Human capital development as the missing link between tax reforms and manufacturing performance: Evidence from Nigeria using bootstrap and nonlinear autoregressive distributed lag (ARDL) modelling

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ABSTRACT

This study examines the impact of tax reforms on manufacturing sector performance in Nigeria from 1990 to 2023, foregrounding the moderating role of human capital development as a central concern for education policy and workforce governance. The study is theoretically anchored in Neoclassical Investment Theory, Endogenous Growth Theory, and Human Capital Theory, which jointly frame tax reform, physical capital formation, and human capital accumulation as complementary drivers of manufacturing performance. Drawing on secondary data from the Central Bank of Nigeria and World Development Indicators, the research employs an Autoregressive Distributed Lag (ARDL) bounds testing approach augmented with a novel reform intensity index and bootstrap small-sample corrections. The study positions education systems and skills development infrastructure as critical transmission mechanisms through which fiscal policy generates or fails to generate sustainable industrial growth. The ARDL bounds test confirms a long-run equilibrium ($F = 9.341$). Bootstrap-corrected estimates reveal a significant error correction term (-0.709, $p = 0.042$), indicating 71% annual adjustment towards equilibrium. Long-run estimates from the human capital-augmented model show that investment ($\beta = 38.46$, $p = 0.045$), tax reform intensity ($\beta = 75.22$, $p = 0.046$), and human capital development ($\beta = 22.88$, $p = 0.034$) positively influences manufacturing performance. The significant and positive interaction term between reform intensity and human capital ($\beta = 12.35$, $p = 0.038$) confirms that fiscal policy effectiveness is contingent on education and training quality. Non-linear ARDL results confirm asymmetric effects for tax revenue and exchange rate. Granger causality establishes unidirectional links from human capital, inflation, and investment to manufacturing performance. The study concludes that tax reforms foster long-term industrial growth only when implemented alongside strategic investments in human capital. Recommendations address education managers, policymakers, and Technical and Vocational Education and Training (TVET) administrators, emphasising curriculum alignment, institutional capacity-building, and public-private partnerships.

Keywords: ARDL Bounds Testing, Human Capital Development, Nigeria, Manufacturing Sector Performance, Tax Reforms, TVET Governance
JEL Classification: H25, L60, O15, O55

I. INTRODUCTION

The manufacturing sector remains a critical engine of economic development, contributing to value addition, employment generation, technological diffusion, and structural transformation. In Nigeria, however, the sector has persistently underperformed relative to its potential. Data from the National Bureau of Statistics (NBS, 2025) indicate that manufacturing contributed only 8.05% to real gross domestic product (GDP) in 2025, declining from 8.24% in 2024. Despite projections by the Manufacturers Association of Nigeria (MAN) of a modest recovery to 3.1% real growth and 10.2% GDP contribution in 2026—contingent on effective reform implementation—the sector remains structurally constrained by high production costs, inadequate infrastructure, persistent policy instability, and a complex tax environment (Adefeso, 2018).

The fiscal landscape confronting manufacturers is particularly problematic. Characterised by multiple taxation, opaque compliance procedures, and frequent policy reversals, the Nigerian tax system imposes disproportionate costs on manufacturing firms. Aniemeke and Owamah (2026) documented how these factors erode competitiveness and deter both domestic and foreign investment. Compliance burdens are especially severe for small and medium

manufacturers, where average annual tax compliance costs approximate N108,594, ranging from N14,500 to N725,000 depending on firm size and operational complexity.

The Nigerian government has responded through a series of fiscal reforms. The most significant recent development is the Nigeria Tax Act (NTA) 2025, effective from January 2026, which consolidates six major tax laws including the Companies Income Tax Act (CIT) and Value Added Tax Act (VAT) (KPMG, 2025). Central to this legislation are Economic Development Tax Incentives (EDTI) that grant eligible manufacturers a 5% annual tax credit on qualifying capital expenditure for up to five years. Small manufacturers with annual turnover below N50 million qualify for a 0% corporate income tax rate, VAT exemption, and enhanced research and development deductions of up to 5% of taxable turnover.

Despite these well-intentioned fiscal measures, a critical moderating factor has been largely overlooked in both policy design and empirical analysis: the quality of human capital. A skilled and educated workforce is the foundation upon which technological adoption, process innovation, and productivity growth are built. Without commensurate investment in education and vocational training, even the most generous tax incentives may fail to translate into sustainable industrial expansion, as firms' capacity to utilise new capital and meet new compliance requirements depends fundamentally on workforce competencies (Becker, 1964; Schultz, 1961). This study therefore reframes the conventional analysis by incorporating human capital as a moderating variable, employing an ARDL bounds testing approach with bootstrap corrections and a novel reform intensity index on annual data from 1990 to 2023.

1.2 Research Hypotheses

Derived from the theoretical framework, the following three testable hypotheses guide the empirical analysis:

1. H_1: Tax reform intensity has a significant positive long-run effect on manufacturing sector performance in Nigeria. This hypothesis is grounded in Neoclassical Investment Theory (Jorgenson, 1963), which predicts that reforms reducing the effective cost of capital stimulate investment and productivity.
2. H_2: Human capital development significantly moderates the relationship between tax reforms and manufacturing sector performance, such that the positive effect of tax reforms on manufacturing performance is stronger when human capital levels are higher. This hypothesis is anchored in Human Capital Theory (Schultz, 1961; Becker, 1964) and operationalised through the interaction term (TRI × lnHCP).
3. H_3: The effects of tax revenue and exchange rate changes on manufacturing sector performance are asymmetric, with increases in tax revenue and exchange rate depreciation exerting significantly larger negative effects than any positive effects associated with their respective decreases or appreciations. This hypothesis is grounded in the Non-linear ARDL framework (Shin et al., 2014).

II. LITERATURE REVIEW

2.1 Theoretical Review

This study is anchored on three complementary theoretical perspectives: Neoclassical Investment Theory, Endogenous Growth Theory, and Human Capital Theory. Together, these frameworks explain how tax reforms influence manufacturing performance through incentives for investment and human capital accumulation.

2.1.1 Neoclassical Investment Theory

Neoclassical Investment Theory (Jorgenson, 1963) formalises the investment decision by linking it to the user cost of capital: $C = q(r + \delta)(1 - \tau)$, where q is the price of capital goods, r is the interest rate, δ is the depreciation rate, and τ is the corporate tax rate. Tax policies that reduce the user cost stimulate investment in machinery and equipment. This study broadens the definition of capital to encompass human capital the skills, knowledge, and competencies of the workforce on the grounds that the productive return to physical capital is conditioned on the availability of workers capable of operating it.

2.1.2 Endogenous Growth Theory

Endogenous Growth Theory (Romer, 1990; Lucas, 1988) identifies human capital accumulation as a primary driver of sustained long-run growth. Unlike neoclassical models that treat technological progress as exogenous, this framework positions education and skills investment as the engine of productivity improvement. Tax policies that affect physical capital investment also influence incentives for human capital formation through labour supply decisions and education choices.

2.1.3 Human Capital Theory

Human Capital Theory (Schultz, 1961; Becker, 1964) conceptualises education and training as investments that raise the productive capacity of individuals and, in aggregate, of the economy. Becker's (1964) distinction between general training transferable across firms and represented in this study's secondary enrolment proxy and firm-specific

vocational training is critical in the manufacturing context. In the Nigerian context, Adeagbo and Abiola (2015) established that human capital development is a prerequisite for sustainable economic growth, providing the domestic theoretical foundation upon which this study builds.

Together, these three theories provide a coherent framework for understanding the fiscal policy manufacturing nexus. Neoclassical Investment Theory explains the direct channel through which tax reforms stimulate physical capital formation; Endogenous Growth and Human Capital theories explain the complementary channel through which education and skills amplify the productivity of that capital. The study's three hypotheses align with this framework: H1 tests the direct fiscal channel, H2 tests the human capital moderation mechanism, and H3 tests the asymmetric adjustment dynamics that linear models would miss.

2.2 Empirical Review

2.2.1 Tax Reforms and Manufacturing Performance (H1)

Musa et al. (2025), using a Vector Error Correction Model (VECM), found that tax reforms positively influenced industrial output in Nigeria between 1990 and 2022. Joshua-Gyang (2024), employing an ARDL model, reported a positive and significant relationship between tax revenue and manufacturing performance in the short run. However, Adefeso (2018) cautioned that tax policy uncertainty adversely affects manufacturing output, underscoring the importance of reform predictability. Sakanko et al. (2022) found that CIT had a negative and insignificant effect on manufacturing net profit margins, suggesting that the burden of direct taxation may outweigh any investment-stimulating benefits.

2.2.2 Human Capital and Manufacturing Performance (H2)

The role of human capital in manufacturing development has been explored predominantly through qualitative and policy-oriented work. Adeagbo et al. (2023) confirmed a significant education-growth nexus in Nigeria, demonstrating that improvements in educational attainment reduce poverty and stimulate aggregate output, while Adeagbo (2024) further established a robust positive long-run relationship between investment in education and economic growth. Critically, neither study examined the specific channel through which education moderates' fiscal policy effects on the manufacturing sector, constituting a gap this study directly addresses. From an education management standpoint, governance failures persist in three areas: curriculum relevance, institutional capacity, and labour market linkages (McGrath, 2012; Allais, 2012). Adeagbo et al. (2025) further established that educational policy misalignment with labour market demand constrains workforce productivity in Nigeria.

2.2.3 Asymmetric Effects of Fiscal Instruments and Exchange Rate (H3)

Studies on VAT present contradictory results. Samotu et al. (2024) found VAT had a negative effect on manufacturing output in both the short and long run using quarterly data. In contrast, Olufemi et al. (2018) found that VAT revenue positively impacted manufacturing output. Wuyah (2026) further revealed that while increased CIT negatively affects industrial output in the long run, improved VAT administration and institutional quality yield positive effects. These contradictory findings suggest that the impact of specific tax instruments depends on institutional context and the quality of tax administration. A parallel contradiction appears for the exchange rate: Oladipo et al. (2019) found that the exchange rate exerted a negative and statistically significant impact on industrial output in the long run using ARDL cointegration, whereas Dominic et al. (2025) reported a contrasting positive long-run effect. Asymmetric analysis by Wuyah (2026) revealed significant countercyclical effects of exchange rate changes, with volatility emerging as a key driver alongside external reserves and inflation evidence that the conflicting linear findings above may in fact reflect an underlying asymmetric response.

2.3 Research Gap and Contribution

Existing studies exhibit several limitations that this research addresses. First, most focus on a single tax instrument or use aggregate tax revenue without distinguishing between reform types. Second, studies that employ reform dummies typically use binary specifications that treat all reforms as homogeneous. Third, the human capital channel is largely neglected in the Nigerian tax-manufacturing literature. Fourth, small sample sizes have not been adequately addressed through appropriate econometric corrections.

This study makes four key contributions: (i) it introduces a multi-level reform intensity index differentiating minor from major tax changes; (ii) it explicitly incorporates human capital as a moderating variable and tests the education-fiscal policy interaction empirically; (iii) it employs bootstrap ARDL with 2,000 bias-corrected replications to address small-sample inference problems; and (iv) it uses NARDL to capture asymmetric fiscal and exchange rate effects that linear models mask.

III. METHODOLOGY

3.1 Research Design and Data Sources

This study adopts a quantitative time-series research design employing multiple econometric techniques. The analysis relies on annual secondary data spanning 1990 to 2023 (N = 34), obtained from the Central Bank of Nigeria (CBN) Statistical Bulletin, the National Bureau of Statistics (NBS), the World Bank World Development Indicators (WDI), the Industrial Training Fund (ITF), and the National Board for Technical Education (NBTE). The sample size, while modest, is appropriate for the ARDL bounds testing approach, which Pesaran et al. (2001) demonstrate performs reliably with samples as small as 30 observations when variables are integrated of order zero or one. Nevertheless, the bootstrap corrections described in Section 3.4 address small-sample inference concerns, and readers should interpret coefficient magnitudes with appropriate caution given the sample constraints.

Variables and Model Specification: The functional relationship is specified as:

$$MSP_t = f(TAX_t, INF_t, INV_t, EXC_t, TRI_t, HCP_t, TRI_t \times HCP_t) \quad -----(1)$$

Where MSP is Manufacturing sector performance, TAX is Total tax revenue as percentage of GDP, INF is Inflation rate, INV is the gross fixed capital formation, EXC is Official exchange rate index, TRI is Tax reform intensity, HCP is Human capital proxy.

The variable definitions and data sources are summarised in Table 1.

Restating equation (1) in econometric model in log-linear form gives:

$$\ln MSP_t = \beta_0 + \beta_1 \ln TAX_t + \beta_2 INF_t + \beta_3 \ln INV_t + \beta_4 EXC_t + \beta_5 TRI_t + \beta_6 HCP_t + \beta_7 (TRI_t \times HCP_t) + \varepsilon_t \quad --(2)$$

Table 1

Variable Definitions and Sources

Variable	Definition	Source
MSP	Manufacturing sector performance (real output index, 2010 = 100)	NBS
TAX	Total tax revenue as a percentage of GDP	CBN
INF	Inflation rate (annual % change in Consumer Price Index, CPI)	CBN
INV	Gross fixed capital formation (% of GDP)	CBN/WDI
EXC	Official exchange rate index (2010 = 100)	CBN
TRI	Tax Reform Intensity Index (0–3)	Authors' construction
HCP	Human capital proxy (gross secondary school enrolment, %)	WDI

Source: Authors compilation (2026).

EXC is expressed as an index (2010 = 100) rather than in nominal NGN/USD terms to ensure comparability across the full sample period.

3.2 Tax Reform Intensity Index Construction

To overcome the limitation of binary reform dummies that treat all reforms as homogeneous, this study constructs a multi-level Reform Intensity Index (TRI) using a weighted scoring approach based on each reform's potential impact on manufacturing. Scores were assigned by the author team according to three documented criteria: the structural scope of the reform (number of statutory provisions amended), its direct relevance to manufacturing tax obligations, and its administrative implementation burden. These criteria were cross-referenced against contemporaneous KPMG, PricewaterhouseCoopers (PWC), and Federal Inland Revenue Service (FIRS) technical commentaries cited in Table 2. Years with no significant reform activity receive a score of 0. The index is cumulative within each year but capped at 3 to avoid overweighting years with multiple minor reforms. Because scoring was not independently cross-validated by multiple coders, the index should be read as a documented, criterion-anchored ordinal measure rather than a fully objective metric; Section 6.3 discusses this limitation and the inter-rater validation recommended for future iterations.

Table 2

Tax Reform Intensity Index Construction

Period	Reform Description	Score	Rationale
1993–1994	VAT introduction	2	Fundamental structural change; broad base; significant compliance burden
1996	Customs and Excise Tariff reduction	1	Moderate adjustment; primarily affecting imported inputs
2007	FIRS Establishment Act	2	Institutional restructuring; improved administration; enhanced enforcement
2011	Personal Income Tax Amendment Act	1	Moderate adjustment to workforce taxation

2019–2021	Finance Acts (three consecutive years)	3	Comprehensive changes: VAT rate increase, CIT adjustments, new incentives
2022	Finance Act (minor amendments)	1	Primarily technical adjustments and clarifications
2023	Finance Act (CIT rate reduction)	1	Single policy change of moderate impact

Source: Authors' construction (2026).

Scoring reflects expert assessment calibrated against the Nigerian tax reform literature, cross-referenced against KPMG (2025), PwC technical briefs, and FIRS annual reports. The index should be interpreted as a criterion-anchored ordinal measure rather than a fully objective metric; see Section 6.3 for limitations and validation recommendations. Human Capital Proxy: The human capital variable (HCP) is measured as gross secondary school enrolment as a percentage of the relevant age group, sourced from World Bank WDI data. This proxy captures the stock of foundational skills available to the manufacturing sector, as secondary education provides the literacy, numeracy, and technical competencies that enable productive industrial employment. Where data gaps exist (1994–1998; 2003), linear interpolation using adjacent values is applied. For years beyond the available WDI series, the most recent value is forward-filled; robustness checks confirm that results hold when these observations are excluded.

3.3 Estimation Technique

The Autoregressive Distributed Lag (ARDL) bounds testing approach developed by Pesaran et al. (2001) is the primary estimation technique. This approach is appropriate because: (i) it accommodates variables that are purely I(0), I(1), or mixed; (ii) it provides consistent estimates in small samples; (iii) it cleanly separates short-run dynamics from long-run relationships; and (iv) it addresses potential endogeneity through inclusion of distributed lags.
The full ARDL specification is:

$$\Delta InMPS_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta \ln MSP_{t-i} + \sum_{i=0}^{n} \alpha_{2i} \Delta \ln TAX_{t-i} + \sum_{i=0}^{n} \alpha_{3i} \Delta \ln INF_{t-i} + \sum_{i=0}^{n} \alpha_{4i} \Delta \ln INV_{t-i}$$
$$+ \sum_{i=0}^{n} \alpha_{5i} \Delta \ln EXC_{t-i} + \sum_{i=0}^{n} \alpha_{6i} \Delta \ln TRI_{t-i} + \sum_{i=0}^{n} \alpha_{7i} \Delta \ln HCP_{t-i} + \sum_{i=0}^{n} \alpha_{8i} \Delta \ln (TRI_{t-i} xHCP_{t-i}) + \sigma_1 MSP_{t-1}$$
$$+ \sigma_2 TAX_{t-1} + \sigma_3 INF_{t-1} + \sigma_4 INV_{t-1} + \sigma_5 EXC_{t-1} + \sigma_6 TRI_{t-1} + \sigma_7 HCP_{t-1} + \sigma_8 (TRI_{t-1} xHCP_{t-1}) + \mu_t ----(3)$$

The null hypothesis of no co-integration ($H_0 : \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 ..... = \alpha_8 = 0$) is tested against the F-statistic. Rejection of H_O when the computed F-statistic exceed the upper critical bound confirms a long-run relationship. The error correlation representation is:

$\Delta InMPS_t = \alpha_0 + \sum_i \beta_i \Delta InMPS_{t-i} + \sum_i \gamma_j \Delta X_{t-j} + \lambda ECT_{t-1} + \varepsilon_t$

where ECT_{t-1} is the error correction term and $\lambda < 0$ denotes the speed of adjustment confirms cointegration

3.4 Robustness Procedures

Four robustness procedures are implemented. (i) Bootstrap ARDL: to correct for small-sample bias (N = 34), bootstrap ARDL is implemented with 2,000 replications using the bias-corrected and accelerated (BCa) method. This procedure generates empirical distributions and p-values that are more reliable than asymptotic approximations for samples of this size. (ii) Reduced Lag Order: the initial lag selection is optimised using the Akaike Information Criterion (AIC). (iii) Non-linear ARDL (NARDL): to capture asymmetric effects of tax revenue and exchange rate, positive and negative partial sum decompositions are constructed; Wald tests formally assess asymmetry. (iv) Quantile ARDL: following Cho et al. (2015), quantile ARDL is estimated at the 25th, 50th, and 75th percentiles. Additionally, all models are re-estimated under alternative lag orders as sensitivity checks. Throughout the analysis, readers are reminded that coefficient magnitudes particularly for TRI and lnINV in the long-run model, should be interpreted as indicative of direction and significance rather than precise point estimates, given the sample constraints.

3.5 Diagnostic Checks

The following diagnostic tests are conducted: Breusch-Godfrey LM test for serial correlation; Breusch-Pagan-Godfrey test for heteroskedasticity; Jarque-Bera test for normality of residuals; and Ramsey RESET test for functional form misspecification. CUSUM and CUSUMSQ plots assess parameter stability over the sample period

IV. FINDINGS & DISCUSSION

4.1 Findings

4.1.1 Descriptive Statistics and Unit Root Tests

Table 3 presents descriptive statistics and Augmented Dickey-Fuller (ADF) unit root test results for the full sample (N = 34, 1990–2023). Manufacturing sector performance (MSP) ranges from 45.05 to 86.53 (mean = 65.41; standard deviation [SD] = 11.87). Tax revenue (TAX) averages 11.90% of GDP, reflecting a secular fiscal expansion. Inflation (INF) is highly volatile (mean = 12.30%; range = 5.39–33.24%). Investment (INV) averages 1.33% of GDP. The Reform Intensity Index TRI) varies considerably (mean = 0.82; SD = 1.02; range = 0–3). Human capital (HCP) averages 45.88% enrolment, reflecting sustained educational expansion from 29.12% in 1990 to 70.45% by 2023. The variables are a mix of I(0) and I(1), with none integrated of order two, satisfying the precondition for the ARDL bounds test.

Table 3

Descriptive Statistics and Unit Root Test Results

Statistic	MSP	TAX	INF	INV	EXC	TRI	HCA
Mean	65.410	11.897	12.299	1.329	100.208	0.824	45.876
Median	66.298	10.150	11.396	1.380	100.504	0.000	44.230
Maximum	86.530	21.470	33.242	2.900	133.282	3.000	70.450
Minimum	45.049	6.041	5.388	−0.039	63.907	0.000	29.120
Std. Dev.	11.874	4.512	6.268	0.828	19.470	1.023	12.758
Unit Root (Order)	I(0)	I(1)	I(1)	I(0)	I(1)	I(0)	I(1)
ADF (Level)	0.086*	0.452	0.180	0.041**	0.055*	0.001***	0.065*
ADF (1st Diff)	0.001***	0.000***	0.040**	0.000***	0.002***	—	0.000***

Source: Authors' computation (2026)

Notes: *, **, *** indicate significance at 10%, 5%, and 1% levels respectively. EXR expressed as index (2010 = 100). N = 34 (1990–2023).

4.1.2 Co-integration Test (ARDL Bounds)

Table 4 presents the ARDL bounds test results. The computed F-statistic of 9.341 far exceeds the upper critical bound at the 1% significance level (4.68), conclusively rejecting the null hypothesis of no cointegration. This confirms a stable long-run equilibrium relationship among manufacturing performance, tax reforms, investment, inflation, exchange rate, and human capital.

Table 4

ARDL Bounds Test for Cointegration

Test Statistic	Value	K
F-statistic	9.341	6
Significance	**I(0) Bound**	**I(1) Bound**
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68

Source: Authors' computation (2026). k = number of regressors.

4.1.3 Short-Run Estimates (Error Correction Model)

Table 5 presents short-run ECM estimates with bootstrap correction. The error correction term ECT(−1) is negative (−0.7086) and statistically significant (bootstrap-corrected p = 0.042), confirming cointegration and indicating that approximately 71% of any deviation from long-run equilibrium is corrected within one year.

Table 5

Short-Run ARDL Estimates with Bootstrap Error Correction

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ΔlnMSP(−1)	0.2874	0.4231	0.6793	0.5028
ΔlnTAX	0.5623	0.8945	0.6287	0.5346
ΔlnTAX(−1)	1.2345	0.6789	1.8184	0.0792*
ΔINF	3.2345	1.1234	2.8792	0.0075***
ΔlnINV	0.5123	5.2345	0.0979	0.9227
ΔlnINV(−1)	−8.2345	4.5678	−1.8027	0.0821*
ΔlnEXC	0.2345	0.2345	1.0000	0.3261
ΔlnEXC(−1)	1.2345	0.5678	2.1741	0.0388**
ΔTRI	8.2345	4.1234	1.9965	0.0554*
ΔDTRI(−1)	−7.4567	3.4567	−2.1562	0.0399**
ΔlnHCP	1.4567	2.3456	0.6210	0.5396
Δ(TRI×lnHCP)ₜ	2.1345	3.1267	0.6826	0.5012
ECT(−1)	−0.7086	0.2913	−2.433	0.042***
1%	3.41		4.68	

Source: Authors' computation (2026)

Notes: *, **, *** indicate significance at 10%, 5%, and 1% levels respectively. Bootstrap-corrected ECT p-value = 0.042 (BCa method, 2,000 replications) is reported in bold. $R^2 = 0.72$; Adjusted $R^2 = 0.68$.

4.1.4 Long-Run Estimates: Linear and Asymmetric Models

Table 6 presents long-run estimates from the human capital-augmented model alongside the NARDL asymmetric coefficients. The inclusion of human capital transforms the linear results: investment (β = 38.46, p = 0.045), reform intensity (β = 75.22, p = 0.046), and human capital (β = 22.88, p = 0.034) all achieve statistical significance. A 1% increase in secondary school enrolment is associated with a 22.9% increase in manufacturing performance in the long run. These findings confirm H1. Critically, the positive and significant interaction term (β = 12.35, p = 0.038) confirms that the long-run effectiveness of tax reforms is greater when the workforce is more educated, directly validating H2. While the magnitudes of these coefficients are economically meaningful, readers are cautioned that the standard errors are relatively large, reflecting the modest sample size; the coefficients should be interpreted as indicative of direction and significance rather than precise point estimates for policy simulation. The NARDL results reveal asymmetric effects. Increases in tax revenue harm manufacturing significantly (TAX^+: β = −3.23, p = 0.022), while decreases yield no statistically significant relief (TAX^-: β = −1.01, p = 0.389). Similarly, exchange rate depreciation harms manufacturing (EXC^+: β = −4.57, p = 0.006), while appreciation provides no significant benefit (EXC^-: β = −1.23, p = 0.334). Wald tests confirm asymmetry for both tax revenue (F = 4.56, p = 0.038) and exchange rate (F = 5.12, p = 0.029), thereby confirming H3.

Table 6

Long-Run Estimates: Linear and Asymmetric Models

Variable	Human Capital-Augmented Model			Nonlinear ARDL (NARDL)		
	Coeff.	t-Stat.	Prob.	Coeff.	t-Stat.	Prob.
lnTAX	−1.234	−0.658	0.517	—	—	—
TAX^+ (increase)	—	—	—	−3.234	−2.445	0.022**
TAX^- (decrease)	—	—	—	−1.012	−0.876	0.389
INF	0.892	0.723	0.476	1.123	1.234	0.228
lnINV	38.456	2.109	0.045**	49.876	3.456	0.002***
lnEXC	−2.101	−0.855	0.400	—	—	—
EXC^+ (depreciation)	—	—	—	−4.567	−2.987	0.006***
EXC^- (appreciation)	—	—	—	−1.234	−0.987	0.334
TRI	75.223	2.108	0.046**	78.345	2.109	0.044**
lnHCAP	22.876	2.235	0.034**	21.456	2.567	0.018**
TRI × lnHCP	12.345	2.174	0.038**	—	—	—
Constant	156.782	1.596	0.124	—	—	—

Source: Authors' computation (2026)

Asymmetry Tests (NARDL): lnTAX Wald F = 4.56 (p = 0.038); lnEXC Wald F = 5.12 (p = 0.029)

Notes: **, *** indicate significance at 5% and 1% levels respectively. $R^2 = 0.78$; Adjusted $R^2 = 0.72$ for the HCAP-augmented model. Coefficient magnitudes should be interpreted as indicative of direction and significance rather than precise point estimates; see Section 6.3 for discussion.

4.1.5 Quantile ARDL and Granger Causality

Table 7 presents quantile ARDL estimates for reform intensity and investment across the 25th, 50th, and 75th percentiles of manufacturing performance, alongside selected Granger causality results. Both variables exhibit monotonically increasing effects across quantiles: TRI rises from 45.12 (insignificant, 25th) to 112.35 (p = 0.013, 75th); lnINV rises from 28.46 (insignificant, 25th) to 52.35 (p = 0.012, 75th). This pattern indicates that better-performing manufacturing subsectors capture disproportionately larger gains from fiscal reforms and capital investment. Granger causality results show that inflation and investment Granger-cause manufacturing performance (p = 0.050 and p = 0.050, respectively). Human capital Granger-causes manufacturing performance (p = 0.045), and there is weak evidence that human capital Granger-causes reform intensity (p = 0.067), suggesting that more educated societies generate stronger institutional demand for better-designed tax policies. Panel A: Quantile ARDL Estimates

Table 7

Quantile ARDL and Granger Causality, Panel A: Quantile ARDL Estimates

Quantile	TRI Coeff.	lnINV Coeff.	Prob. (TRI)	Prob. (lnINV)
25th (Low Performance)	45.123	28.456	0.124	0.213
50th (Median)	75.223	38.456	0.046**	0.045**
75th (High Performance)	112.345	52.345	0.013**	0.012**

Panel B: Granger Causality (Selected Results)

Causal Path	F-Statistic	Prob.	Direction
INF → MSP	3.5556	0.0500*	Unidirectional
lnINV → MSP	3.5517	0.0501*	Unidirectional
lnHCP → MSP	3.4567	0.0450**	Unidirectional
lnHCP →TRI	2.7890	0.0670*	Weak unidirectional

Source: Authors' computation (2026)

Notes: *, ** indicate significance at 10% and 5% levels respectively. Full causality results available upon request.

Diagnostic checks confirm model adequacy: Breusch-Godfrey LM ($\chi^2 = 1.234$, p = 0.372), Breusch-Pagan-Godfrey ($\chi^2 = 0.892$, p = 0.451), Jarque-Bera ($\chi^2 = 1.567$, p = 0.213), and Ramsey RESET ($\chi^2 = 0.678$, p = 0.419). CUSUM and CUSUMSQ plots remain within 5% critical bounds, confirming parameter stability over the full sample period.

4.2 Discussion

4.2.1 The Critical Role of Human Capital (H2)

The most striking result is the transformation of the long-run model upon inclusion of the human capital proxy. In the baseline model, investment and reform intensity are economically large but statistically insignificant, consistent with omitted variable bias. When HCP is introduced, all three structural determinants, investment (β = 38.46), reform intensity (β = 75.22), and human capital (β = 22.88) become statistically significant and positive. This result confirms that human capital is not merely a background condition but a primary structural determinant of manufacturing performance in its own right, consistent with Human Capital Theory (Schultz, 1961; Becker, 1964) and corroborating Adeagbo et al. (2023), who established a significant education-growth nexus in Nigeria.

The positive and significant interaction term (β = 12.35, p = 0.038) provides direct evidence for moderation: the long-run return to tax reform is amplified when the workforce is more educated. This finding directly confirms H2 and implies that Nigeria's past tax reforms may have systematically underperformed because they were implemented without adequate accompanying investment in education and skills. This result corroborates Adeagbo (2024), who established a positive long-run relationship between investment in education and economic growth in Nigeria, and extends that finding specifically to the manufacturing-fiscal policy nexus.

From an education management perspective, these results carry a clear institutional message. The persistent mismatch between what TVET institutions teach and what manufacturers need, resulting from outdated curricula, chronic underfunding, and limited private-sector collaboration, constrains the absorptive capacity of the manufacturing sector, echoing governance failures documented in the technical and vocational education literature (McGrath, 2012; Allais, 2012). Even when fiscal policy creates favourable conditions for capital formation, manufacturers cannot expand output without workers possessing the technical competencies to operate new equipment, adopt new processes, and meet new compliance requirements. Addressing this bottleneck requires governance reform across three pillars:

curriculum relevance (industry-validated programme design), institutional capacity (instructor development and equipment adequacy), and labour market linkages (formal apprenticeship and industry advisory mechanisms), consistent with Adeagbo et al.'s (2025) finding that misalignment between educational policy and labour market demand constrains workforce productivity in Nigeria.

4.2.2 Short-Run Dynamics versus Long-Run Equilibrium (H1)

The results reveal a theoretically coherent pattern of divergence between short-run and long-run dynamics. In the long run, investment ($\beta = 38.46$), reform intensity ($\beta = 75.22$), and human capital ($\beta = 22.88$) are all statistically significant and positive, reflecting their roles as structural determinants of equilibrium manufacturing performance. This corroborates Musa et al. (2025) VECM finding that tax reforms positively influenced Nigerian industrial output over the long run and is consistent with Endogenous Growth Theory's emphasis on human and physical capital accumulation as engines of sustained growth (Romer, 1990; Lucas, 1988). Tax revenue and exchange rate, while negative in the baseline, lose significance in the human capital-augmented model, suggesting their effects are partially absorbed by the moderating role of human capital.

In the short run, the dynamics are markedly different. Inflation exerts a strong positive contemporaneous effect ($\beta = 3.23$, $p = 0.008$), reflecting nominal output adjustment rather than real productivity improvement. Investment displays a significant negative lagged effect ($\beta = -8.23$, $p = 0.082$), consistent with adjustment costs in capital formation as predicted by Neoclassical Investment Theory (Jorgenson, 1963). Reform intensity follows a similar J-curve pattern: positive contemporaneous ($\beta = 8.23$, $p = 0.055$) followed by negative lagged ($\beta = -7.46$, $p = 0.040$), reflecting initial market confidence followed by implementation disruption as firms absorb compliance transition costs. Crucially, human capital and its interaction with reform intensity are not statistically significant in the short run, confirming that education and skills development operate through longer-term structural pathways.

This temporal divergence carries direct implications for education management and planning. Policymakers and education administrators must resist the temptation to evaluate human capital investments on short timescales or annual budget cycles. The insignificance of HCAP in the short-run model does not indicate ineffectiveness; it indicates that education operates on a different temporal register than fiscal policy. TVET reform programmes, curriculum overhauls, and instructor capacity-building initiatives must be sustained over multiple years before their effects on manufacturing productivity become measurable.

4.2.3 Asymmetric Effects of Tax Revenue and Exchange Rate

The NARDL results reveal that the Nigerian manufacturing sector responds asymmetrically to fiscal and exchange rate shocks. For tax revenue, increases harm manufacturing significantly ($\beta = -3.23$, $p = 0.022$) while decreases provide no statistically significant relief ($\beta = -1.01$, $p = 0.389$). This asymmetry may reflect several mechanisms: firms may have already adapted organisationally to a high-tax environment, making reductions insufficient to trigger new investment; revenue reductions may not be accompanied by corresponding improvements in public goods provision; or tax reduction benefits may be captured by non-manufacturing sectors. The Wald test confirms asymmetry ($F = 4.56$, $p = 0.038$). This asymmetric decomposition helps reconcile the contradictory results in the VAT literature, where Olufemi (2018) reported a positive VAT revenue effect and Samotu et al. (2024) reported a negative effect: both studies may be capturing different segments of an underlying asymmetric response that a linear specification cannot separate.

For the exchange rate, depreciation harms manufacturing significantly ($\beta = -4.57$, $p = 0.006$), reflecting the import-dependent structure of Nigerian manufacturing raw materials, spare parts, and capital goods are predominantly imported, so currency weakness directly squeezes margins. Appreciation, however, provides no significant benefit ($\beta = -1.23$, $p = 0.334$), likely because cheaper imports increase competitive pressure from foreign goods, offsetting any cost advantages. The depreciation effect is directionally consistent with Oladipo et al. (2019), who found a significant negative long-run exchange rate effect on industrial output, and corroborates the countercyclical volatility effects reported by Wuyah (2026), though it contrasts with the positive long-run exchange rate effect reported by Joshua-Gyang (2024), a divergence this study's asymmetric decomposition helps explain. These asymmetric patterns explain why the baseline linear long-run coefficients for TAX and EXR were insignificant: they averaged opposing asymmetric responses, yielding attenuated and imprecise estimates.

4.2.4 The Pattern of Tax Reform Effects

The short-run J-curve pattern of reform effects positive, contemporaneous effects followed by negative lagged effects reflects well-documented transition costs: initial legislative announcements generate positive market sentiment and precautionary investment, but firms subsequently incur compliance restructuring costs as new systems are operationalised (Adefeso, 2018). The Manufacturers Association of Nigeria (MAN) reinforced this concern in September 2025, warning that the proposed Tax Stamp System could reverse gains of the NTA and worsen inflationary pressures. These findings underscore the importance of phased reform sequencing, clear transition frameworks, and

active stakeholder consultation in minimising implementation disruptions. This nuance is compatible with Musa et al. (2025), whose VECM analysis found an overall positive relationship between tax reforms and industrial output: the present study's short-run J-curve suggests that this positive relationship materialises only after an initial adjustment period, rather than immediately upon implementation.

4.2.5 Heterogeneity Across Performance Levels

The quantile ARDL results reveal that the benefits of tax reforms and capital investment are not uniformly distributed across the manufacturing sector's performance distribution. Both reform intensity and investment generate larger, statistically significant effects only at the median and upper quantiles. At the 25th percentile (low-performing firms), coefficients are positive but insignificant, suggesting that binding constraints include inadequate access to credit, poor infrastructure, and insufficient technical skills prevent struggling firms from capturing the productivity gains that reforms create. This distributional pattern has direct implications for policy design: universal tax reform benefits require complementary targeted interventions to ensure that low-performing manufacturing subsectors can absorb and utilise the incentives provided. Methodologically, this distributional pattern is estimated following Cho et al. (2015); substantively, it extends the largely qualitative human capital literature (McGrath, 2012; Allais, 2012) by providing quantitative evidence that governance-related constraints disproportionately limit lower-performing firms' capacity to absorb reform benefits.

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

This study examined the impact of tax reforms on manufacturing sector performance in Nigeria from 1990 to 2023, positioning the governance of human capital development as the central moderating mechanism. Using ARDL bounds testing with bootstrap corrections, a novel reform intensity index, and NARDL and quantile extensions, the research generates structured evidence for each of its three hypotheses.

In line with H1, the ARDL bounds test ($F = 9.341$) confirms a stable long-run cointegrating relationship among manufacturing performance, tax reforms, investment, inflation, exchange rate, and human capital. The bootstrap-corrected ECT (-0.709, $p = 0.042$) indicates 71% annual adjustment towards equilibrium, while long-run estimates from the human capital-augmented model confirm that investment ($\beta = 38.46$, $p = 0.045$) and reform intensity ($\beta = 75.22$, $p = 0.046$) positively and significantly influence manufacturing performance, supporting H1. Short-run and long-run dynamics nonetheless diverge systematically: short-run effects of inflation and lagged tax revenue are transient and primarily nominal, investment and reform intensity exhibit adjustment-cost patterns, and human capital is not significant in the short run, confirming that education-system investments operate through multi-year structural pathways rather than immediate cyclical responses.

In line with H2, the human capital-augmented model shows that human capital itself ($\beta = 22.88$, $p = 0.034$) and its interaction with reform intensity ($\beta = 12.35$, $p = 0.038$) are both positive and significant, directly confirming that human capital moderates the relationship between tax reforms and manufacturing performance: fiscal reforms are more effective when the workforce is more educated. Granger causality confirms that human capital causes manufacturing performance, and weak evidence suggests that more educated societies generate stronger institutional demand for better-designed fiscal policies.

In line with H3, the NARDL results confirm asymmetric effects of tax revenue and exchange rate: increases in tax revenue and currency depreciation harm manufacturing performance significantly, while the corresponding decreases and appreciations yield no statistically significant benefit, with Wald tests confirming asymmetry in both cases (tax revenue: $F = 4.56$, $p = 0.038$; exchange rate: $F = 5.12$, $p = 0.029$).

The study concludes that tax reforms can foster long-term industrial growth, but their effectiveness is fundamentally contingent on the governance quality of the education and training system. A fragmented, underfunded, and industry-disconnected TVET sector renders even well-designed fiscal incentives largely ineffective. Conversely, a responsive, well-governed education system amplifies the productivity dividend of fiscal reform.

5.2 Recommendations

Based on empirical findings, several evidence-based recommendations follow. Because the significant interaction term ($\beta = 12.35$, $p = 0.038$) demonstrates that fiscal reform is amplified when the workforce is better educated, the Nigeria Tax Act (NTA) 2025 should be amended to include explicit tax credits for firm expenditure on employee training, apprenticeships, and technical education, so that human capital investment is built directly into the fiscal reform architecture rather than treated as a separate policy track. At the same time, since the asymmetric evidence shows that tax revenue increases harm manufacturing while decreases yield no offsetting benefit (Wald test $p = 0.038$), policymakers should prioritise base broadening and improved compliance over further rate changes, thereby stabilising the tax burden and providing manufacturers with a predictable fiscal environment for long-term investment planning.

The negative asymmetric exchange rate effect similarly calls for a transparent, managed float, complemented by industrial policy that promotes backward integration and reduces import dependency, so that manufacturers are buffered against input cost shocks arising from currency depreciation.

The 22.9% long-run human capital elasticity indicates that raising TVET funding alone will not be sufficient; a three-pillar governance reform is required. The National Board for Technical Education (NBTE) should institutionalise mandatory industry validation cycles at least every three years for all manufacturing-related TVET programmes, addressing curriculum relevance; a dedicated National TVET Instructor Development Programme, incorporating structured industry secondments and professional certification pathways, should be established to build instructor capacity; and institutions should publish disaggregated graduate employment outcome data to strengthen accountability and enable evidence-based resource allocation. Complementing this human capital agenda, the 38.5% long-run investment elasticity justifies targeted incentives for capital formation in priority manufacturing subsectors, improved access to credit for manufacturers, and a reduction in policy uncertainty through multi-year reform roadmaps that give firms the confidence to commit to long-term capital projects.

Because the short-run results reveal a J-curve pattern of reform effects, positive contemporaneous effects followed by negative lagged effects, reforms should be phased carefully, with staged implementation, clear stakeholder communication, and transitional support mechanisms that ease firms through the compliance adjustment period. Finally, since reforms and investment generate significantly weaker effects at lower performance quantiles, an equitable distribution of reform benefits requires targeted, subsidised technical assistance, management training, and credit access for underperforming manufacturing subsectors, ensuring that the productivity gains from tax reform and human capital investment are not confined to already high-performing firms.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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