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Effect of Public-Private Partnerships Expenditure on Economic Development: A Vector Autoregressive (VAR) Approach

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Abstract
This study examines the effects of Public-Private Partnerships (PPPs) expenditure on road (PERI) and electricity infrastructure (PEEI) on Nigeria's economic growth process, proxy by real gross domestic product (RGDP), from 2000 to 2024. An unrestricted Vector Autoregressive (VAR) and Vector Error Correction (VEC) models were adopted to forecast the short and long run dynamic relationships between the multiple time series variables. The Augmented Dickey Fuller (ADF) unit root test was conducted to determine the stationarity of the series while the Johansen cointegration test was used to determine the long run relationship of the series. The findings show that real gross domestic product was positively related to public-private partnership expenditure on road infrastructure but not statistically significant in explaining changes in public-private partnership expenditure on road infrastructure. Public-private partnership expenditure on electricity infrastructure was positive but not statistically significant in explaining changes in public-private partnership expenditure on road infrastructure. However, real gross domestic product was negative and not statistically significant in explaining changes in public-private partnership expenditure on electricity infrastructure. The study recommended a more holistic, diverse and innovative financing models, digitized project management and regulatory process and strategic plans that embraces communities and stakeholders in order to promote a culture of shared responsibility for infrastructure.

Keywords: *Pblic-Private Partnerships, Road Infrastructure, Electricity Infrastructure, Economic Growth, Vector Autoregressive, Nigeria*

Introduction

The importance of infrastructure to economic growth cannot be overemphasized. This is because infrastructure forms the pillar or backbone of every society and economies, promoting daily life by providing essential services like clean water, education, energy, healthcare, sanitation, internet and transportation (Mienye et al., 2024). Good and sustainable infrastructure investment promote economic growth through increased job creation, efficiency, productivity and reduction in social and economic inequalities by improving access to business opportunities, facilitating the movement of goods and services and supporting supply chains and hence, alleviates poverty (Zeng et al., 2024). Modern and well maintained infrastructure enhances quality of life and safety through well-lit streets and sidewalks, which reduces risk and promotes public safety, which are pre requisite for human wellbeing (Zahnow, 2024). Infrastructure also provides resilience against challenges like natural disasters and climate change, enhancing continuity and enabling sustainable growth and development for every nation (Ma et al., 2023). Furthermore, a robust and viable infrastructure framework puts a country in a better competitive position, attracting both local and foreign investment and fostering innovations which are major drivers of growth and development (Danja & Wang, 2024). Investment in modern and sustainable infrastructure, like constant and affordable power supply, good roads and effective internet services, can potentially reduce the cost of doing business in the country, make cheaper goods and services available and hence reduce inflation, a core macroeconomic objective of every economy (Olabi et al., 2023).

In relation to the importance of infrastructure to the viability of the economy, the Nigerian government participates in infrastructure development through direct budget investment, establishment of regulatory bodies like the Infrastructure Concession Regulatory Commission (ICRC), and the utilizing Public-Private Partnerships (PPPs) to bridge the infrastructure deficits in the country (Kadiri et al., 2015). Through direct budgetary investment, the government finances infrastructure through direct budget spending from the federal, state and local government revenue (Bao et al., 2024). Through regulatory frameworks, like the ICRC, the government ensures that the policies, rules and purpose of the infrastructure development process are achieved and maintained (Azubuike et al., 2023). The government sometimes partners with the private sector to finance and develop infrastructure projects in a bid to addressing the infrastructure deficiency and inequalities which has been a bane to sustainable growth and development in Nigeria (Olujobi et al., 2023). In the same to address the deficit, the government created the Nigeria Infrastructure Fund (NIF), with the aim of attracting local and foreign investments into domestic infrastructure projects across Nigeria, with focus on education; healthcare; power generation, transmission and renewable energy projects,; road construction, expansion, and an Aviation Leasing Company and a National Carrier, through Public-Private Partnerships (PPPs) (Shao et al., 2025).

Private Sector Participation (PSP) in the Nigeria infrastructure development has usually been in PPPs and other models, with significant involvement in energy, education, healthcare, ports, transportation and solid waste management, with the aim of leveraging private sector efficiency and capital for projects completion and quality service delivery (Olukanni & Nwafor, 2019). The national PPPs policy and other supportive legislations that ensure the successful completion of projects faces challenges like political influence, unclear contract terms and regulatory weakness, especially in energy and water (Bagenda & Ndevu, 2024). Another key mechanism of Private Sector Participation (PSP) other than PPPs is the Concession Agreement (CA). A good example is the Build-Operate-Transfer (BOT) model, a common Public-Private Partnership (PPP) arrangement located at the Lagos Murtala Mohammed International Airport Terminal 2 (MMA2), built and operated by a private company, but later transferred ownership and control to the Nigerian government. Filling the infrastructure gap, improving efficiency and innovations through cutting-edge technology and efficient management techniques and the need to stimulate economic growth and development, are some of the drivers of Private Sector Participation (PSP) in infrastructure development in Nigeria (Diugwu et al., 2015).

Despite huge investment on infrastructure development through PPPs, Nigeria still wallow in severe infrastructure deficit which has adverse effects on her economic growth and development process across sectors like housing, power, healthcare and roads (Onwuemeka et al., 2022).With a huge gap estimated to require trillions of naira in infrastructure investment and a projected population of about 400 million in 2050, does Nigeria have the appropriate plans, resources, technology and strategies to bridge the infrastructure deficit gap and enhance the resilience and inclusivity of the infrastructure network? For instance, as at 2024, about 80% of Nigeria's road networks are in poor state, hindering effective connectivity, production and economic growth (Wudad et al., 2024). There is a significant housing deficit, with a shortage of about 28 million housing units in Nigeria, representing the urgent need to provide adequate shelter for the growing population, especially in urban areas (Ezeanah, 2022). Reports between 2024 and 2025 revealed that about 59.5% to 61% of the Nigerian population has access to electricity supply (World Bank, 2025). However, the national electricity grid is highly unreliable with rising electricity demand from population pressure, causing its numerous collapses (Golobish et al., 2025). Furthermore, a substantial deficit exist in clean water supply and sanitation infrastructure with 70% having access to basic drinking water services and only 44% use basic sanitation services (Isukuru et al., 2024). Nigeria's performance in the Global Innovation Index (GII), the primary global innovation index, has generally shown poor performance with a poor ranking, within the bottom 10 countries, of 123rd in 2024 (Duarte & Carvalho, 2025). Nigeria's oil pipeline infrastructure faces significant challenges despite government and private sector efforts to sustain its operations and functions (Shao et al., 2025). These challenges include pipeline vandalism, crude theft, and damage which leads to huge financial loss and the effective implementation of surveillance programs to reduce environmental pollution (Bello & Nwaeke, 2023).

Objectives of the Study

The broad objective of this study is to examine the effects of Public-Private Partnership (PPP) expenditure on infrastructure development on economic growth of Nigeria from 2000 to 2024.

The specific objectives include to:

i. establish the effects of Public-Private Partnership expenditure on road infrastructure development on real gross domestic product of Nigeria.

ii. investigate the effects of Public-Private Partnership expenditure on electricity infrastructure development on real gross domestic product of Nigeria

Research Questions

i. What are the effects of Public-Private Partnership expenditure on road infrastructure development on real gross domestic product of Nigeria?

ii. What effects has Public-Private Partnership expenditure on electricity infrastructure development has on real gross domestic product of Nigeria?

Research Hypotheses

H_{o1}: There is no significant relationship between Public-Private Partnership expenditure on road infrastructure development and real gross domestic product of Nigeria.

H_{o2}: There is no significant relationship between Public-Private Partnership expenditure on electricity infrastructure development and real gross domestic product of Nigeria.

Review of Related Literature

Conceptual Review

Infrastructure and its Importance

In its literal sense, infrastructures are those fundamental facilities in an economy that facilitates the operations of the economy and are usually non-excludable (Fourie, 2006). The term "infrastructure" comes from Latin *infra* meaning "below," reflecting its role as the underlying framework upon which societies and economies are built. The words "infra" and "structure" are combined to form the word which refers to an interrelated collection of components that support an economy's structure towards achieving government fundamental macroeconomic goals and objectives (Ifoghere & Olele, 2024). The word infrastructure is used to describe permanent installations that are utilized for a long period of time, with the purpose of adding value to human existence and the economy in general (Du et al., 2022). Although the phrase has many different meanings in different sectors, it is most commonly used to refer to the fundamental infrastructure and systems that support a nation, city, or region, such as transportation and communication networks, water and power lines, schools, hospitals, etc. Infrastructure is also seen as the structural components that enable and sustain production in order to lower production costs and, eventually, prices (Akomolehin et al., 2025). The study of Große (2023) defines infrastructure as an underlying base or supporting framework, as well as the facilities, tools, and services required for a nation, community, or organization to thrive and function optimally.

Furthermore, infrastructure is the foundational physical and organizational systems that support a country, city, or society's daily functioning and economic growth. It includes hard infrastructure**,** which are tangible assets like roads, bridges, airports, water supply, electrical grids, and telecommunications networks (Weijnen & Correljé, 2021). It also includes soft infrastructure, which are institutions and services such as education, healthcare, law enforcement, prison services and financial systems that maintain social and economic wellbeing (Kruk et al., 2018). These systems provide sustainable transportation, clean water access, communication, energy distribution, waste management, and public safety, which are essential for human wellbeing and economic growth (Wang et al., 2024). Investment in infrastructure drives economic development, creates jobs, reduces supply chain disruptions, and improves quality of life worldwide (Avordeh et al., 2024).

Nigeria faces a massive infrastructure deficit, with current infrastructure stock at only 30% of GDP—less than half the 70% international benchmark (Ebehung & Ogar, 2025). To close this gap and support a population projected to reach 400 million by 2050, Nigeria needs an estimated \$2.3 to \$3 trillion in infrastructure investment by mid-century (Riahi et al., 2023). Key sectors requiring urgent development include energy (\$759B), transport (\$575B), housing (28 million-unit deficit), and digital infrastructure (Shao et al., 2025). Government funding is constrained by a low revenue-to-GDP ratio (~7%), making private sector participation and innovative financing models essential (Fay et al., 2021). Initiatives like the National Integrated Infrastructure Master Plan and Presidential Infrastructure Development Fund are underway but require accelerated support and investment. Closing Nigeria's infrastructure gap is critical to unlocking economic potential, improving quality of life, and ensuring sustainable development for future generations (Shao et al., 2025).

Road Infrastructure and its Importance

Road infrastructure refers to the entire network of fixed physical structures designed to facilitate the movement of people and goods, including roads, tunnels, bridges, and associated facilities like parking areas and interchanges (Afrin & Yodo, 2020). This essential public works system enables transportation, supports economic development, and underpins societal well-being by ensuring efficient and safe travel from one geographical location to another (Kaiser & Barstow, 2022). Road infrastructure comprises two main categories of components: the road structure (subgrade, sub-base, base, and surface layers) and roadway elements (carriageway, shoulders, curbs, medians, and drainage systems). The roadways are the physical pathways such as national highways (Trunk A Road), state highways (Trunk B Road) and local feeder roads (Trunk C) managed by the local governments (Odewale, 2020). The bridges and tunnels are structures that are built to overcome obstacles like traffic jam, valleys, rivers or other roadways to maintain a continuous path. The interchanges are the complex structures that permit vehicles to switch from one road to another, improving connectivity and traffic. Ancillary facilities are component of road infrastructure that supports road use, including rest stops, parking lots, and terminals for public transportation like bus stops. These components work together to provide a durable, safe, and functional surface for traffic, managing loads, and facilitating movement and drainage (Sukur et al., 2023).

Electricity Infrastructure and its Importance

Electricity infrastructure refers to the entire system of networks, facilities and equipment required to generate, transmit and distribute electricity from its source to end-use consumers (Ayamolowo et al., 2019). It includes power plants (e.g., for wind, solar, or fossil fuels), high-voltage sub-stations and transmission lines that transmit power over long distances, and lower-voltage distribution lines that deliver it to homes and businesses. This complex network is essential for human development and economic growth.

Power generation involves those facilities that produce electricity, such as coal-fired, solar power generators, nuclear generators, gas-fired, hydro generators, wind power generators and geothermal generators. Power transmission networks are High-voltage lines, towers, and substations that transmit electricity from power plants to substations located closer to consumers. This is done at high voltages to minimize energy loss over long distances. Power distribution refers to the network of lower-voltage lines, transformers, and feeder lines that branch out from substations to deliver electricity directly to homes, businesses, and industrial users, while the supporting structures are the foundations, poles, wires, and associated equipment necessary to support the generation, transmission, and distribution systems.

Electricity infrastructure is crucial to every nation development process because it serves as an economic and social foundation through the provision of the fundamental power required for economic activities, domestic and industrial processes (Shi et al., 2025). Furthermore, electricity is required for the crucial operation of all other private and public services, like water systems, telecommunications, healthcare, education and transportation (Ukoba et al., 2024). Every society's electricity infrastructure must adapt to increasing demand, as it grows and integrates renewable energy sources, shifting towards a more flexible and distributed system (Nwagu et al., 2025)

Empirical Literature

The study of Ifoghere & Olele (2024) examined the effects of public sector investment on infrastructure and Gross Domestic Product (GDP) growth using the PSS Autoregressive Distributed Lag Model (ARDL) techniques to focus on the causality between the related variables and found a positive long run relationship between public sector investment in infrastructure, fixed capital stock and GDP growth. The study of Nedozi et al., (2024) investigated the link between real gross domestic product (RGDP) and water infrastructure in Nigeria, using a multivariate cointegration model. The model established a long term interaction between the included variables and concluded that an indirect relationship exist between RGDP and water infrastructure stock, with growing infrastructure stock stimulating fixed capital investment and raising RGDP. Zhang & Cheng (2023) examined the effects of public infrastructure on economic growth, using real gross domestic product as proxy for growth. The core findings of the study revealed that electricity generation have direct influence on real GDP, with an elasticity of 0.2. This means that a percentage increase in electricity generation capacity will directly increase the RGDP by 0.2%. However, some of the results are not robust to replace the total road length by other selected infrastructure measures. The control for property rights was further introduced to test for institutional roles in the infrastructure-growth relationship. Incorporating this control preserves the indirect relationship through fixed capital stock while also revealing a strong positive direct association with elasticity ranging from 0.4 to 0.5. (Du et al., 2022) investigated the impact of economic and social infrastructure and tests the causality direction using the PSS ARDL technique and the existing relationship between private investment, infrastructure indicators and Gross Value Added (GVA). The study adopted the Vector Error Correction Model (VECM). The study revealed that social infrastructure influences private investment, economic infrastructure and GVA using physical measures of social and economic infrastructure that were built from classrooms and road data respectively. Adeniyi (2021) reported an ambiguous causal relationship between economic infrastructure, GVA and private investment. The study adopted the VECM model to establish the influence of social infrastructure expenditure and private spending on GVA, with an elasticity of 0.06 and 0.02 respectively and found positive relationship between infrastructure growth and GVA. The study further tested for the probability of non-linear relationship that government expenditure on infrastructure initially boosts economic growth. The major findings revealed the existence of a positive relationship for economic and social infrastructure for investment in infrastructure in South Africa.

Particularly for Nigeria, several studies on government spending on infrastructure have emphasized on the rising tendency of public spending at the federal and state levels (Chiadika & Egbon 2024; Babatunde 2018; Okunlola et al., 2024). Others adopted the traditional Ordinary Least Square (OLS) estimation techniques to evaluate the effects of government spending on infrastructure on economic growth and find positive indicators (Onabote et al., 2023; Ahamba et al., 2024). However, little or no study has examined the aggregated and disaggregated effects of the core infrastructure development on real gross domestic product in Nigeria. Furthermore, literature on Public-Private Partnerships (PPPs) on infrastructure development as it influences Nigeria's economic growth process is scarce. Hence, this study aims to bridge the lacunae with policy implications.

It is not possible to overstate the importance and roles of infrastructure in a country's growth process. This study's examines the effects of Public-Private Partnerships (PPPs) on infrastructure development and economic growth, using a Vector Autoregressive approach that will support wise policy decisions.

Theoretical Framework

Infrastructure development theories examine how public and private investments in essential facilities, like roads, electricity, telecommunication, water and sanitation systems, drive social and economic progress by reducing cost of doing business, attracting both local and foreign investments and boosting productivity (Javid, 2019). This paper modifies the Infrastructure-Led Development Theory (ILDT) which emphasized that public spending on infrastructure triggers positive multiplier effects, enhances labour mobility and market access, which in turn promotes industrial growth and economic growth (Du et al., 2022). The theory also highlights infrastructure interactions with other sectors of the Nigerian economy, such as education, electricity, telecommunication, health water and sanitation, to create virtuous cycles of growth and development in Nigeria (Ebehung & Ogar, 2025).

Research Methodology

Nature and Sources of Data

Time series data on Public-Private Expenditure on Road Infrastructure (PERI), Public-Private Expenditure on Electricity Infrastructure (PEEI) and Real Gross Domestic Product (RGDP) for Nigeria, were sourced from the World Bank Development Indicator (WDI) and Central Bank of Nigeria (CBN) Statistical Bulletin from 2000 to 2024. PERI is measured using the Road Infrastructure Index (RII), a metric that assesses the quality and extent of Nigeria's road network, and calculated using data from the total road network as percentage to total land areas. PEEI is measured using the Global Electricity Development Index (GEDI), while RGDP is measured at constant price for inflation.

Methods of Data Analysis

The descriptive statistics conducted establish the normal distribution of the series around their mean. The Augmented Dickey Fuller (ADF) unit root test established the order of integration while the Johansen cointegration test established the long run relationship of the variables. The unrestricted Vector autoregressive (VAR) model established the dynamic relationships between the included variables. The VAR model permits the collective dynamic behaviour of time series variables without restrictions (Antonakakis et al., 2020). Our specified models contain 3 variables, expressed as a function of 3 lags of each variable plus a stochastic term (v_t). The variance decomposition tests quantify how much of the forecast error variance of the variables are explained by their own past shocks in relation to shocks to other variables in our model. The speed of adjustment to equilibrium of the variables from shocks, in the long run, was established through the Vector Error Correction (VEC) estimation. Diagnostic tests, like the VAR residual correlation LM test, were conducted to establish the absence of autocorrelation in our models.

Model Specifications

The VAR model is specified as:

$$RGDP_t = \beta_0 + \beta_1 RGDP_{t-1} + \beta_2 RGDP_{t-2} + \beta_3 RGDP_{t-3} + \beta_{21} PERI_{t-1} + \beta_{22} PERI_{t-2} + \beta_{23} PERI_{t-3} \\ \beta_{31} PEEI_{t-1} + \beta_{32} PEEI_{t-2} + \beta_{33} PEEI_{t-3} + v_t \quad (1)$$

$$PERI_t = \beta_0 + \beta_1 PERI_{t-1} + \beta_2 PERI_{t-2} + \beta_3 PERI_{t-3} + \beta_{21} PEEI_{t-1} + \beta_{22} PEEI_{t-2} + \beta_{23} PEEI_{t-3} + \beta_{31} \\ RGDP_{t-1} + \beta_{32} RGDP_{t-2} + \beta_{33} RGDP_{t-3} + v_t \quad (2)$$

$$PEEI_t = \beta_0 + \beta_1 PEEI_{t-1} + \beta_2 PEEI_{t-2} + \beta_3 PEEI_{t-3} + \beta_{21} PERI_{t-1} + \beta_{22} PERI_{t-2} + \beta_{23} PERI_{t-3} + \\ \beta_{31} RGDP_{t-1} + \beta_{32} RGDP_{t-2} + \beta_{33} RGDP_{t-3} + v_t \quad (3)$$

RGDP = Real Gross Domestic Product

PERI = Public-Private Expenditure on Road Infrastructure Development
PEEI = Public-Private Expenditure on Electricity Infrastructure Development
β and v_t represent the variable parameters and stochastic term, respectively.
The above specification is plausible, with the variables *a priori* stationary and ergodic. The error term v_t represents the parts of RGDP, PERI and PEEI not captured by or related to the past values of the variables.

Results and Discussion

Descriptive Statistics

Descriptive statistics presents a more precise idea of the distribution of the variables and examined the mean, median, maximum values, minimum values, standard deviation, skewness, kurtosis and Jarque-Bera statistic. Table 1 presents the descriptive statistic.

Table 1: Summary of Descriptive Statistics

	PERI	PEEI	RGDP
Mean	50.76101	58.07701	75.39431
Median	51.121211	59.31111	76.82111
Maximum	61.00000	64.20000	86.98000
Minimum	41.00000	50.70000	62.31000
Standard Dev.	4.895439	3.969192	7.298831
Skewness	-0.265634	-0.453947	-0.462431
Kurtosis	2.978931	2.815668	2.798075
Jarque-Bera	0.697199	1.826751	1.361933
Probability	0.519715	0.401279	0.506128
Sum	1269.000	1451.900	1884.830
Sum Sq. Dev.	572.5600	376.1856	1274.661
Observations	25	25	25

Source: Author's Computation

In table 1, the mean values of PERI, PEEI and RGDP are 50.76, 58.077 and 75.39 respectively. The mean of RGDP is higher but statistically not significant in influencing public-private partnership expenditure on road infrastructure development (PERI) and electricity infrastructure development (PEEI). The minimum and maximum values show that there are no data-entry error and outliers in the data. A comparison between PERI, PEEI and RGDP revealed that the data are normally distributed. The standard deviation values of 4.895439, 3.969192 and 7.298831 for PERI, PEEI and RGDP respectively show that the data are normally distributed from their respective means. The skewness is a measure of the asymmetry of the distribution of variables around the mean. The skewness values of -0.265634, -0.453947 and -0.462431 for PERI, PEEI and RGDP respectively show that the data are normally distributed and skewed around their respective means. The kurtosis is a measure of the peakedness or flatness of the distribution. From table 1 the kurtosis values are close to 3, which imply the series are normally distributed around their means. Furthermore, the respective probability values are less than the respective Jarque-Bera values, which imply that the series are normally distributed around their means.

Unit Root Test

The unit root test results are reported in tables 2a and 2b at level and first difference respectively.

Table 2a: Augmented Dickey Fuller (ADF) Summary of Unit Root Test Results

Variables	ADF Test Statistics (At level)	Mackinnon Critical Values			Prob. (values)	Remark
		1%	5%	10%		
PERI	-4.0799	-3.8388	-2.9929	-2.6366	0.0047	Stationary
PEEI	-5.1780	-3.8388	-2.9929	-2.6366	0.0004	Stationary
RGDP	-1.9397	-3.8388	-2.9929	-2.6366	0.3534	Not Stationary

Source: Author's Computation

The unit root results presented in table 2a show that PERI and PEEI are both stationary at level because their respective probability values are lower than 0.05 and the absolute values of their test statistics are higher than their critical values at 1%, 5% and 10% respectively. However, RGDP is not stationary at level because the probability value of 0.3534 is greater than 0.05 and the absolute value of the test statistic is lower than the critical values at 1%, 5% and 10%. Table 2b presents the 1st difference of the unit root results.

Table 2b: Augmented Dickey Fuller (ADF) Summary of Unit Root Test Results

Variables	ADF Test Statistics (1st Diff.)	Mackinnon Critical Values			Prob. (values)	Remark
		1%	5%	10%		
PERI	-4.9979	-4.5436	-3.6847	-3.3784	0.0041	Stationary
PEEI	-8.8877	-4.4163	-3.6321	-3.3586	0.0000	Stationary
RGDP	-2.3123	-2.6968	-1.9691	-1.6175	0.0351	Stationary

Source: Author's Computation

At 1st difference PERI, PEEI and RGDP are stationary because their respective probability values of 0.0041, 0.0000 and 0.0351 are less than 0.05. Furthermore, the absolute values of their respective test statistics are greater than their critical values at 5% and 10%. These conditions satisfy the application of the Johansen cointegration test.

Johansen Cointegration Test

Long Run Effects of Public-Private Partnership Expenditure on Road (PERI) and Electricity (PEEI) Infrastructure on Real Gross Domestic Product (RGDP)

Table 3a: Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Values	Prob **
None *	0.548274	35.49641	29.79808	0.0098
At Most 1 *	0.355213	17.72742	15.49572	0.0237
At Most 2 *	0.294522	7.992631	3.842466	0.0057

Trace test indicates 3 cointegration eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table 3b: Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max. Eigen Statistic	0.05 Critical Values	Prob. **
None *	0.539274	17.77999	21.13263	0.1397
At Most 1 *	0.355213	9.736696	14.26561	0.2290
At Most 2 *	0.294531	7.991622	3.842476	0.0048

Max-eigenvalue test indicates no cointegration eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level

Results from the Johansen cointegration test show the existence of a long run relationship between PERI, RGDP and PEEI. The unrestricted cointegration rank test (table 3a) revealed that the trace statistic (35.49641, 17.72742 and 7.992631) exceed the respective critical values (29.79808, 15.49572 and 3.842466) at 5% level of significance. This indicates 3 cointegrating equations with respective probability values of 0.0098, 0.0237 and 0.0057 (less than 0.05) at 5% significant level. The values of the maximum Eigen statistic corroborate the trace statistic values of 3 cointegrating equations. This implies the absence of a full rank because subtracting the number of cointegrating equations from the number of variables (PERI, RGDP and PEEI) is not equal to 0. This suggests that a linear combination of PERI, RGDP and PEEI is stationary, implying a long run equilibrium relationship among the variables. This further implies that the model is good and in functional form. The positive value of the log-likelihood indicates the absence of multicolinearity.

These conditions satisfy the application of the VAR estimation to estimate the models parameters. Table 4 presents the VAR estimates of the variables

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Table 4: Vector Autoregressive Estimates

	RGDP	PERI	PEEI
RGDP(-1)	0.553299* (1.23887) [2.31590]	0.266105 (0.26297) [1.01191]	0.405660 (0.32517) [1.24753]
RGDP(-2)	0.396532 (0.23846) [1.66290]	0.029780 (0.26252) [0.11344]	-0.692288* (0.32460) [-2.13272]
PERI(-1)	-0.335560* (0.14651) [-2.29029]	0.372944* (0.16130) [2.31218]	0.327290 (0.19944) [1.64101]
PERI(-2)	-0.095358 (0.13515) [-0.70558]	0.215890 (0.14878) [1.45103]	-0.029273 (0.18397) [-0.15912]
PEEI(-1)	0.024069 (0.16581) [0.14516]	0.090965 (0.18254) [0.49834]	-0.278764 (0.22571) [-1.23506]
PEEI(-2)	0.203582 (0.18113) [1.12393]	0.096300 (0.19941) [0.48293]	-0.258529 (0.24657) [-1.04850]
C	13.33380 (21.3408) [0.62480]	-12.40329 (23.4938) [-0.52794]	95.07914* (29.0504) [3.27290]
R-squared	0.876482	0.620892	0.367099
Adj. R-squared	0.830163	0.478727	0.129760
Sum sq. resids	116.1471	140.7643	215.2239
S.E equation	2.694289	2.966104	3.667628
F-statistic	18.92262	4.367395	1.546733
Log likelihood	-51.25827	-53.46890	-58.35171

* denotes rejection of the hypothesis at the 0.05 significance level
Source: Author's Computation, 2025

From model 1, the Vector autoregressive (VAR) estimates show that real gross domestic product in the previous period, RGDP(-1) and expenditure on road infrastructure in the previous period, PERI (-1) are statistically significant in explaining changes in real gross domestic product in the current period ($RGDP_t$), with probability values less than 0.05. However, the other lag values of RGDP, PERI and PEEI are not statistically significant in explaining changes in RGDP for the current period. The coefficient of RGDP (-1) is 0.553299 implying that a I percent increase in real gross domestic product in the previous period causes a 55.3 percent increase in real gross domestic product in the current period. However, real gross domestic product in the current period has negative effects on road infrastructure expenditure in the previous period, with a coefficient of -0.335560. This implies that a 1 percent increase in real gross domestic product causes a 33.5 percent decrease in expenditure on road infrastructure in the previous period. The R-squared of 0.876482 implies that an 87.6 percent change in the endogenous variables is explained by the exogenous variables. It remained strong after the adjustment for degree of freedom as 88 percent (Adjusted R-squared). Durbin Watson statistic of 1.90 implies a model free from autocorrelation.

From model 2, only the previous estimate of expenditure on road infrastructure PERI (-1) is statistically significant in explaining changes in PERI in the current period. However, expenditure on electricity infrastructure at 1 and 2 periods lag, PEEI (-1) and PEEI (-2), are not statistically significant in explaining changes in expenditure on road infrastructure (PERI). With positive coefficients of 0.090965 and 0.096300, a 1 percent increase in PEEI (-1) and PEEI (-2) respectively, brings about a negligible 9 percent increase in PERI in the current period.

From model 3, real gross domestic product at 2 lags period RGDP (-2), with a negative coefficient of -0.692288, is statistically significant in explaining changes in PEEI in the current period. This implies that a 1 percent increase in real gross domestic product brings about a 69 percent decrease in expenditure on electricity infrastructure in Nigeria.

VAR Variance Decomposition Test

The primary purpose of the variance decomposition test is to determine the degree of the forecast error variance of each endogenous variable is explained by shocks to other variables and to itself in the model. Thus, it enables us to understand the contributions of each variable to the variability of other variables over time. Using a 5-year forecast period from the short run to the long run, the variance decomposition estimates are presented in tables 5a, 5b and 5c.

Table 5a: Variance Decomposition of RGDP

Periods	SE	RGDP	PERI	PEEI
1	2.694289	100.0000	0.000000	0.000000
2	3.253008	90.82342	9.105098	0.071482
3	3.871991	82.82618	14.31214	2.861682
4	4.312396	77.66377	20.02866	2.307566
5	4.609228	71.24483	26.84183	2.033336

Source: Author's Computation

From the results in table 5a, the rows represent the percentage of forecast error variance by RGDP. In the short run, a 100 percent of forecast error variance in RGDP is explained by the variable itself while about 71.24 percent of forecast error variance, on average, is explained in the long run. This implies that RGDP strongly influences itself from the short to long run and is strongly endogenous in predicting itself. Other variables of the model (PERI and PEEI) do not have strong influence on RGDP. This means that PERI and PEEI, on average, have strong exogenous influence on RGDP both in the short and long run periods.

Table 5b: Variance Decomposition of PERI

Periods	SE	RGDP	PERI	PEEI
1	2.966104	0.270104	99.72990	0.000000
2	3.259514	3.920131	95.06294	1.016931
3	3.497145	8.103662	89.69104	2.205299
4	3.634812	13.70077	83.77403	2.525199
5	3.728654	17.61994	79.63181	2.748248

Source: Author's Computation

From the results in table 5b, the rows represent the percentage of forecast error variance by PERI. In the short run, a 99.73 percent of forecast error variance in PERI is explained by the variable itself while about 79.63 percent of forecast error variance, on average, is explained in the long run. This implies that PERI strongly influences itself from the short to long run and is strongly endogenous in predicting itself. Other variables of the model (RGDP and PEEI) do not have strong influence on PERI. This means that RGDP and PEEI, on average, have strong exogenous influence on PERI both in the short and long run periods.

Table 5c: Variance Decomposition of PEEI

Periods	SE	RGDP	PERI	PEEI
1	3.667628	0.966098	1.965883	97.06802
2	4.056486	8.729305	5.754472	85.51622
3	4.303803	16.31149	6.311153	77.37736
4	4.386892	15.74822	7.024959	77.22682
5	4.421339	15.51370	7.443710	77.04259

Source: Author's Computation

From the results in table 5c, the rows represent the percentage of forecast error variance by PEEI. In the short run, a 97.06 percent of forecast error variance in PEEI is explained by the variable itself while about 77.04 percent of forecast error variance, on average, is explained in the long run. This implies that PEEI strongly influences itself from the short to long run and is strongly endogenous in predicting itself. Other variables of the model (RGDP and PERI) do not have strong influence on PEEI. This means that RGDP and PERI, on average, have strong exogenous influence on PEEI both in the short and long run periods.

VAR Residual Serial Correlation LM Test

The VAR serial correlation LM tests assess whether the residuals (errors) of the estimated VAR models exhibit serial correlation or are correlated with their own lag or past values. Table 6 presents the results of the serial correlation LM tests.

Table 6: VAR Residual Serial Correlation LM Tests

Null Hypothesis: No serial correlation at lag h						
Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	8.810558	9	0.4549	1.004814	(9, 26.9)	0.4601
2	5.551246	9	0.7839	0.598816	(9, 26.9)	0.7866
3	3.001879	9	0.9642	0.310222	(9, 26.9)	0.9647
Null Hypothesis: No serial correlation at lags 1 to h						
Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	8.810558	9	0.4549	1.004814	(9, 26.9)	0.4601
2	16.39480	18	0.5650	0.890810	(18, 23.1)	0.5939
3	51.47386	27	0.0031	3.045213	(27, 15.2)	0.0131

Source: Author's Computation

The VAR residual serial correlation LM test results in table 6 show that the probability values are all greater than 0.05 which suggest the result is non-significant and hence we accept the null hypothesis of no serial correlation or the absence of serial correlation in the residuals at lags 1, 2 and 3. This also suggests that the models adequately capture the time series dynamics or shocks in the long run. Thus, the VAR model correctly captures the time-dependent relationships in the series. Similarly, the LRE statistic captures the pattern of autocorrelation in the residuals of the model. The LR statistic is non-significant due to their probability values all greater than 0.05 which implies the absence of serial correlation in our models.

Vector Error Correction (VEC) Estimation

The primary aim of the Vector Error Correction (VEC) estimates is to present the long-run equilibrium and the short-term dynamic adjustments when the variables deviate from their equilibrium. Table 7 presents the long-run and short-run adjustments of the variables to equilibrium.

Table 7: Vector Error Correction (VEC) Estimates

Cointegrating Eq	CointEq1		
PERI(-1)	1.000000		
RGDP(-1)	-1.199617 (0.32565) [-3.68379]		
PEEI(-1)	-4.042631 (0.98498) [-4.10429]		
C	274.7776		
Error Correction	D(PERI)	D(RGDP)	D(PEEI)
CointEq1	-0.181208 (0.10860) [-1.10692]	0.114015 (0.12376) [0.92125]	0.433656 (0.15149) [2.86262]

Source: Author's Computation

The upper segment of table 7 presents the error correction term signifying the long-run cointegrating relationships among the variables, while the lower segment presents the short-run coefficients. The error correction adjustment coefficient of -0.181208 implies that the previous period deviation from the long-run equilibrium is corrected in the current period with an adjustment speed of 18.12 percent. Ceteris paribus, in the long-run, a 1 percent change in the previous value of PERI will bring about a 100 percent increase in the error correction term. A 1 percent change in the previous value of the RGDP will cause the error correction term to decrease by 119.9 percent while a 1 percent change in the previous value of PEEI will cause the error correction term to also decrease by 404.2 percent.

Discussion of the Results/Policy Implications
Hypothesis One (PERI vs RGDP)

From the results obtained, real gross domestic product (RGDP) was positive and has insignificant impact on public-private partnership expenditure on road infrastructure (PERI). A 1 percent increase in 1 and 2 years lag period of RGDP only increases PERI by 26 and 2.9 percent respectively. This result underscores the declining value of the real gross domestic product due to inflation and internal policy missteps like expensive subsidies for road infrastructure and distorted exchange rate systems adversely influencing loans for road infrastructure in Nigeria (Okunlola et al., 2024)**.**

Hypotheses Two (PERI vs PEEI)

The result shows public-private partnership expenditure on electricity infrastructure (PEEI) is not significant in explaining changes in public-private partnership expenditure on road infrastructure (PERI). Although positive, a 1 percent increase in PEEI has a negligible effect of 9 percent average increase on PERI. This implies that expenditure on road infrastructure has not significantly influenced expenditure on electricity infrastructure in Nigeria. Road and electricity infrastructure are complementary systems. The former allows for the efficient delivery of materials to build and maintain power grids, while electricity powers the transportation systems and supports businesses that benefit from good roads (Pandiyan et al., 2023).

Hypotheses Three (PEEI vs RGDP)

The result shows an inverse relationship between public-private partnership expenditure on road infrastructure and real gross domestic product of Nigeria. A 1 percent increase in RGDP, after a 2 period lag, brings about an average of 69.2 percent decrease in PEEI in Nigeria. This outcome reflects government and private sector lack of commitment in strengthening the moribund electricity infrastructure base in Nigeria (Kayode 2023). Despite huge investment on infrastructure, the state of electricity infrastructure is abysmal. This is due to insufficient investment, aging and vandalized equipment, lack of skilled manpower and poor maintenance culture.

Conclusions

Public-Private Partnership expenditure on road infrastructure (PERI) is positively related with real gross domestic product (RGDP) in Nigeria. The moribund state of road and electricity infrastructure and rising inflation in Nigeria underscores the declining value of the real gross domestic product. Internal policy missteps like expensive subsidies for road and electricity infrastructure and distorted exchange rate systems have adversely influenced loans for road and electricity infrastructure in Nigeria within the period of study. Investment efforts by the government and private sector on infrastructure development have negligible effects on real gross domestic product due to government and private sectors' lack of commitment, corruption and mismanagement of public-private funds for infrastructure development. Road and electricity infrastructure are complementary systems. The former allows for the efficient delivery of materials to build and maintain power grids, while electricity powers the transportation systems and supports businesses that benefit from good roads.

Recommendations

i. To achieve sustainable solutions to the poor road and electricity infrastructure in Nigeria, a more holistic, diverse and innovative financing models, like infrastructure bonds and green bonds, should be adopted to supplement government and private sector financing.
ii. Project management and regulatory processes should be simplified, digitized. This will permit the reduction in bureaucratic hurdles and expedite project actions.
iii. The government should create the enabling environment for advanced technologies, digital platforms and smart infrastructure systems to promote project management and improve service delivery of infrastructure facilities. Furthermore, adopting comprehensive regional infrastructure plans that utilize data and mapping technologies will monitor roads and electricity conditions.
iv. The government should adopt broader policies and community initiatives, through

sustainable practices for long-term viability, promote alternative transport systems and make more investments in renewable energy, to reduce the pressure on the road network and power systems respectively. Communities and stakeholders should be engaged in the planning and execution process to ensure projects align with their needs and promotes a culture of shared responsibility for infrastructure.

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