innovation is yet to be achieved (Ko et al., 2021). The data imply that African nations neglect the environmental impact of technological innovation and institutional issues. These factors cause more CO2 emissions from energy use, such as burning fossil fuels, in Africa. (Ben Youssef, Boubaker, and Omri2018). Thus, African countries face environmental challenges that may be influenced by institutional and technological factors.

This paper explores how green technological innovation and quality institutions affect CO2 emissions. The study used Ordinary Least Square analysis to study the link between these factors and the environmental performance in Nigeria. It considers how institutional and technological factors may influence the environmental challenges faced by Nigerian

In the light of this background, the study intends to examine the impact to technological innovations and institutional quality on Co2 emissions a proxy for Environment. The rest of the study is structured as follows, following the introductory part is section 2 which covers literature review visa-viz theoretical literature, empirical literature and value addition. Section three of the study is methodology which comprises theoretical framework, model specification and estimation techniques. Section four discusses the results and findings. The last section gives summary, conclusion and policy recommendation.

2. LITERATURE REVIEW

2.1. Theoretical Literature

Historical validation has provided limited empirical evidence on the role of technological innovation and institutional quality on climate change in selected countries in West Africa. iProminent among these studies are (You *et al*; Samuel A.k, Njiforti, P.P, Duru,M.C and Jibril,M.S 2022) Quetta. 2020 among others. They argued that environmental related technology innovation has developed a significant instrument for organization to accomplish market reputation, sustainable development and compliance with international environmental laws and standards. Studies by Fernandez*etal*. 2018: Petro Vic and Tobago etal. (2020); Shabir,

2022 used research and development to measure the level of technological innovation, energy efficiency is also considered as essential indicator for measuring technological innovation. These studies conducted that energy efficiency plays a relatively significant role in product C02 emissions.

Study conducted by Alvarez – Herranz*etal*, 2017, cheng*etal* 2019, Has brain and Alam, 2019, Erdogan *et al.* 2020). They proposed foreign direct investment as a measure of technological innovation. They concluded that technological innovation positively impacts sustainability growth and lowers environmental pollution. Studies conducted by Adebayo*etal* (2023) on the effect of technological innovation on the environment in BRICS countries using panel data estimation. They drew an inference that technological advancement reduces $C0_2$ emissions for selected countries in BRICS. In another study conducted by Usman and Hammar, (2021) in APEC countries using panel data analysis. They demonstrate that technological advancement harm the environment overtime. This result was also confirmed by Acemoglu *et al*, (2012), that while technological innovation encourages economic growth, it can also raise carbon emissions. It is then suggested that government must employ cutting edge technology to encourage infant industry, stressing that technological innovation increases the industrial production levels and destroys the environment. In contrast, (Dumitrescu*etal.* 2021,Shamwil,M, Bala A, Sheu, K.K,Yunusa and Yaro I.M 2023) investigated the association between innovation, carbon emissions and trade openings in African countries and found an inverted U – shaped relationship between innovation and carbon emission.

However, the linkage between institutional quality and environment has been found to be under explored in the literature (Jiang *et al,Oduntan,O,ObisesanA.A nd Ayo,Bello 2022*).A more recent study conducted by Egbetokun *et al.* 2020) proposed that a country's environmental legislation also requires competent institutions to encourage the use of renewable energy and achieve sustainable development. Studies by (Wang *etal.* 2023) investigated the impact of institutional quality, environmental governance and technological innovation on consumption of fossil fuels in the selected European union countries. Their result show that environmental governance and institutional quality reduces the consumption fossil fuels. This result was corroborated by the work of (holder and Seethe, 2021) who concluded that poor institutional quality has a negative impact on C02 emissions in emerging countries. A similar conclusion was also emphasized by (Wawrzniak and Dri, 2020) that better government effectiveness reduces C02 emissions in emerging and developed countries. Obobisa*etal* (2022b) also documented that green technical innovation and institutional quality reduce C02 emissions and supports sustainable developments. Similar study conducted by (Salman *etal.,* 2019) investigated the relationship among institutional quality, economic growth and C02 emissions, in Indonesia, South Korea and Thailand. They observed that extensive role of institutional quality goes a long way in decreasing emissions, and increasing economic growth, Kahn and Rae also corroborated the findings of (Salman *etal* ., 2019) by revealing that institutional reduce C02 emissions. Having reviewed that literature so far, it is therefore imperative to unravel the extent to which technological innovation and institutional quality can reduce C02 emissions.

2.2 Empirical Literature:

Quite a number of studies have been conducted on the link between institutional quality and environment but limited and scanty literature exist between technological innovation, environment and institutional quality. Notable among these studies include Obobisa, Chen *et al* (2021), who investigated the role of technology innovations, institutional quality, and

economic growth on carbon dioxide emission from 2000 to 2018 in 25 selected African countries. The study adopted cross sectional heterogeneity and average mean group tools. Their result indicate that green technology innovations and renewable energy consumption has a negative association with carbon dioxide emission. However, the positive association between institutional quality and economic growth reduces environmental quality.

In another study conducted by Xudong Gao and Mingjun fan (2023) on the role of technological innovation on the environmental sustainability in BRI countries from 2002 to 2019. This study adopted generalized method of moment estimate to the panel data analysis. The result of their study revealed that energy from fossil fuels, economic growth and technological innovation accentuates environmental degradation by increasing carbon dioxide emission. The study also observed that the rule of law and quality of institutions positively affect environment quality. The study suggested an improvement in institutional framework and technological innovation in order to achieve sustainable development. In a related study conducted by Chhabara, Giri*et al* (2023) on the impact of institutional quality and trade openness on carbon dioxide emission from 1991 to 2019 in BRIC countries. The study adopted dynamic correlated effects model. The result revealed that trade cause environmental degradation while institutional quality significantly reduce emission and raise environmental quality.

Similar study conducted by Suk, Suk *et al* (2022), on the impact of renewable energy and technology on carbon dioxide emission in Malaysia. The study employed ARDL model. Their result revealed that the use of renewable energy source lead to lower levels of carbon dioxide emission and as a result the quality of the environment improved. Bilal (2022) conducted an empirical analysis between technology innovation, globalization and carbon dioxide emissions. These regions include South Asia, South East, West Asia, central Europe, the middle East and North Africa. Their result revealed a negative association between carbon dioxide emission and technological innovation in all regions. Abid, Mehmood *et al* (2022) conducted an empirical analysis between carbon dioxide levels technology and energy consumption. The study coverage period was from 1990 to 2019. For g8 countries. The study used fully modified least square. The data was applied to BRICS countries. It was observed that an increase in economic growth led to an increase in carbon dioxide emission.

Leg and Wei (2021) conducted an empirical analysis on the linkage between innovation, economic growth, and carbon dioxide emission from 1987 to 2017. The study employed panel-based econometric model. It was observed that different level of carbon dioxide emission had a variety effect of economic growth for different sub samples.

2.3 Gaps in Literature and Value Addition.

Having reviewed the literature so far, there are conflicting result from the existing studies while some results were positive, others had negative association between technological innovation and environment. (Abid *et al* ,2022, Suk *et a*l, 2022) and host of others. Most of the existing studies concentrate more on panel data analysis thus, neglecting specific study as this study tends to unravel.

3. METHODOLOGY.

3.1Theoretical Framework

Environmental Kuznets Curve.

The underlying theoretical model underlining the relationship between environment, technological innovations and institutional takes its root from Environmental Kuznetscurve as proposed by Simon- Kuznets. (EKC) conjecture seeks to establish an inverted U-shaped nexus between income per capita and environmental degradation. It emphasizes that at early stages of economic growth and development, environmental degradation increases at an increasing rate. Nonetheless, after some threshold of economic developments, the movements tend to reverse at higher levels of economic progress.

Kuznets curve when used to analyses environments income and pollution it is called (EKC). This means that for a society to attain higher level of development, natural resources must be employed because it will have some residual effects on the environment there by achieving prolonged and sustained development with better institutional quality in the process.

As economy develops, pollution grows at a faster rate since priority and attention are devoted to rising and increasing material production output. This leads to insensitivity of the people which makes them more interested in financial gains other than the environment in which they live in. The rapid growth therefore leads to higher use and utilization of natural resources and subsequently higher levels of pollutants which degrades and reduces environmental quality.

3.1.1 Innovation Claudia curve

The theoretical underpinning of this study is innovation Claudia curve which states that if innovations are below the permissible level for enhancing environmental quality, carbon emission will continue to rise, even when there are more patented application and innovation hit its peak. When countries reach their maximum degree of economic development. Environmental Kuznets curve will determine whether economic expansion will continue to increase carbon dioxide. The innovation Claudia and environmental Kuznets curve are related and it is crucial to determine effect of technological innovation and economic growth on the carbon dioxide peak level.

3.2 Data

Since the study intends to unravel the extent to which innovation related technology and institutional quality impact on the environment. It is therefore imperative to identifying some key variables needed for estimation namely dependent and independent variables. The study use carbon emission $C0_2$ as proxy for environmental (Umar *et al.,* 2020) while technological innovation and institutional quality are used as independent variables. The study went further to incorporate some control variables such as economic growth, energy consumption and trade openness. The data were sourced from World Bank Development indicator, 2021, institution quality was used as governance indicator.

3.3ModelSpecification.

Following the work of (Shabir *et al.*, 2021) and (Wang *et al*,. 2023) the model as specifies as follows.

$C0_2$ – fF (TI, IQ, TOP, ECO, GDP).

This implicit equation above can be express in an econometric form as follows:

$CO_2=\beta_0 + \beta_1$ TI+ β_2 IQ+ β_3TOP+ β_4 ECO+ β_5GDP + μ

Where TI represents Technological innovations, Technological index was used to represent technology innovation, TOP represents trade openness, ECO represents energy consumption, GDP represents gross domestic product a proxy for economic growth, and IQ – represents institutional Quality which according to Wang *et al*. (2023) include six governance indicators namely control of corruption (CC), government effectiveness (GE), Political stability (PS), and regulatory quality (RQ). Rule of law (RL) and voice and Accountability (VA). The data were obtained from world development indicators and in the range of – 2.5 to 2.5.

TOP – represents trade openness which could be obtained by the addition of export plus import as a ratio of GDP.EO represents energy consumption – Aggregate energy consumption as a ratio of GDP.GDP – represents Gross domestic product as a proxy for economic growth.

4. RESULT PRESENTATION, ANALYSISAND INTERPRETATION.

This section entails the presentation of results from the data analysis also well as the interpretation of the obtained results on the effects of technological innovation, institutional quality on environment.

The remaining aspects comprise the descriptive statistics unit root result, correlation and ordinary least square regression result.

Table 4.1 Description Statistics.

Variable	C02	TI	IQ	ECO	GDP
Mean	0.057243	0.030695	0.026638	0.001248	0.045129
Median	0.058150	0.039250	0.026450	0.009000	0.038800
Maximum	0.230500	0.153300	0.031100	0.43220	0.097900
Minimum	l-0.055800	-0.131300	0.024400	-0.435700	0.035,000
Std. Dev.	0.60750	0.053224	0.001419	0.145360	0.017653
Skewness	0.628366	-0.842927	1.160923	l-0.434319	2.116536
Kurtosis	3.430486	4.740159	4.700781	6.70l86971	5.l894809
Jarqu-Bera	3.088214	10.27295	14.49634	25.39069	46.02294
Probability	0.213502	0.00587842	0.000711	0.000003	0.000000
Observation	42	42	42	42	42

Source: Authors' Computation (2023) Using E-views (10)

The statistical measure of central tendency, dispersion, skewness, kurtosis and normality test describe the characteristics of the above data. The jarque–Bera (JB) statistics rejected the null hypothesis of normal distribution for all the variables namely Carbon dioxide emission, technological innovation institutional qualities, energy consumption and Gross domestic product are statistically significant at 5% as their JB probability is lesser than 5%, this indicate that cross. sectional variables are normal. According to the probability of the used variable (CO_2, TI, IQ, ECO, GDP) except for $C0_2$ with the probability value of 0.1213502 which is greater than 5% level.

Table 4.1 reveal that the average growth rate within the period was 0.030695 with the maximum of 0.153300 reported in 2012, while the minimum is 0.039250 observed in 2017. Similarly the P-value of all estimates and result which represented the probability of observing a simple value as extreme as the value actually observed given that the null hypothesis is true served as a guide for accepting or rejecting null hypothesis at various stage in the analysis, by comparing it to significance level.

Table 4.2 Correlation Matrix of the Variables.

Variable	$C0_2$	TI	IQ	ECO	GDP
$C0_2$	1.0000	0.3700	0.0415	+0.2046	-0.1313
TI	0.3700	1.0000	0.257	-0.0606	-0.4l848
IQ	0.0415	0.2537	1.0000	l-0.0571	-0.5188
ECO	-0.2046	- 0.06066	-0.0606	-0.0571	1.0000
GDP	-0.1318	-90.4848	-0.5188	0.0360	1.000

Source: Authors' Computation, 2023 Using E-view 10.

Table 4.2 Shows the correlation matrix of variables for detection of possible strong correlation between technology innovation, institutional quality on the environment. From the result, it shows there's a strong and positive relationship between technological innovation and institutional quality on the environment.

It can be inferred that positive association exist between technological innovation and institution quality with technological innovation value of 0.3700 and 0.045 for institutional quality which means that $C0_2$ emission is positively associated with technological innovation and institutional quality in Nigeria. Also, the result shows that there is a positive relationship between $C0_2$ emission and energy consumption and negative relationship with Gross domestic product. This result validates the energy led $C0_2$assumption. This shows that a 1% rise in energy usage will probably enhance carbon emissions by 0.2046 and a decrease of 0.4313 percent in the Gross domestic product in the long run. This outcome is consistent with the previous studies of (Lawson, 2002, Islam *et al,* 2021 and Musha *etal,* 2021).

4.3 STATIONARITY TEST

The study examined the unit root test on the selected variables using the Augmented Dickey Fuller (ADF) and the result of the unit root is presented below:

Table 4.3

Variable	Test Order	Critical Value	P Value	Order of Int.
$C0_2$	Level	-4.145238	0.0033	I(O)
TI	Level	-6-529573	0.0000	I(O)
IQ	Level	-2.630404	0.0122	I(O)
ECO	Level	l-5.128463	0.0001	I(O)
GDP	Level	l-3.750442	0.0320	I(O)

Table 4.3 displays the stationary of the variables used in the study. It can be inferred from the table that all the variables are integrated at levels. This means that there is no long run relationship among the variables, a short run relationship may exist and there is no need for co-integration estimation.

Table 4.4 Ordinary Least Square Result

Dependent Variable: $C0_2$.

Methods: least square.

Variables	Coefficient	Std Error	t-statute	Pro
TI	0.0311679	0.151565	2.056406	0.0468
IQ	-0.073356	0.054395	l-1.348270	0.1857
ECO	-0.1070l57	5.641250	L0.108977	0.9850
GDP	-0.083095	0.ll876187	-0l.0948370	-9,250
C	0.019752	0.198422	0.09905470	.9212

R-Squared	0.178194	Mean dependent view	0.031190
Adjusted R-Square	0.089350	S.D deponent View	0.053475
S.C. Regression	0.051030	Akaike Info Criterion	3.001477
Slum Square resultt	0.096349	Schwarz criterion	-2.794611
Log (Likelihood	68.0101	Hannah – Qulin Crater	2.92565
F – Statistic	2.005700	Durbin – Watson stat	1.219277
Prob (F-statiscs)	0.113856		

Source: Authors' Computation (2023) using E-view 10

Table 4.4 Show the ordinary least square result coefficients, standard error, t-statistics and probability value for all the selected variables. The result of the coefficient show the influence of specified independent variable of technological innovation, institutional quality and gross domestic product on environment in Nigeria. The study observed that a unit change in variable such as technological innovation charge in variable such as technological innovation (0.04468, $P < 0.05$), Renewable energy consumption (0.9850, $P > 0.05$), and institutional quality (1Q), (0.1857, $P > 0.5$) and Gross domestic product (0.9212, $P > 0.05$) will result into an increase in the growth rate in carbon emission in the long run. This implies that all the indicators of

Technological innovation and gross domestic product contributed positively toward the Carbon Dioxide Emission but does not statically significant at 5% level of significance.

Similarly, the coefficient of determination (R- Square) value of 0.3608.38 Indicate that 36.08% of the variation in technological innovation and Gross domestic product attributed to changes in variables such as carbon emission while standard error of the regression value of 0.46029supports the overall fitness.

The results analyzed above is corroboration with the findings of Zoundi (2017); Chiem*eta*l 2021 and Usman *et al* (2020)

Conclusion

The aim of this research was to examine how technological innovation, institutional quality and gross domestic product affect carbon emission in Nigeria using ordinary least square (OLS) and various diagnostic test methods. The unit root test results show that all the variables in the model are level-stationary and the correlation results show that there is a positive relationship between technological innovation, institutional quality and the environment, which means that there is a short-term relationship between carbon emission, technological innovation and gross domestic product. This research investigated the effects of technological innovation, institutional quality and gross domestic product on carbon emission in Nigeria using ordinary least square (OLS) and various diagnostic test methods. The unit root test results indicate that all the variables in the model are level-stationary and the correlation results reveal that there is a positive relationship between technological innovation, institutional quality and the environment, implying that there is a short-term relationship between carbon emission, technological innovation and gross domestic product.

Recommendation:

This study therefore recommends that policy makers in Nigeria should prioritize technology innovation to get renewable energy and discourage the use of fossil fuel. By replacing fossil fuel with technology and renewable energy, it is possible to improve economic growth which will invariably lead to sustainable development and the recommendation corroborate the conclusion of Dauda *et al* (2021) that renewable energy will reduce carbon dioxide emission.

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