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CARBON TRANSITION AND INCLUSIVE WELFARE DYNAMICS IN NIGERIA: EVIDENCE FROM AN ARDL BOUNDS TESTING APPROACH

ABSTRACT

This study investigates the dynamic relationship between carbon transition indicators and inclusive welfare in Nigeria over the period 1999–2024. The Human Development Index (HDI) is employed as a proxy for inclusive welfare, while carbon dioxide emissions (CO2), energy intensity (ENRGI), and renewable energy consumption (REC) serve as carbon transition indicators, with population (POP) included as a demographic control variable. Annual time-series data were analysed using descriptive statistics, the Phillips–Perron (PP) unit root test, and the Autoregressive Distributed Lag (ARDL) bounds testing procedure. Results show that the variables are integrated of mixed order: HDI, CO2, REC, and POP are stationary at first difference I(1), while ENRGI is stationary at level I(0), which justifies the use of the ARDL bounds approach rather than conventional cointegration techniques. The computed bounds F-statistic (6.618) exceeds the upper critical bound at the 5% significance level, confirming a long-run cointegrating relationship among the variables. The long-run and short-run ARDL estimates indicate that energy intensity exerts a significant negative effect on inclusive welfare, while population exerts a significant positive effect; carbon emissions and renewable energy consumption are not statistically significant. The error correction term (−0.327) is negative and significant, implying that approximately 33% of any disequilibrium in inclusive welfare is corrected within one year. Diagnostic tests confirm the absence of serial correlation and heteroskedasticity in the residuals. The study concludes that Nigeria's carbon transition pathway remains structurally inefficient from a welfare standpoint and recommends targeted investment in energy efficiency, diversified renewable energy adoption, and population-responsive welfare policy to reconcile decarbonisation with inclusive human development.

Keywords: *ARDL bounds testing, Carbon transition; Energy intensity; Human Development Index Inclusive welfare; Nigeria*

1. Introduction

Climate change has emerged as one of the defining developmental challenges of the twenty-first century, compelling both advanced and developing economies to reorganise their energy systems around low-carbon pathways. This reorganisation, commonly described as carbon transition, entails a structural shift away from fossil-fuel-intensive production and consumption toward cleaner, more efficient and renewable sources of energy. For oil-dependent economies such as Nigeria, carbon transition is not merely an environmental undertaking; it is entangled with questions of energy access, industrial competitiveness, employment, and, ultimately, human welfare. Nigeria occupies a paradoxical position in the global carbon transition discourse. On one hand, the country is a major contributor to greenhouse gas emissions in Sub-Saharan Africa through gas flaring, an oil-dependent power sector, and rapidly expanding transportation and industrial activity. On the other hand, it remains one of the most energy-poor nations in the world, with millions of households and firms relying on biomass, kerosene, and diesel generators for basic energy needs. Nigeria's third Nationally Determined Contribution (NDC), submitted in 2025, sets an economy-wide target of a 32% reduction in emissions by 2035 relative to 2018 levels, signalling a formal policy commitment to decarbonisation (UNDP, 2025).

Alongside this environmental commitment, Nigeria continues to grapple with weak and unevenly distributed human development outcomes. The country's Human Development Index (HDI), a composite measure of longevity, education, and income capturing the breadth of inclusive welfare, has improved only modestly over the past two decades, moving from the low-0.4 range in the early 2000s to approximately 0.56 by the early 2020s, a level that remains below the global average (UNDP, 2025). This raises an important empirical question: as Nigeria pursues carbon transition, is the process complementing or undermining inclusive welfare? A transition that is poorly sequenced, driven mainly by intensity gains in already carbon-intensive sectors rather than genuine diversification into renewables, risks imposing adjustment costs on households and firms without commensurate welfare gains. Conversely, a transition anchored on efficiency improvement and expanded renewable access could plausibly widen access to modern energy services, with positive spillovers for health, education, and productivity.

The relationship between carbon-related variables and human development has attracted growing empirical attention, but much of this literature has concentrated on the carbon–growth nexus rather than the carbon–welfare nexus specifically, and studies that examine carbon transition indicators jointly, carbon emissions, energy intensity, and renewable energy consumption, against inclusive welfare in a single dynamic framework for Nigeria remain scarce. Existing Nigerian studies have separately examined CO_2 emissions and economic growth (Abubakar & Kassim, 2016; Adebayo et al., 2021), population growth and CO_2 emissions (Sulaiman & Abdul-Rahim, 2018), and renewable energy consumption in isolation, but a unified assessment of how the constituent elements of carbon transition jointly shape inclusive welfare dynamics, using an appropriate cointegration framework that accommodates the mixed order of integration typical of Nigerian macroeconomic time series, is largely absent.

2. Literature Review

2.1 Conceptual Review

Carbon transition refers to the structural process by which an economy shifts its energy mix and production technologies away from carbon-intensive fossil fuels toward lower-carbon and renewable alternatives, typically measured through indicators such as carbon dioxide emissions, energy intensity (energy consumed per unit of output, a proxy for production efficiency), and the share of renewable sources in final energy consumption. Inclusive welfare, by contrast, is a broader construct than income growth alone; it captures the extent to which the benefits of economic activity are translated into improvements in the substantive freedoms and capabilities of the population, most commonly operationalised through the Human Development Index (HDI), which aggregates life expectancy, educational attainment, and income per capita into a single index bounded between 0 and 1 (UNDP, 2025). Population, while not a transition variable per se, is widely treated as a control or demographic driver in this literature because population growth simultaneously expands the labour force and the base of energy demand, with ambiguous net implications for both emissions and welfare (Dimnwobi et al., 2021; Sulaiman & Abdul-Rahim, 2018).

2.2 Theoretical Review

The study is anchored on the Environmental Kuznets Curve (EKC) hypothesis and the human capability approach. The EKC hypothesis, formalised by Grossman and Krueger (1995), posits an inverted-U relationship between economic development and environmental degradation: as an economy develops, environmental degradation initially rises with output but eventually declines beyond a threshold income level as cleaner technologies, stronger institutions, and shifting consumption preferences take hold. Applied to carbon transition, the EKC framework implies that the welfare consequences of decarbonisation are not fixed but depend on where an economy sits along its development trajectory. The human capability approach, associated with Sen (1999), provides the theoretical justification for treating welfare as a multidimensional construct rather than a purely monetary one, underpinning the use of the HDI as the study's dependent variable. Energy transition theory further supplements these two frameworks by emphasising that shifts in energy systems are path-dependent, technology-driven processes whose welfare effects unfold gradually and are mediated by the pace and structure of the transition itself, rather than by any single point-in-time indicator (Gershon et al., 2022).

2.3 Empirical Review

A substantial body of empirical work has examined the relationship between carbon emissions and macroeconomic outcomes in Nigeria, though comparatively few studies have extended the analysis to inclusive welfare specifically. Abubakar and Kassim (2016) applied ARDL bounds testing to Nigerian data and found a significant relationship between CO_2 emissions and economic growth, while Adebayo et al. (2021) similarly used ARDL bounds testing and reported that the long-run and short-run effects of CO_2 emissions on Nigerian economic growth differ in sign and magnitude, underscoring the importance of distinguishing short-run adjustment from long-run equilibrium relationships, precisely the distinction this study draws for the carbon–welfare nexus.

On the demographic dimension, Sulaiman and Abdul-Rahim (2018) used a recursive ARDL approach to show that population growth exerts a short-run effect on CO_2 emissions in Nigeria but an insignificant long-run effect, concluding that population stabilisation policies offer only limited long-run leverage over emissions. At the continental level, Dimnwobi et al. (2021) examined population dynamics and environmental quality across African countries and found that population pressures interact with weak institutional capacity to worsen environmental outcomes, a finding with direct relevance to Nigeria's rapidly growing population base.

Studies on the energy side of the transition have generally found renewable energy consumption to be welfare-enhancing when it substitutes for fossil-based sources. Ahmad et al. (2020), studying China, found that renewable energy consumption reduces carbon emissions in the long run, a relationship that has motivated similar investigations across African contexts, including studies applying panel ARDL techniques to examine how renewable energy uptake and energy efficiency shape green growth and environmental quality outcomes across Sub-Saharan African economies. Outside Africa, Issaoui et al. (2015) examined the relationship between carbon dioxide emissions, economic growth, urbanisation, and welfare in the Middle East and North Africa and found that welfare effects of carbon emissions are highly context-dependent, varying with a country's energy mix and stage of industrialisation. Similarly, Dogan and Seker (2016) found that renewable energy consumption is a significant determinant of lower CO_2 emissions in European Union economies, reinforcing the theoretical expectation that renewable energy adoption and carbon-intensity reduction are welfare-complementary in the long run.

Taken together, the empirical literature establishes three recurring findings relevant to this study: first, the carbon–growth (and by extension carbon–welfare) relationship in Nigeria is characterised by important short-run/long-run asymmetries that necessitate an error-correction framework; second, population dynamics matter for environmental and welfare outcomes but their effects are not uniformly signed across studies; and third, energy intensity and renewable energy consumption operate through structurally different channels, energy intensity as an efficiency indicator and renewable share as a substitution indicator, that should be modelled jointly rather than treated as interchangeable proxies for carbon transition.

Despite this growing body of work, no known Nigerian study has jointly modelled carbon emissions, energy intensity, and renewable energy consumption as constituent elements of a single carbon transition construct against the Human Development Index as an explicit measure of inclusive welfare, within an ARDL bounds testing framework that accommodates the mixed order of integration characteristic of Nigerian macroeconomic series. This study addresses that gap and, in doing so, offers evidence on whether Nigeria's carbon transition, as currently unfolding, is compatible with, or in tension with, the country's inclusive welfare objectives.

3. Methodology

3.1 Research Design and Sources of Data

The study adopts an ex post facto research design, relying on annual secondary time-series data spanning the period 1999 to 2024 (26 observations). Data on the Human Development Index (HDI) were sourced from the United Nations Development Programme's Human Development Report database (UNDP, 2025); carbon dioxide emissions (CO2) and energy intensity (ENRGI) were sourced from World Bank World Development Indicators and International Energy Agency databases; renewable energy consumption (REC, expressed as a percentage of total final energy consumption) was sourced from World Bank and IEA data; and population (POP) figures were sourced from World Bank and National Bureau of Statistics records.

3.2 Model Specification

Consistent with the study's objective of examining how carbon transition indicators shape inclusive welfare, the functional relationship is specified as:

$$HDI = f(CO2, ENRGI, REC, POP) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

This is expressed in explicit econometric form as

$$HDIt = \beta 0 + \beta CO2t + \beta 2ENRGIt + \beta 3RECt + \beta 4POPt + \mu t \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

Given the mixed order of integration established by the unit root tests (Section 4.2), the long-run relationship in Equation (2) is estimated within an Unrestricted Error Correction Model (UECM) representation of the ARDL (p, q1, q2, q3, q4) model:

$$\begin{aligned} \Delta HDIt = {} & \beta 0 + \beta 1HDIt-1 + \beta 2CO2t-1 + \beta 3ENRGIt-1 + \beta 4RECt-1 + \beta 5POPt-1 \\ & + \Sigma\, \gamma i\, \Delta HDIt-i + \Sigma\, \delta i\, \Delta CO2t-i + \Sigma\, \theta i\, \Delta ENRGIt-i + \Sigma\, \varphi i\, \Delta RECt-i \\ & + \Sigma\, \lambda i\, \Delta POPt-i + ECTt-1 + \varepsilon t \quad \ldots\ldots\ldots\ldots \quad (3) \end{aligned}$$

Where Δ is the first-difference operator, β1–β5 are the long-run coefficients, γ, δ, θ, φ, and λ are short-run coefficients, ECTt−1 is the one-period-lagged error correction term whose coefficient measures the speed of adjustment toward long-run equilibrium, and εt is a white-noise error term. HDI is the dependent variable, proxying inclusive welfare; CO2, ENRGI, and REC are the carbon transition indicators; and POP enters as a demographic control.

3.3 Technique of Data Analysis

The empirical analysis proceeds in five stages. First, descriptive statistics (mean, median, maximum, minimum, and standard deviation) are computed to characterise the central tendency and dispersion of each series. Second, the Phillips–Perron (PP) unit root test is applied to determine the order of integration of each variable; the PP test is preferred over the standard Augmented Dickey–Fuller test because it corrects non-parametrically for serial correlation and heteroskedasticity in the error term without requiring the addition of lagged difference terms, which is advantageous given the relatively short span of the series. Third, because the unit root results indicate a mixed order of integration, i.e., some variables stationary at level I(0) and others at first difference I(1), the ARDL bounds testing procedure of Pesaran *et al.* (2001) is applied to test for the existence of a long-run cointegrating relationship; the computed F-statistic is compared against lower I(0) and upper I(1) critical value bounds, with cointegration confirmed if the F-statistic exceeds the upper bound. Fourth, having confirmed cointegration, the long-run and short-run ARDL coefficients, together with the error correction term, are estimated and interpreted. Fifth, post-estimation diagnostics, the Breusch–Godfrey serial correlation LM test and the ARCH heteroskedasticity test, are conducted to confirm that the estimated model satisfies the classical assumptions of no serial correlation and homoskedastic residuals.

4. Results and Discussion

4.1 Descriptive Statistics

Table 1: Descriptive Statistics

	CO2	**ENRGI**	**HDI**	**POP**	**REC**
Mean	110.9614	7.373077	0.502692	1.744515	83.07423
Median	111.1125	6.810000	0.500000	1.724010	82.35000
Maximum	137.9515	10.80000	0.570000	2.339609	88.10000
Minimum	80.91740	6.140000	0.420000	1.228520	79.90000
Std. Dev.	15.62060	1.294115	0.042479	0.344010	2.358369

Note: CO2 = Carbon Emissions; HDI = Human Development Index; ENRGI = Energy Intensity; POP = Population; REC = Renewable Energy Consumption. Source: Author's computation using EViews 13, 2026.

Table 1 presents the descriptive profile of the study variables over the 26-year sample period. The Human Development Index (HDI), the dependent variable proxying inclusive welfare, records a mean of 0.5027 and a median of 0.5000, with values ranging from a minimum of 0.42 to a maximum of 0.57. The closeness of the mean and median, combined with a notably tight standard deviation of 0.0425, indicates low dispersion and a broadly symmetric, near-normal distribution, consistent with the gradual, incremental nature of human development improvement typically observed in developing economies. Carbon dioxide emissions (CO2) exhibit a mean of 110.96 and a median of 111.11, with a wider range (80.92 to 137.95) and a standard deviation of 15.62, reflecting the substantial growth in emissions associated with gas flaring, expanding urban transportation, and industrial activity over the review period. Renewable energy consumption (REC) shows a high mean share of 83.07%, tightly clustered between 79.90% and 88.10% (SD = 2.36); however, this apparently high renewable share is consistent with Nigeria's continued heavy reliance on traditional biomass, fuelwood, and charcoal, classified as renewable but not necessarily clean, energy, rather than modern renewables such as solar or wind, a pattern the literature describes as an energy trap (Ahmad et al., 2020). Energy intensity (ENRGI) records a mean of 7.37 against a median of 6.81, with the largest relative spread among the variables (6.14 to 10.80, SD = 1.29), signalling structural production inefficiency and vulnerability to energy supply shocks. Population (POP) rises from a minimum of approximately 1.23 (billion-scaled units) to a maximum of 2.34, with a mean of 1.74 and a standard deviation of 0.34, capturing Nigeria's rapid and sustained demographic expansion over the sample period, which compounds pressure on both environmental quality and welfare-distribution systems.

4.2 Unit Root Test Results

Table 2: Phillips–Perron (PP) Unit Root Test

Variable	Test Statistic (t-stat)	5% Critical Value	p-value	Order of Integration
HDI	4.36836	2.991878	0.0023	I(1)
CO2	6.541151	2.991878	0.0000	I(1)
ENRGI	5.856715	2.986225	0.0001	I(0)
REC	5.791689	2.991878	0.0001	I(1)
POP	3.096508	2.991878	0.0404	I(1)

Source: Author's computation using EViews 13, 2026.

Table 2 reports the Phillips–Perron unit root test results. HDI, CO2, REC, and POP are found to be non-stationary at level but stationary after first differencing, i.e., integrated of order one [I(1)], while ENRGI is stationary at level [I(0)]. This mixed order of integration, none of the series being integrated of order two or higher, satisfies the essential precondition for the ARDL bounds testing approach and rules out the applicability of conventional cointegration techniques such as the Johansen procedure, which require all variables to be integrated of the same order. The presence of I(0) and I(1) variables together implies that ENRGI is characterised by short-run transitory fluctuations, whereas HDI, CO2, REC, and POP follow longer-run structural paths, reinforcing the appropriateness of an error-correction-based dynamic framework for capturing both the short-run adjustment and long-run equilibrium dimensions of the carbon transition–inclusive welfare relationship.

4.3 ARDL Bounds Cointegration Test

Table 3: ARDL Bounds Test for Cointegration

Test Statistic	Value	Significance	I(0) Bound	I(1) Bound
F-statistic	6.618299	10%	2.45	3.52
k	4	5%	2.86	4.01
		2.5%	3.25	4.49
		1%	3.74	5.06

Source: Author's computation using EViews 13, 2026.

The computed F-statistic of 6.618 exceeds the upper bound critical value of 4.01 at the 5% significance level (and indeed the 1% upper bound of 5.06), leading to rejection of the null hypothesis of no cointegration. This confirms the existence of a stable long-run relationship among carbon transition indicators (CO_2, ENRGI, REC) and inclusive welfare (HDI), controlling for population, validating the estimation of both long-run and short-run ARDL coefficients in the section that follows.

4.4 Long-Run and Short-Run ARDL Estimates

Table 4: Long-Run and Short-Run ARDL Estimates (Dependent Variable: HDI)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
HDI(-1)	0.672947	0.058183	11.56608	0.0000
CO2	7.60E-05	0.000116	0.654734	0.5142
ENRGI	-0.002394	0.000774	-3.094046	0.0026
POP	0.031870	0.006952	4.584224	0.0000
REC	0.000439	0.000548	0.802310	0.4243
C	0.082525	0.013814	5.973939	0.0000
CointEq(-1)*	-0.327053	0.055717	-5.869931	0.0000

Statistic	Value	Statistic	Value
R-squared	0.994494	F-statistic	3503.872
Adjusted R-squared	0.994210	Durbin-Watson stat	1.757024
Prob(F-statistic)	0.000000		

Source: Author's computation using EViews 13, 2026.

The estimated model explains an exceptionally high proportion of the variation in inclusive welfare, with an R-squared of 0.9945 and an adjusted R-squared of 0.9942, and the overall model is highly significant ($F = 3503.87$, $p < 0.01$). The lagged dependent term, HDI(-1), carries a positive and highly significant coefficient of 0.6729 ($p < 0.01$), reflecting strong persistence in human development outcomes, welfare gains accumulate gradually and are not easily reversed year-on-year. Among the carbon transition indicators, energy intensity (ENRGI) exerts a negative and statistically significant effect on inclusive welfare (coefficient = −0.0024, $p = 0.0026$), indicating that structurally inefficient energy use, more energy consumed per unit of output, erodes welfare, most plausibly by raising the effective cost of energy for households and firms and by signalling weaker productive capacity. Carbon dioxide emissions (CO_2) and renewable energy consumption (REC) both carry positive but statistically insignificant coefficients ($p = 0.5142$ and $p = 0.4243$, respectively), suggesting that, within the estimation period, neither the carbon-intensity of Nigeria's growth nor the (biomass-dominated) renewable energy share has yet exerted a measurable independent effect on the HDI once energy intensity and population are accounted for. Population (POP) exerts a positive and highly significant effect on inclusive welfare (coefficient = 0.0319, $p < 0.01$); while population growth is often associated with rising environmental pressure, its positive coefficient here is consistent with the interpretation that, over the review period, demographic expansion has been accompanied by an expanding labour force, urbanisation, and market size that have, on net, supported rather than eroded the composite welfare index, even as it adds structural pressure to Nigeria's carbon transition trajectory.

The error correction term, CointEq(-1), is negative and highly significant, as required for a stable long-run equilibrium, with a coefficient of −0.3271 ($p < 0.01$). This indicates that approximately 32.7% of any deviation of inclusive welfare from its long-run equilibrium path is corrected within a single year, implying a moderately fast adjustment speed and a full return to equilibrium within roughly three years following a shock to the system.

4.5 Post-Estimation Diagnostic Tests

Table 5: Post-Estimation Diagnostic Tests

Test	Value	Probability
Breusch–Godfrey Serial Correlation LM Test	2.554890	0.0830
Heteroskedasticity Test: ARCH	1.754251	0.1884

Source: Author's computation using EViews 13, 2026.

The Breusch–Godfrey LM test fails to reject the null hypothesis of no serial correlation at the conventional 5% level ($p = 0.0830$), and the ARCH test similarly fails to reject the null hypothesis of homoskedasticity ($p = 0.1884$). The residuals of the estimated ARDL model are therefore free of serial correlation and heteroskedasticity, supporting the reliability and validity of the reported coefficient estimates and standard errors.

It is worth noting that the reported denominator degrees of freedom for the diagnostic F-tests in the EViews output, F(2,95) for the serial correlation test and F(1,100) for the ARCH test, appear inconsistent with the 26-observation annual sample used in the main estimation, and should be re-verified against the underlying Eviews work file before submission, as a genuine 26-observation ARDL model would ordinarily generate single-digit residual degrees of freedom rather than 95–100.

4.6 Discussion of Findings

The results provide three broad insights into the carbon transition–inclusive welfare nexus in Nigeria. First, the confirmation of cointegration, together with a highly significant and correctly signed error correction term, indicates that carbon transition indicators and inclusive welfare do not drift apart indefinitely but are bound by a stable long-run relationship, consistent with the broader ARDL-based Nigerian literature on carbon emissions and macroeconomic outcomes (Abubakar & Kassim, 2016; Adebayo et al., 2021). Second, the finding that energy intensity, rather than the level of carbon emissions per se, is the dominant welfare-eroding channel suggests that Nigeria's carbon transition challenge is less about the volume of emissions and more about the efficiency with which energy is converted into output, a structural inefficiency consistent with an economy still heavily reliant on diesel and petrol back-up generation, ageing grid infrastructure, and gas flaring. This nuances the standard Environmental Kuznets Curve narrative (Grossman & Krueger, 1995): rather than welfare being squeezed directly by rising emissions, it is squeezed by the inefficiency embedded in current energy use patterns, a distinction with material implications for policy sequencing.

Third, the statistically insignificant coefficient on renewable energy consumption, despite its high average share (83%) in the descriptive statistics, is consistent with the concern raised in the wider literature that Nigeria's renewable energy statistics are dominated by traditional biomass rather than modern renewables such as solar, wind, or small hydro (Ahmad et al., 2020; Dogan & Seker, 2016). A high biomass-driven renewable share does not straightforwardly translate into welfare gains in the way that modern, clean renewable adoption would be expected to under energy transition theory, which may explain why REC fails to register a significant independent effect on the HDI in this model. Finally, the positive and significant population coefficient echoes the short-run findings of Sulaiman and Abdul-Rahim (2018) and the broader African evidence of Dimnwobi et al. (2021) that population dynamics are consequential for environment–welfare outcomes, even where their sign and significance vary by context and estimation window; in Nigeria's case, population growth over the review period appears to have been a net contributor to, rather than a drag on, measured inclusive welfare, likely operating through labour force and market-size channels that are not fully captured by the carbon transition variables alone.

5. Conclusion and Recommendations

5.1 Summary and Conclusion

This study examined the long-run and short-run dynamics between carbon transition indicators, carbon emissions, energy intensity, and renewable energy consumption, and inclusive welfare, proxied by the

Human Development Index, in Nigeria over the period 1999–2024, using an ARDL bounds testing framework. The results confirm a stable long-run cointegrating relationship among the variables and show that energy intensity is the principal carbon-transition-related channel through which inclusive welfare is eroded, while population exerts a significant positive effect and carbon emissions and renewable energy consumption exert no significant independent effect over the review period. The error correction mechanism is correctly signed and significant, confirming that deviations from long-run equilibrium are self-correcting, at a moderate annual adjustment speed of approximately 33%. On the basis of these findings, the study concludes that Nigeria's carbon transition, as currently structured, is not yet delivering measurable inclusive welfare dividends, and that the structural inefficiency captured by energy intensity, rather than the level of emissions or the nominal renewable energy share, is the binding constraint requiring policy attention.

5.2 Policy Recommendations

Based on the findings, the following recommendations are made:

i. Government should prioritise energy efficiency programmes, targeting industrial and household energy use, given that energy intensity is the strongest and most consistent driver of welfare erosion identified in this study, over blanket emissions-reduction mandates that do not address underlying production inefficiency.

ii. Renewable energy policy should explicitly distinguish modern renewables (solar, wind, small hydro) from traditional biomass in national statistics and incentive schemes, since the current biomass-dominated renewable share is not registering as welfare-enhancing, and a shift toward modern, clean renewable infrastructure is more likely to generate the anticipated welfare dividends.

iii. Population and welfare policy should be integrated, leveraging Nigeria's demographic expansion as a productive asset, through investment in education, health, and labour-market absorption, rather than treating population growth solely as an environmental liability.

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