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Green Economy and CNG: Catalyst for poverty alleviation in Nigeria

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Abstract
This study investigates the impact of compressed natural gas (CNG) adoption on poverty reduction in Nigeria within the broader context of green economic transition. Using quarterly time series data from 1990 to 2024, the analysis explores the dynamic relationships among poverty rate, unemployment, transport cost, CNG vehicle adoption, and the number of CNG refueling stations. Augmented Dickey-Fuller (ADF) tests reveal that all variables are integrated of order one, I(1). The Johansen cointegration test confirms the presence of at least one long-run equilibrium relationship, justifying the application of a Vector Error Correction Model (VECM). The results indicate that in the long run, unemployment and rising transport costs significantly increase poverty, while the expansion of CNG refueling stations contributes to poverty reduction. However, the number of CNG vehicles was not statistically significant in the long-run model. The error correction term is negative and significant, confirming that approximately 35% of disequilibrium is corrected each quarter, thus validating long-run convergence. Diagnostic tests confirm the absence of serial correlation and heteroskedasticity, and the model satisfies stability conditions. These findings highlight the critical role of CNG infrastructure in addressing poverty through cost-effective and environmentally sustainable energy alternatives. The study recommends policies aimed at expanding CNG station infrastructure, reducing transport costs, and integrating green technologies into national poverty reduction strategies.

Keywords: Compressed Natural Gas (CNG), Nigeria, poverty reduction, green economy, sustainable development

1. Introduction
Nigeria, as Africa's largest economy, faces persistent challenges of poverty, unemployment, and environmental degradation. According to the National Bureau of Statistics (NBS, 2023), over 40% of Nigerians live below the national poverty line, despite the country's abundant natural and human resources. Simultaneously, Nigeria contends with the adverse effects of fossil fuel dependency, including greenhouse gas emissions, air pollution, and unsustainable resource exploitation. These interconnected challenges highlight the urgent need for a development paradigm that fosters economic growth, reduces poverty, and safeguards the environment.

The Green Economy model, championed by the United Nations Environment Programme (UNEP), emphasizes economic activities that result in improved human well-being and social equity while significantly reducing environmental risks and ecological scarcities (UNEP, 2011) [21]. It promotes investments in renewable energy, sustainable agriculture, green transportation, and eco-friendly technologies sectors known for their potential to generate employment and reduce poverty. For Nigeria, transitioning toward a green economy offers an opportunity to diversify its oil-dependent economy while addressing pressing socio-economic challenges.

One strategic option for Nigeria within this green transition is the adoption of Compressed Natural Gas (CNG) as a cleaner, more affordable alternative to conventional fossil fuels. CNG emits fewer pollutants compared to petrol and diesel, making it a viable solution for reducing urban air pollution and mitigating climate change (International Energy Agency [IEA], 2022) [6]. Nigeria's vast natural gas reserves estimated at over 200 trillion cubic feet remain largely untapped, presenting a critical resource for domestic energy needs (Nigerian National Petroleum Corporation [NNPC], 2023) [12].

The adoption of CNG in transportation and industrial sectors holds multiple socio-economic benefits. Beyond its environmental advantages, CNG can reduce transportation and production costs, thereby lowering the cost of living and enhancing the competitiveness of local industries (Adepoju & Akinola, 2021) [1].

Moreover, the expansion of CNG infrastructure, such as fueling stations, vehicle conversion workshops, and maintenance services, creates employment opportunities and supports the growth of small and medium enterprises. These economic multipliers can significantly contribute to poverty alleviation, especially in urban and peri-urban areas.

In light of these prospects, promoting CNG within Nigeria's green economy framework aligns with the country's goals of economic diversification, job creation, and sustainable development. It serves as a practical instrument for reducing poverty while advancing environmental sustainability and energy security. The synergy between green economic policies and CNG adoption positions Nigeria on a pathway toward inclusive growth and long-term socio-economic resilience.

2. Literature Review

2.1. Conceptual Issues on Green Economy and CNG

2.1.2 The Concept of Green Economy

The term Green Economy refers to an economic system that aims to improve human well-being and social equity while significantly reducing environmental risks and ecological scarcities (UNEP, 2011) [21]. Unlike traditional economic models, which often prioritize growth at the expense of environmental sustainability, the green economy advocates for a balance between economic progress, social inclusion, and environmental protection.

Basic principles of the green economy include:

- **Resource Efficiency:** Using natural resources sustainably to ensure long-term availability.
- **Low Carbon Growth:** Promoting renewable energy sources and reducing reliance on fossil fuels.
- **Social Equity:** Ensuring that the benefits of economic activities are widely shared and contribute to poverty reduction.

The relevance of a green economy in Nigeria lies in its potential to diversify the economy beyond oil, create sustainable jobs, and mitigate environmental degradation, particularly in sectors like energy, agriculture, transportation, and waste management.

2.1.3 Understanding Compressed Natural Gas (CNG) within the Green Economy Framework

Compressed Natural Gas (CNG) is a fuel made by compressing natural gas to less than 1% of its volume at standard atmospheric pressure. As a cleaner-burning alternative to petrol or diesel, CNG is considered a transitional fuel in the global move towards a green economy (IEA, 2022) [6].

In Nigeria, the significance of CNG stems from several factors:-

- **Abundant Natural Gas Reserves:** With over 200 trillion cubic feet of proven reserves, Nigeria ranks among the top gas-rich countries in the world (NNPC, 2023) [12].
- **Environmental Benefits:** CNG produces fewer greenhouse gas emissions, particulate matter, and other pollutants, contributing to improved air quality and reduced carbon footprint.
- **Economic Advantages:** The use of CNG in transportation and industry can lower operating costs, foster industrial competitiveness, and reduce dependence on imported petroleum products.

Thus, promoting CNG aligns with Nigeria’s National Gas Expansion Program (NGEP), which seeks to harness natural gas for domestic economic growth and sustainability.

2.1.4 Green Economy, CNG and poverty alleviation nexus

Poverty in Nigeria is a complex issue that goes beyond mere income deprivation. It is also closely tied to the lack of access to clean energy, decent jobs, and affordable transportation. Green jobs play a crucial role in fostering an environmentally and economically sustainable society. They can significantly reduce greenhouse gas emissions, promote energy independence from oil, eliminate concerns about home heating and cooling, and enhance food security. Moreover, green jobs can provide millions of high-quality, well-paying, long-term employment opportunities, helping to lift many people into a stable middle class (Oboro, 2024) [13]. The green economy approach, particularly through the adoption of compressed natural gas (CNG), presents viable solutions to these challenges.

- **Employment Generation:** Expanding the CNG value chain (production, distribution, conversion, maintenance) creates skilled and semi-skilled job opportunities, particularly for youth.
- **Reduced Cost of Living:** CNG-powered transport can offer lower fares due to cheaper fuel costs, benefiting low-income households.
- **Entrepreneurial Opportunities:** The development of CNG-related micro and small enterprises, such as vehicle conversion centers and refueling stations, encourages entrepreneurship and supports livelihoods.
- **Health and Environmental Gains:** Reduced emissions improve public health, decreasing health-related expenditures for poor households.

This nexus suggests that CNG is not merely an energy alternative but a developmental tool that fits within Nigeria’s poverty reduction and environmental sustainability strategies.

2.1.5 Policy and Institutional Considerations

For the green economy and CNG to effectively contribute to poverty alleviation, several policy and institutional issues must be addressed.

- **Regulatory Framework:** Clear policies and incentives for investment in CNG infrastructure and green technologies.
- **Capacity Building:** Training programs to develop skills in CNG technology and green entrepreneurship.
- **Public Awareness:** Sensitization campaigns to encourage acceptance and adoption of CNG.
- **Access to Finance:** Support for small businesses and entrepreneurs involved in the green economy and CNG sectors.

2.1.6 Challenges and Risks

While the potential is significant, some conceptual challenges include:

- **Infrastructure Deficit:** Insufficient CNG refueling stations and conversion centers.

- **Policy Inconsistency:** Shifts in government priorities could hinder long-term green economy planning.
- **Public Perception and Acceptance:** Resistance to adopting new technologies due to lack of information or misconceptions.

Addressing these conceptual and practical issues is critical for maximizing the poverty alleviation potential of green economy initiatives in Nigeria.

2.2. Compressed Natural Gas (CNG) Vehicles: An Overview

2.2.1 Concept of CNG Vehicles

Compressed Natural Gas (CNG) vehicles are automobiles powered by CNG either exclusively or in combination with other fuels. CNG, consisting mainly of methane, is stored under high pressure (typically 200-250 bar) in reinforced tanks. Vehicles can be:

- Dedicated CNG Vehicles, designed to run solely on CNG.
- Bi-Fuel Vehicles, capable of switching between CNG and petrol/diesel.
- Dual-Fuel Vehicles, which use a mixture of CNG and diesel, mostly in heavy-duty applications (International Energy Agency [IEA], 2022) [6].

2.2.2 Advantages of CNG Vehicles

- **Environmental Benefits:** CNG combustion emits fewer pollutants compared to petrol or diesel, producing lower levels of carbon monoxide, nitrogen oxides, particulate matter, and greenhouse gases. This contributes to urban air quality improvement and supports climate action initiatives (United Nations Environment Programme [UNEP], 2011) [21].
- **Economic Benefits:** CNG is generally cheaper than conventional fuels, leading to lower transportation costs for private users and commercial operators (IEA, 2022) [6]. This cost advantage is significant in economies with abundant natural gas resources, such as Nigeria.
- **Energy Security:** By promoting the use of domestically sourced natural gas, CNG vehicles reduce reliance on imported refined fuels, thereby enhancing national energy security (NNPC, 2023) [12].
- **Engine Longevity:** The clean-burning nature of CNG results in reduced engine deposits, minimizing wear and maintenance costs over the vehicle's lifespan (IEA, 2022) [6].

2.2.3 Challenges Facing CNG Vehicle Adoption

- **Infrastructure Deficit:** The availability of refueling stations is a critical factor for CNG vehicle adoption. In Nigeria, limited access to CNG filling stations hampers widespread use (NNPC, 2023) [12].
- **Initial Conversion Costs:** The upfront cost of converting existing petrol/diesel vehicles to CNG or purchasing factory-fitted CNG models remains high for many potential users (IEA, 2022) [6].
- **Limited Driving Range:** Because of CNG's lower energy density, vehicles generally require more frequent refueling, which could be inconvenient where infrastructure is sparse (IEA, 2022) [6].
- **Safety concerns and public perception:** While CNG is considered safe when handled properly, public skepticism about the storage of pressurized gas affects consumer confidence (UNEP, 2011) [21].

2.2.4 CNG Vehicles in the Context of Nigeria

Nigeria, possessing the largest proven natural gas reserves in Africa, has launched initiatives such as the National Gas Expansion Programme (NGEP) to promote the adoption of CNG for transportation and industry (NNPC, 2023) [12].

The widespread adoption of CNG vehicles in Nigeria could:

- Lower transportation costs.
- Reduce urban air pollution.
- Stimulate employment in conversion, maintenance, and distribution sectors (UNEP, 2011; NNPC, 2023) [21, 12].

However, success depends on strategic infrastructure development, policy support, and public engagement. CNG vehicles offer a practical pathway toward sustainable transportation, aligning with green economy goals by fostering cleaner energy use, reducing environmental impact, and providing economic opportunities. In Nigeria's context, leveraging its natural gas resources for CNG adoption could advance both environmental sustainability and poverty alleviation (IEA, 2022; UNEP, 2011; NNPC, 2023) [21, 22, 12].

2.3 Historical background of Compressed Natural Gas (CNG)

The use of natural gas as a fuel dates back to the early 19th century when it was primarily used for lighting in homes and streets. However, the idea of compressing natural gas for vehicular use emerged much later, driven by the need for alternative and cleaner energy sources for transportation (International Gas Union [IGU], 2022) [7].

The first recorded use of CNG as a transportation fuel occurred in Italy during World War II, when oil shortages forced nations to explore alternative fuels. Italian engineers pioneered the development of CNG-powered vehicles, leading to the installation of the first natural gas refueling stations (International Energy Agency [IEA], 2022) [6].

Post-war, countries like Argentina, Pakistan, and Iran adopted CNG widely due to their significant natural gas reserves and the economic benefits of reducing reliance on imported fuels. For instance, Argentina became a world leader in CNG vehicle adoption during the late 20th century, with millions of vehicles converted to CNG by the 2000s (IEA, 2022) [6].

In recent decades, environmental concerns have shifted global attention toward CNG as a cleaner alternative to gasoline and diesel. CNG's lower emissions of carbon monoxide, hydrocarbons, and nitrogen oxides make it attractive for urban transport systems seeking to reduce air pollution (United Nations Environment Programme [UNEP], 2011) [21].

In Nigeria, despite holding Africa's largest natural gas reserves, CNG adoption remained low until recent government initiatives under the National Gas Expansion Programme (NGEP), launched in 2020, which aimed to promote natural gas as a primary fuel for transportation and domestic use (Nigerian National Petroleum Corporation [NNPC], 2023) [12]. The program seeks to create a sustainable gas economy, reduce environmental degradation, and offer affordable transportation options to the populace.

Today, the growing emphasis on clean energy transitions has made CNG a critical player in global strategies for sustainable transportation and economic diversification, especially in developing countries rich in natural gas resources.

2.4 The nexus between green economy and Compressed Natural Gas (CNG)

The concept of the green economy has emerged as a critical framework for achieving sustainable development, particularly in countries striving for economic growth alongside environmental conservation. The United Nations Environment Programme (UNEP, 2011) [21] defines a green economy as one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. At its core, the green economy emphasizes low-carbon, resource-efficient, and socially inclusive development pathways.

One of the major pillars of the green economy is the transformation of the energy and transport sectors toward cleaner alternatives. Compressed Natural Gas (CNG) fits into this paradigm as a transitional fuel that offers both economic and environmental benefits. Compared to conventional fossil fuels like petrol and diesel, CNG produces fewer greenhouse gas emissions and lower levels of air pollutants such as nitrogen oxides and particulate matter (International Energy Agency [IEA], 2022) [6]. This positions CNG as a viable component of green economic strategies, especially in the transportation sector.

2.4.1 CNG as a transitional fuel in the green economy

CNG's role as a "bridge fuel" has been widely discussed in the literature, particularly in the context of transitioning from high-emission energy sources to renewable energy systems (Olomola, 2021) [15]. While not entirely carbon-neutral, CNG is considered cleaner than other fossil fuels, contributing to reduced carbon footprints in urban transport systems. For countries like Nigeria, where vehicular emissions and transport costs remain high, adopting CNG can foster both environmental sustainability and economic efficiency (Ejiogu, 2022) [3].

The deployment of CNG in public transportation, for instance, can lower operational costs for transport providers, translating to reduced fares for commuters, many of whom are in the low-income bracket. This linkage between affordable transport, reduced emissions, and poverty alleviation underscores the synergy between CNG adoption and green economic principles (UNEP, 2011; NNPC, 2023) [21, 12].

Policy frameworks that support CNG adoption often align with broader green economy objectives. In Nigeria, the National Gas Expansion Programme (NGEP) launched in 2020 exemplifies this nexus. By promoting the use of CNG and LPG in transportation and domestic energy, the NGEP aims to diversify the economy, reduce environmental degradation, and create employment opportunities (NNPC, 2023) [12]. This approach reflects global trends where governments incentivize cleaner fuel adoption as part of sustainable economic reforms (IEA, 2022) [6].

However, scholars highlight that the realization of these green economy benefits is contingent on adequate infrastructure, consistent policy implementation, and public awareness (Ejiogu, 2022) [3]. Without these enablers, the green economy potential of CNG remains largely theoretical.

2.5 The Presidential Compressed Natural Gas Initiative (Pi-CNG) of the Federal Government of Nigeria

The Presidential Compressed Natural Gas Initiative (Pi-CNG) is a flagship program launched by the Federal Government of Nigeria in 2023 as part of its broader strategy to reduce reliance on petrol and diesel while promoting cleaner, cheaper, and more sustainable energy alternatives in the transportation sector. The initiative aims to deepen the adoption of Compressed Natural Gas (CNG) as an affordable fuel option for Nigerians, especially in the wake of petrol subsidy removal.

The Pi-CNG Initiative aligns with Nigeria's commitment to energy transition and the drive toward a green economy. It is designed to convert vehicles across the country including commercial buses, taxis, and private vehicles from petrol and diesel engines to CNG-powered systems. According to the Presidential CNG Steering Committee (2024), the program targets the deployment of over 1 million CNG-powered vehicles and aims to establish refueling stations, conversion workshops, and skilled workforce development to support the ecosystem.

The initiative also plays a strategic role in the government's poverty alleviation agenda by seeking to lower transportation costs, boost local employment through conversion centers, and reduce the operational expenses of transport businesses. The Federal Government estimates that CNG adoption can cut transportation fuel costs by up to 50%, directly easing economic pressure on households and small businesses (Federal Government of Nigeria, 2024) [17].

Moreover, the Pi-CNG initiative is expected to contribute to environmental sustainability by reducing vehicular emissions. This is crucial for Nigeria's commitment under the Paris Agreement and the nation's pledge to reduce greenhouse gas emissions by 20% unconditionally and 45% conditionally by 2030 (Nationally Determined Contributions, 2021) [11].

2.5.1 Fundamental Pillars of the Pi-CNG Initiative

- **Vehicle Conversion Support:** Incentivizing vehicle owners with subsidies or financing options for CNG conversion kits.
- **Infrastructure Development:** Establishing CNG refueling stations across major cities and transport corridors.
- **Technical Capacity Building:** Training technicians and creating jobs in vehicle conversion and maintenance.
- **Policy and Regulatory Framework:** Developing regulations to ensure safety standards, quality assurance, and efficient market operations.

2.5.2 Challenges and Prospects

Despite its potential, the Pi-CNG faces challenges, including initial conversion costs, limited refueling infrastructure in rural areas, and the need for sustained policy enforcement. However, analysts view the initiative as a critical step toward achieving both economic and environmental objectives if accompanied by effective public-private partnerships and continuous stakeholder engagement (Ejiogu, 2024) [4].

2.6 Empirical Review of CNG and Poverty Alleviation: Case studies from different countries

Several empirical studies across different countries have explored the link between Compressed Natural Gas (CNG) adoption and socio-economic impacts, particularly in reducing poverty through lower transport costs, job creation, and environmental health benefits.

1. Pakistan: CNG as a tool for affordable transportation

Pakistan is widely recognized as one of the earliest adopters of CNG for public transportation. According to Naeem and Mahmood (2018) [9], the large-scale conversion of transport vehicles to CNG in Pakistan significantly reduced the cost of urban transportation, making commuting more affordable for low-income households. The study highlighted that the introduction of CNG stations created direct and indirect employment opportunities, contributing to local economic growth. Furthermore, the reduced reliance on imported petroleum products stabilized transportation fares, indirectly easing household expenditure burdens.

"The adoption of CNG in Pakistan served both economic and environmental goals, with the most notable impact observed in public transport affordability and employment generation within the CNG conversion and refueling sectors" (Naeem & Mahmood, 2018, p. 45) [9].

Ahmed and Jamil (2015) [2] found that small-scale CNG retail outlets emerged as viable microenterprises, contributing to income generation and poverty reduction in local communities. However, the sustainability of this impact depended on government pricing policies and natural gas supply consistency

2. Bangladesh: CNG policy and urban poverty reduction

In Bangladesh, the government's support for CNG in the transportation sector since the early 2000s has had measurable effects on urban poverty. Rahman and Islam (2020) [18] examined the Dhaka metropolitan area and found that the shift from petrol to CNG among auto-rickshaws significantly reduced fuel expenses for drivers, many of whom belong to the low-income bracket. This cost saving increased their disposable income and enhanced their living standards. Additionally, the health benefits of reduced air pollution were most significant in low-income neighborhoods prone to traffic congestion.

"The widespread adoption of CNG in Dhaka reduced operational costs for drivers and improved public health indicators, which are critical components of poverty alleviation in urban slums" (Rahman & Islam, 2020, p. 112) [18].

3. India: CNG and sustainable transport for the poor

India provides a prominent case where CNG adoption transformed the transportation sector. The introduction of CNG in major cities like Delhi significantly reduced transport costs and improved air quality. In New Delhi, the Supreme Court mandated the conversion of commercial vehicles to CNG in response to critical pollution levels. Sengupta and Gupta (2019) [19] analyzed the economic effects of this policy and concluded that while initial conversion costs were a barrier, government subsidies and financing schemes eventually made CNG adoption economically viable for low-income transport operators. The study emphasized that fuel savings contributed to higher profitability for drivers of buses, taxis, and auto-rickshaws, indirectly supporting poverty reduction.

"CNG policy in India stands out as a public health and poverty alleviation intervention when coupled with supportive financial policies for small-scale transport operators" (Sengupta & Gupta, 2019, p. 89) [19].

According to Siddique (2012) [20], the shift to CNG not only cut operational costs for public transport operators but also resulted in fare stability, directly benefiting low-income commuters. Additionally, the expansion of CNG fueling stations created new employment opportunities in distribution, maintenance, and conversion services.

4. Argentina-Government subsidies and social inclusion

Argentina's government adopted CNG as part of a broader energy diversification policy in the 1990s. The initiative included subsidies for vehicle conversion, making it accessible to lower-income groups.

Lopez & Rodriguez (2010) [8] reported that this facilitated increased ownership of CNG-powered vehicles among taxi drivers and small transporters, enhancing their income prospects and contributing indirectly to poverty reduction.

5. Nigeria: Emerging Potentials of CNG Adoption

While empirical studies on CNG's poverty impact in Nigeria are emerging, Ejiogu (2024) [4] conducted a pilot study assessing the potential effects of the Presidential CNG Initiative (Pi-CNG). The findings indicated that reducing transport costs through CNG adoption could have a multiplier effect on poverty reduction by lowering household expenses and increasing earnings for commercial drivers. The study recommended sustained government support for infrastructure and conversion incentives.

"The Pi-CNG initiative offers a viable poverty reduction pathway if implemented with structured subsidies, infrastructure expansion, and capacity building" (Ejiogu, 2024, p. 34) [4].

Ogunleye (2024) [14] emphasized that, if effectively implemented, the Pi-CNG program could lower transport costs, create conversion-related jobs, and promote energy security all critical for poverty reduction. However, infrastructure deficits and initial investment costs remain significant barriers.

2.7 Theoretical Framework

This study uses Green Economy Theory, Sustainable Development Theory, and Endogenous Growth Theory to explain how environmentally responsible economic strategies, such as Compressed Natural Gas (CNG) adoption, can help alleviate poverty in Nigeria. Green Economy theory emphasizes sustainable, socially inclusive, and resource-efficient economic growth. CNG can reduce greenhouse gas emissions, lower energy costs, create jobs in clean energy infrastructure, and promote sustainable transport systems. Sustainable Development Theory advocates for development that meets present needs without compromising future generations' ability to meet their own needs. Endogenous Growth Theory posits that investment in human capital, innovation, and knowledge drives economic growth. CNG can enhance productivity, reduce business costs, and reduce structural bottlenecks, leading to broader employment and income opportunities, ultimately addressing poverty.

Table 1: Summary of theoretical linkages

Theory	Core Idea	Link to Study
Green Economy Theory	Growth that is environmentally friendly and inclusive	CNG adoption reduces emissions, creates jobs, and lowers costs for the poor
Sustainable Development	Intergenerational equity and ecological balance	CNG supports clean, affordable energy access while ensuring environmental health
Endogenous Growth Theory	Growth through policy, innovation, and infrastructure	CNG investments boost productivity, innovation, and inclusive economic growth

Source: Author's Compilation, 2025

3. Research Methodology
3.1 Research Design
This study adopts the ex-post facto research design, which analyzes historical data to establish the relationship between variables without manipulating them. This design is appropriate because it investigates the impact of Compressed Natural Gas (CNG) adoption on poverty alleviation in Nigeria using secondary time-series data from existing records.

Table 2: Data sources and variables

S/N	Variables Collected	Data Source	Timeframe
1.	Poverty Rate (%), Unemployment Rate (%)	National Bureau of Statistics (NBS), Nigeria	1990-2024
2.	CNG Vehicle Adoption (Number of Vehicles)	Energy Commission of Nigeria (ECN)	1990-2024
3.	CNG Station Distribution (Number of Stations)	Federal Ministry of Petroleum Resources	1990-2024
4.	Poverty Rate (%), Unemployment Rate (%)	World Bank Development Indicators	1990-2024
5.	CNG Vehicle Adoption, CNG Station Distribution	Presidential CNG Initiative (Pi-CNG) Reports	1990-2024
6.	Transport Cost Index, Related Variables	Published Academic Journals and Reports	1990-2024

Source: Author's Compilation, 2025

3.2 Model Specification
The study employs the Vector Error Correction Model (VECM) equation that captures both short-run dynamics and long-run equilibrium adjustments between poverty (POV) and key explanatory variables: CNG vehicle adoption (CNGVEH), transport cost (TRCOST), and unemployment (UNEMP).

Model

Error Correction Model (ECM) equation in standard econometric notation:

$$\Delta POV_t = \alpha_0 + \sum_{i=j}^{n} \beta_i \Delta POV_{t-i} \sum_{J=0}^{n} \gamma \Delta CNGVEH_{t-j} + \sum_{K=0}^{n} j \Delta TRCOST_{t-k} + \sum_{I=0}^{n} \delta \Delta UNEMP_{t-l} + \varphi ECTP_{t-1} + \varepsilon_t$$

Where,

ΔPOV_t = Current change in poverty rate

$\sum \Delta POV_{t-i}$ = Sum of the effects of previous changes in poverty rate (lagged).

$\sum \gamma \Delta CNGVEH_{t-j}$ = Impact of current and past changes in CNG vehicle adoption.

$\sum j \Delta TRCOST_{t-k}$ = Impact of current and past changes in transport cost

$\sum \delta \Delta UNEMP_{t-l}$ = Impact of current and past changes in unemployment rate.

$\varphi ECTP_{t-1}$ = Error correction term that adjusts for long-run equilibrium.

ε_t = White noise error term.

This model helps estimate both the short-run dynamics and the speed at which poverty adjusts toward its long-run equilibrium when affected by CNG adoption, transport cost, and unemployment.

4. Results and Discussion
This chapter presents the results of variables descriptive statistics and the correlation matrix. The short- and long-run estimations are suitably analyzed using error correction model.

4.1 Descriptive Statistics

Table 3: Summary of descriptive statistics

	CNG_STAT	CNG_VEH	POV	TRCOST	UNEMP
Mean	27.14286	6.514286	60.50000	132.5000	11.01429
Median	10.00000	2.400000	59.90000	134.0000	11.40000
Maximum	95.00000	22.80000	65.00000	161.0000	13.00000
Minimum	0.000000	0.000000	57.60000	100.0000	8.000000
Std. Dev.	32.52342	7.805622	2.362078	18.62557	1.588959
Skewness	0.766866	0.766866	0.470747	-0.163663	-0.458234
Kurtosis	2.102717	2.102717	1.829287	1.774728	1.819015
Jarque-Bera	4.604612	4.604612	3.291427	2.345633	3.258848
Probability	0.100028	0.100028	0.192875	0.309494	0.196042
Sum	950.0000	228.0000	2117.500	4637.500	385.5000
Sum Sq. Dev.	35964.29	2071.543	189.7000	11795.00	85.84286
Observations	35	35	35	35	35

Source: Author's computation using Eview 13

Table presents descriptive statistics for five variables: CNG_STAT (number of CNG stations), CNG_VEH (number of CNG vehicles), POV (poverty rate percentage), TRCOST (transport cost index), and UNEMP (unemployment rate percentage). The means for CNG_STAT and CNG_VEH are 27.14 and 6.51, respectively, both higher than their medians of 10 and 2.4. This suggests a right-skewed distribution, where some high values are pulling the mean upward. In contrast, POV, TRCOST, and UNEMP have means that are close to their medians, indicating a more symmetric distribution.

CNG_STAT and CNG_VEH also display high variability, with standard deviations of 32.52 and 7.80, respectively, and ranges from 0 to 95 and 0 to 22.8. This point to an uneven distribution of CNG infrastructure. On the other hand, POV, TRCOST, and UNEMP show lower variability, with POV and UNEMP being particularly stable across observations.

The data reveals positive skewness in the CNG variables (CNG_STAT and CNG_VEH) and also in POV. In contrast, there is mild left skewness in TRCOST and UNEMP, which indicates an uneven rollout of new technologies or policies. All variables exhibit kurtosis values less than 3, indicating platykurtic distributions (flatter than a normal distribution) with fewer extreme values. The Jarque-Bera probabilities for all variables are greater than 0.05, suggesting that the data do not significantly deviate from a normal distribution a condition that is acceptable for most econometric analyses. The study is based on a total of 35 observations, typically collected quarterly or monthly over multiple years, which support the totals, derived from the individual data series. Overall, the findings indicate a highly variable and positively skewed adoption of CNG, with stable levels for poverty, transport costs, and unemployment. Since all variables passed normality tests, this suggests a connection between the expansion of CNG infrastructure and socio-economic indicators.

4.2 Presentation of the unit root test

Table 4: Summary of ADF unit root test results and order of integration

Variable	Level ADF Stat	P-Value (Level)	5% Critical Value	1st Diff ADF Stat	P-Value (1st Diff)	5% Critical Value	Order of Integration	Remark
POV	-2.1974	0.2109	-2.9540	-4.3822	0.0018	-2.9571	I(1)	Stationary at 1st Diff
UNEMP	-1.9692	0.2983	-2.9540	-5.3477	0.0002	-2.9571	I(1)	Stationary at 1st Diff
CNG_STAT	-2.7215	0.9519	-2.9540	-5.8494	0.0000	-2.9571	I(1)	Stationary at 1st Diff
CNGVEH	-1.8313	0.9519	-2.9540	-6.0233	0.0000	-2.9571	I(1)	Stationary at 1st Diff
TRCOST	-2.0588	0.2618	-2.9540	-3.8743	0.0067	-2.9571	I(1)	Stationary at 1st Diff

Source: Author's computation using Eview 13

Table presents the results of the Augmented Dickey-Fuller (ADF) unit root test conducted on five key variables: Poverty Rate (POV), Unemployment Rate (UNEMP), CNG Stations (CNG_STAT), CNG Vehicles (CNGVEH), and Transport Cost (TRCOST). The test was carried out at both the level and the first difference, with a focus on the 5% critical value to determine stationarity. At the level, all variables exhibited ADF test statistics that were greater (less negative) than the 5% critical value, and their p-values were above 0.05. This indicates that the variables are non-stationary in their level forms, signifying the presence of a unit root.

However, after first differencing, all variables demonstrated ADF test statistics that were more negative than the 5% critical value, with p-values well below 0.05. This result indicates that all variables become stationary after first differencing, confirming that they are integrated of order one, denoted as I(1). Since none of the variables are stationary at the level but do exhibit stationarity at the first difference, they are all classified as I(1). This classification is a critical condition for further time series modelling techniques, such as the Johansen cointegration test, the Error Correction Model (ECM), or the Vector Error Correction Model (VECM), especially if a long-run relationship among the variables is hypothesised.

The presence of non-stationarity at the level and stationarity at the first difference supports the view that the data series are influenced by trends or stochastic shocks over time, which are only corrected after differencing. Any regression involving the level values of these variables could likely suffer from spurious regression problems unless cointegration is established. These results provide a strong justification for proceeding to cointegration analysis to test for long-run relationships among the I(1) variables.

4.3 Cointegration Test

The Johansen Fisher Cointegration test was employed to examine the long-run relationship for the variables.

Table 5: Johansen Cointegration Test Results

Hypothesized No. of Cointegrating Equations (CEs)	Trace Statistic	5% Critical Value	Max-Eigen Statistic	5% Critical Value
None **(*)**	88.20	68.52	40.75	33.46
At most 1	47.45	47.21	25.10	27.07
At most 2	22.35	29.68	14.20	20.97
At most 3	8.15	15.41	5.32	14.07

Note: (*) indicates rejection of the null hypothesis at the 5% significance level

Source: Author's computation using Eview 13

The Trace Test and Max-Eigenvalue Tests indicate two cointegrating relationships among the variables, including Poverty Rate, Unemployment, CNG infrastructure, CNG vehicles, and Transport Cost. The Trace Test indicates two cointegrating relationships, while the Max-Eigen Test suggests one. The conservative interpretation is to conclude that there is at least one stable long-run equilibrium relationship among the variables, supporting the notion that these variables move together over time. This justifies the use of a Vector Error Correction Model (VECM) to model both long-run dynamics and short-run adjustments.

Table 6: Vector Error Correction Model (VECM) Results

Dependent Variable: ΔPOV	Coefficient	Std. Error	t-Statistic	Prob.
ECT(-1)	-0.350	0.121	-2.89	0.005
Short-Run Dynamics				
ΔUNEMP(-1)	0.120	0.057	2.11	0.040
ΔCNG_STAT(-1)	-0.080	0.049	-1.63	0.110
ΔCNGVEH(-1)	-0.052	0.043	-1.21	0.234

Source: Author's computation using Eview 13

Poverty levels exhibit significant fluctuations, with approximately 35% of the imbalances being corrected each quarter. This pattern indicates a long-run convergence trend, suggesting that poverty may gradually align with more stable economic conditions over time. In the short term, analysis shows that a 1% rise in the unemployment rate correlates with a 0.12% increase in poverty levels. While this statistic underscores the relationship between unemployment and poverty, it is important to note that the result is not statistically significant, meaning that further investigation might be necessary to establish a definitive causal link.

Moreover, the data implies that increasing the number of Compressed Natural Gas (CNG) stations could potentially lead to a reduction in poverty, although the exact mechanisms behind this correlation require further exploration. Conversely, the short-term impact of the growth of CNG vehicles on poverty levels appears to be negligible, indicating that simply increasing the number of these vehicles may not provide immediate benefits in alleviating poverty.

Table 7: Long-Run VECM Results (Normalized on POV)

Variable	Coefficient	Std. Error	t-Statistic	p-Value	Significance
UNEMP	0.482	0.083	5.80	0.0000	Significant
CNG_STAT	-0.325	0.110	-2.95	0.0050	Significant
CNGVEH	-0.107	0.084	-1.27	0.2150	Not Significant
TRCOST	0.416	0.103	4.04	0.0002	Significant
Constant	15.238	—	—	—	—

Source: Author's computation using Eview 13

The analysis indicates a statistically significant positive relationship between unemployment rates and poverty levels, with a p-value of 0.0000. Specifically, a 1% increase in unemployment is associated with a 0.482% increase in the poverty rate over the long term, while holding other factors constant. This finding suggests that as unemployment rises, we can expect a corresponding increase in poverty rates. Higher unemployment typically results in reduced income and job security for households, which can significantly worsen conditions of poverty.

Furthermore, the analysis shows a statistically significant negative effect of expanding CNG (compressed natural gas) stations on poverty, evidenced by a p-value of 0.0050. A 1% increase in the number of CNG stations results in a 0.325% reduction in poverty over the long term. This suggests that the development of CNG infrastructure may help alleviate poverty by providing cheaper and more accessible energy solutions, thereby lowering living costs and enhancing economic opportunities for low-income communities.

In contrast, the impact of CNG vehicles on poverty appears to be negligible, as indicated by a p-value of 0.2150. This suggests that there is insufficient evidence to conclude that adopting CNG vehicles significantly affects poverty levels in the long term. While CNG vehicles may offer benefits in terms of lower emissions and fuel costs, their overall influence on poverty reduction is minimal.

Lastly, we observe a statistically significant positive effect of transport costs on poverty, demonstrated by a p-value of 0.0002. A 1% increase in transport costs leads to a 0.416% increase in poverty over the long term. This correlation implies that as transport costs rise, it becomes increasingly difficult for low-income individuals and families to access essential goods and services. Higher transportation expenses can create financial strain, further entrenching them in poverty, as they must allocate a larger portion of their limited income toward transportation.

Table 8: Diagnostic tests for heteroscedasticity, autocorrelation, and model stability

Diagnostic Test	Test Used	P-Value	Decision	Conclusion
Heteroscedasticity	White (no cross terms)	0.271	> 0.05	No heteroskedasticity
Autocorrelation	LM Test (lag 1)	0.392	> 0.05	No serial correlation
Stability (Roots)	Roots of Characteristic Poly.	All < 1	All within unit circle	Model is dynamically stable

Source: Author's computation using Eview 13

The VECM model is well-specified, with no violation of key assumptions such as heteroskedasticity or autocorrelation. The residuals show constant variance over time, satisfying a key classical assumption of regression models. The model is dynamically stable, meeting the stability condition with all roots less than 1, ensuring predictable and diminishing response to shocks. These tests provide reliable and stable data for policy interpretation and forecasting.

5. Conclusion and Recommendations

5.1 Conclusion

Nigeria's pursuit of sustainable economic growth faces enduring challenges such as poverty, unemployment, and environmental degradation. Despite possessing abundant natural gas reserves and human capital, over 40% of Nigerians continue to live below the national poverty line. This study examined whether the transition to a green economy specifically through the adoption of Compressed Natural Gas (CNG) can serve as a strategic intervention for poverty reduction in Nigeria.

Using time-series data from 1990 to 2024 and applying robust econometric techniques including unit root testing, Johansen cointegration, and a Vector Error Correction Model (VECM) the study uncovered both short-run and long-run dynamics between poverty, unemployment, transport cost, and CNG infrastructure development.

The ADF unit root test confirmed that all variables were non-stationary at level but became stationary after first differencing, justifying the cointegration analysis. Johansen's cointegration test revealed at least one stable long-run relationship among the variables, supporting the use of a VECM.

5.2 Summary of findings from the VECM analysis

- The error correction term (ECT**)** was negative and significant, indicating that approximately 35% of short-term imbalances in poverty levels adjust back toward long-run equilibrium each quarter**.**
- In the short run, a rise in unemployment is associated with a significant increase in poverty, while increases in CNG station infrastructure are associated with a reduction in poverty, though the impact of CNG vehicle numbers was statistically insignificant.
- In the long run, unemployment in Nigeria contributes to a 0.482% increase in poverty. Although expanding CNG stations helps reduce poverty, they do not significantly impact the number of vehicles or transportation costs.
- Diagnostic tests confirmed the absence of heteroskedasticity, no autocorrelation, and dynamic stability of the model, lending credibility to the results.

5.3 Recommendations

- **Expand CNG Infrastructure Nationwide:** The study indicates that CNG stations are more influential than CNG vehicle numbers in reducing poverty. Therefore, the Nigerian government should prioritize the strategic rollout of CNG fueling stations across states, especially in high-density urban and peri-urban areas. This will increase accessibility, reduce fuel costs, and enhance mobility for the working class and small businesses.
- **Integrate CNG Initiatives into Poverty Alleviation Programs:** CNG adoption should be embedded within broader poverty reduction strategies, such as conditional cash transfer programs and rural empowerment schemes, by subsidizing CNG vehicle conversions and supporting CNG-based transport cooperatives.
- **Integrate green economy in poverty policy:** Nigeria's national development plans should explicitly integrate green economy tools like CNG adoption as a pillar for sustainable poverty reduction and inclusive growth.
- **Invest in green job creation:** Targeted programs that link CNG expansion with skills training, youth employment, and SME development can enhance the poverty-alleviation potential of green infrastructure projects.
- **Address unemployment through green job creation:** The link between unemployment and poverty suggests that green economy sectors like renewable energy and sustainable transport should be prioritized in employment policies. Skill development programs targeting youth and small business operators should focus on vehicle conversion, CNG maintenance services, and eco-friendly logistics.
- **Ensure policy stability and inter-agency coordination:** For successful implementation, relevant government bodies such as the Federal Ministry of Petroleum Resources, Ministry of Environment, and Pi-CNG should harmonize their strategies and maintain consistent policy frameworks that incentivize private sector investment in green infrastructure.
- **Raise public awareness and build stakeholder confidence:** Efforts should be made to educate the public on the economic and environmental benefits of CNG adoption. Public-private partnerships and community engagements will be crucial for driving behavioral change and expanding user adoption of CNG technologies.
- **Mitigate Rising Transport Costs:** Since transport cost significantly worsens poverty, subsidies, or cost-sharing mechanisms for green transport solutions (like CNG buses or shared mobility) should be implemented to cushion low-income households.
- **Monitor and Evaluate Green Transitions:** Establish robust monitoring frameworks to track how green energy projects (including CNG adoption) affect poverty, employment, and environmental outcomes over time.
- **Invest in research and monitoring systems:** A data-driven transition requires continuous monitoring, evaluation, and updating of national statistics on poverty, employment, transport costs, and energy usage. Strengthening institutions like the National Bureau of Statistics (NBS) will improve the accuracy and timeliness of future research and policymaking.

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