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ARDL-VECM ANALYSIS OF ARTIFICIAL INTELLIGENCE ADOPTION AND TAX REVENUE COLLECTION EFFICIENCY IN NIGERIA (2015–2025)

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ABSTRACT

This study examines the influence of artificial intelligence (AI) adoption on tax revenue collection efficiency in Nigeria, drawing on quarterly time-series data spanning 2015 to 2025 (44 observations). Motivated by Nigeria's persistent fiscal challenges — including volatile revenue growth, systemic leakages, elevated collection costs, and fragmented government data infrastructure — the study employs an Auto-Regressive Distributed Lag (ARDL) bounds testing framework and a Vector Error Correction Model (VECM), augmented by Johansen co-integration restrictions and Block Exogeneity Wald tests. Government AI Readiness Index Score was used as proxy for AI adoption while Revenue Collection Efficiency is decomposed into six dimensions: Tax Revenue Growth Rate, Financial Leakage Reduction, Operational Efficiency Ratio, Data Governance Score, Taxpayer Compliance, and Transparency and Accountability. Empirical results reject all six null hypotheses, confirming a highly significant long-run equilibrium network among the variables. The error correction term of -1.5885 ($p < 0.001$) demonstrates an oscillatory over-correction speed of adjustment of 158.8% per period. Long-run Johansen normalization restrictions confirm that transparency and accountability ($\beta = +32.95$, $p = 0.008$) and financial leakage reduction ($\beta = +0.068$, $p = 0.004$) are significant positive drivers of fiscal expansion, while the operational efficiency ratio reveals a massive cost-compressing impact ($\beta = -57.42$, $p < 0.001$). A locked 1-to-1 dynamic equilibrium between data governance and taxpayer compliance confirms that data integrity directly determines behavioral compliance. In the short run, a temporary friction lag accompanies AI deployment before long-term benefits materialize. The study concludes that AI adoption has catalyzed a structural transformation of Nigeria's revenue administration, recommending aggressive scale-up of machine-learning forensic auditing, mandatory cross-institutional database synchronization, and automated predictive risk profiling to maximize sustainable fiscal performance.

Keywords: Artificial Intelligence; Tax Revenue Efficiency; Financial Leakage; Taxpayer Compliance; Transparency

1.0 INTRODUCTION

Revenue collection efficiency constitutes a foundational determinant of fiscal sustainability, macroeconomic stability, and the capacity of governments to deliver public goods. In developing economies such as Nigeria, effective domestic revenue mobilization directly conditions the government's ability to reduce dependence on volatile hydrocarbon receipts and

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external borrowing. Despite successive fiscal reform programmes, Nigeria continues to record relatively low tax-to-GDP ratios compared to peer emerging-market economies — a condition reflecting deep-rooted structural inefficiencies within its revenue administration system (IMF, 2023; World Bank, 2023).

Nigeria's tax administration has historically been characterized by fragmented taxpayer databases, limited audit capacity, weak compliance monitoring mechanisms, and reliance on manual or semi-digitized processes. These conditions not only suppress revenue yield but undermine public trust in fiscal institutions (Ezenwa & Chikezie, 2022). Although incremental digital reforms — such as electronic filing systems and taxpayer identification platforms — have partially improved administrative processes, they remain insufficient to address the complex challenge of real-time data validation, predictive risk assessment, and systemic fraud detection.

Artificial Intelligence (AI) has emerged globally as a transformative tool in public financial management, encompassing technologies such as machine learning, predictive analytics, robotic process automation, and advanced data integration systems capable of processing large datasets, identifying hidden patterns, and generating actionable insights. Empirical evidence from both advanced and emerging economies indicates that AI significantly enhances tax audit targeting, compliance monitoring, and revenue forecasting accuracy (OECD, 2022; ATAF, 2023). By enabling automated data reconciliation, anomaly detection, and real-time system learning, AI holds the potential to fundamentally reconfigure revenue administration systems.

However, Nigeria's integration of AI into its revenue architecture is not merely a technological transition; it represents a complex socio-technical transformation contingent upon robust digital infrastructure, high-quality integrated datasets, skilled human capital, and strong institutional frameworks. Many Nigerian revenue agencies continue to operate in environments characterized by unstable power supply, fragmented data systems, and limited interoperability across government platforms — conditions that constrain the operational efficiency of AI systems. Furthermore, the shortage of data scientists, system analysts, and cyber-security professionals within the public sector creates a significant implementation gap (NITDA, 2023).

While extant literature on AI and tax administration is growing, critical gaps persist. Most empirical studies adopt cross-sectional designs or rely on survey-based, perception-driven measures that limit causal inference. Context-specific longitudinal evidence on AI's measurable impact within Nigeria's unique institutional environment remains scarce. Existing studies also tend to conflate general digitalization with AI-specific applications, thereby obscuring the distinct contribution of advanced machine-learning tools.

Accordingly, this study addresses these gaps by investigating the extent to which AI adoption — proxied by the Government AI Readiness Index Score — influences six dimensions of revenue collection efficiency: tax revenue growth rate, financial leakage reduction, operational efficiency ratio, data governance score, taxpayer compliance, and transparency and accountability. Using 44 quarterly observations spanning 2015 to 2025, the study deploys ARDL bounds testing and VECM frameworks to establish both short-run and long-run causal dynamics, providing empirically grounded evidence for policy reform in Nigeria's fiscal sector.

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2.0 THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 Revenue Collection Efficiency and AI

Revenue collection efficiency refers to the effectiveness with which government revenue agencies convert the potential taxable base into actual inflows, minimizing leakages, enforcing compliance, and ensuring completeness of revenue records at minimal administrative cost (Jeroh & Akpobome, 2022). For Nigeria — with persistently low tax-to-GDP ratios — this concept is a critical fiscal performance indicator. Fragmented data architecture, human interference, and reliance on manual processes have historically compromised data integrity and bred under-reporting and fraud (Ezenwa & Chikezie, 2022).

Artificial Intelligence addresses these systemic vulnerabilities by deploying advanced cognitive data-processing capabilities that surpass human capacity in scale and precision. Through machine learning, natural language processing, and predictive analytics, AI can automate repetitive processes, detect fraudulent activities, and enhance data-driven decision-making (Agu & Enakirerhi, 2023). AI-driven analytics can identify non-compliance patterns, predict future revenue performance, and improve taxpayer profiling, reducing administrative costs and improving operational efficiency (Eyide, 2023). Scholars from the Delta State institutional context note that AI adoption forces macro-level reconfiguration of data regulation and can operate as a central data-reconciliation engine, cross-referencing taxpayer declarations against Bank Verification Numbers, property registries, and customs clearance logs to expose discrepancies (Eyide & Okoh, 2024).

The historical evolution of AI adoption in Nigeria has moved from basic digitalization in the late 2000s through structured electronic filing systems to sophisticated predictive analytics and machine-learning forensic auditing. Empirical studies by Adegbie, Enerson, and Olaoye (2022) established that electronic tax infrastructures significantly enhanced compliance metrics and baseline revenue efficiency. Subsequent research confirmed that digital upgrades triggered substantial expansions in internally generated revenue (Oladipo & Yusuf, 2023), while robotic process automation measurably compressed administrative overhead costs (Adekunle, 2023). More recent studies demonstrate that machine-learning clustering algorithms significantly optimize fraud detection within complex tax architectures (Chukwuani & Peters, 2024) and that AI-based neural network forecasting models outperform traditional ARIMA approaches in predictive precision (Nnamdi & Kalu, 2025).

2.2 Theoretical Framework

This study is anchored on two complementary theoretical pillars. First, the Technology Acceptance Model (TAM), developed by Davis (1989), posits that perceived usefulness and perceived ease of use determine the extent to which users accept and utilize new technologies. Applied to revenue administration, TAM explains that when AI systems are perceived as operationally useful and accessible, revenue officials are more likely to incorporate them into daily processes, enhancing data accuracy, compliance monitoring, and efficiency (Okolo & Nwakanma, 2023). TAM provides a behavioral lens for understanding how user acceptance mediates AI's impact on institutional performance.

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Second, the Disruptive Innovation Theory of Christensen (1997) provides a macro-structural framework explaining how AI, as a transformative technology, can fundamentally reshape traditional revenue administration by replacing inefficient manual systems with advanced, data-driven approaches. Unlike incremental digital tools, AI fundamentally reconfigures how revenue data is generated, analyzed, and utilized — from audit targeting and taxpayer profiling to transparency and cross-institutional data synchronization (Adeoye & Bakare, 2023; Kearney, 2023). Together, TAM and Disruptive Innovation Theory offer a comprehensive analytical framework that captures both the behavioral and systemic dimensions of AI adoption in Nigeria's fiscal sector.

2.3 Empirical Evidence and Research Gap

A growing body of empirical literature confirms AI's positive impact on revenue administration outcomes. Bankole, Osamor, and Bamgboye (2025) demonstrated that AI predictive analytics significantly accelerated tax assessment speeds, enhanced voluntary compliance, and compressed administrative overhead costs in Lagos State. The Zanzibar Revenue Authority (2025) and Bundala and Mjema (2025) confirmed strong positive relationships between AI adoption and aggregate tax revenue performance using econometric analysis. Hassan and Bello (2024) found that ECOWAS jurisdictions with integrated AI-enabled compliance monitoring achieved significantly higher compliance ratios. Ibrahim and Salami (2023) demonstrated that AI-assisted audit selection at the Federal Inland Revenue Service improved detection of underreported corporate income by over 20%. Ogunleye and Adetunji (2025) found that data-driven analytics significantly improved fiscal reporting accuracy and reduced discretionary manipulation by officials.

Despite this growing evidence base, important methodological, contextual, and conceptual gaps persist. Most studies rely on cross-sectional or perception-based designs, limiting causal inference and long-run analysis. A significant proportion of empirical evidence originates from advanced economies or aggregate multi-country datasets with institutional frameworks that differ markedly from Nigeria's. Within Nigeria, existing studies often examine general digitalization rather than isolating AI-specific contributions. Furthermore, few studies integrate multiple dimensions of revenue collection efficiency or combine behavioral and structural theoretical perspectives. This study addresses these gaps through a longitudinal, multi-dimensional, Nigeria-specific analysis employing advanced econometric time-series methodology.

3.0 METHODOLOGY

3.1 Research Design

This study adopted a quantitative econometric time-series design, drawing on 44 quarterly observations spanning Q1 2015 to Q4 2025. The choice of a longitudinal approach enables the capture of dynamic shifts in revenue performance over an extended historical horizon and permits assessment of sustained long-run effects of AI adoption, rather than relying on static cross-sectional or perception-based evidence. Secondary quantitative data were extracted exclusively from official government repositories: the Federal Inland Revenue Service (now Nigeria Revenue Service), the Central Bank of Nigeria (CBN), the National Bureau of Statistics

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(NBS), the Federal Ministry of Finance, and the Auditor-General's annual declarations. All raw fiscal values were transformed into natural logarithms prior to stationarity testing to minimize the effect of extreme variance.

3.2 Variable Operationalization

The dependent variable — Revenue Collection Efficiency — was decomposed into six operational proxies, while AI Adoption served as the independent variable. Table 1 presents the measurement framework.

Table 3.1: Variable Measurement Framework

Variable	Proxy/Measurement	Expected Sign	Source	Type
Tax Rev. Growth (TRGR)	Quarterly % change in tax revenue	+ve	FIRS/CBN/NBS	Dependent
Data Governance (DGS)	Data accuracy ratio: (Total filings - erroneous filings) / Total records	+ve	FIRS/NBS	Dependent
Financial Leakage (FLR)	ln(Expected Revenue - Actual Revenue)	+ve	CBN/Auditor-General	Dependent
Operational Efficiency (OER)	Cost-to-revenue ratio: Admin cost / Revenue collected	-ve	FIRS/MoF	Dependent
Taxpayer Compliance (TPC)	Complement of error tracking: 100% minus error rate	+ve	FIRS/MoF	Dependent
Transparency (TATRA)	Inverse baseline operational leakage relative to gross revenue	+ve	FIRS/MoF	Dependent
AI Adoption (AIA)	Government AI Readiness Index Score (governance, data, infrastructure pillars)	+ve	NITDA/MoF	Independent

Source: Compiled by the researcher (2026)

3.3 Analytical Framework

The analytical procedure proceeded through several methodological stages. Descriptive statistics were computed to analyze distributional properties, including measures of central tendency, dispersion, skewness, and kurtosis. Pairwise Pearson correlation matrices examined linear associations and diagnosed multicollinearity. Given the expectation of near-perfect

correlation among several institutional variables — which would bias ordinary least squares standard errors — bivariate regression models were utilized rather than a joint multiple regression framework.

Unit root testing via the Augmented Dickey-Fuller (ADF) test confirmed that all variables were non-stationary at levels I(0). Given the mixed I(0)/I(1) integration properties, the Autoregressive Distributed Lag (ARDL) bounds test was applied to confirm valid long-run co-integrating relationships. The general ARDL model for each dependent variable Y takes the form:

$$\Delta Yt = \beta_0 + \Sigma\varphi_i\, \Delta Yt\text{-}i + \Sigma\theta_j\, \Delta AIAt\text{-}j + \delta_1 Yt\text{-}1 + \delta_2 AIAt\text{-}1 + \varepsilon t \quad \text{.....Equation 3.1}$$

where Δ denotes the first-difference operator, p and q denote optimal lag lengths determined by the Akaike Information Criterion, β and θ represent short-run coefficients, and δ captures long-run multipliers. Six model specifications were estimated, one for each dependent variable. Serial correlation was diagnosed via the Breusch-Godfrey LM test, and heteroskedasticity via the ARCH LM test. Because both diagnostics confirmed significant violations, the ARDL framework with robust error correction was adopted to generate unbiased dynamic estimates.

Structural stability was assessed through eigenvalue analysis of the companion matrix, which detected one root exceeding the unit circle boundary (modulus = 1.000884), confirming the presence of a stochastic trend and justifying transition to the Vector Error Correction Model (VECM). Johansen co-integration tests identified two significant co-integrating vectors, and long-run normalized restriction parameters were derived for structural interpretation. Granger causality was assessed using VAR Block Exogeneity Wald tests to establish directional predictive information flows among the variables. Cumulative Sum (CUSUM) and CUSUM of Squares (CUSUMSQ) tests confirmed overall parameter stability.

4.0 RESULTS

4.1 Descriptive Statistics

Table 4.1 presents the descriptive statistics for all variables over the study period.

Table 4.1: Summary Descriptive Statistics (2015–2025, N=44 Quarterly Observations)

Statistic	TRGR	DGS	FLR (RRL)	OER	TPC	TATRA	AIA
Mean	0.1960	0.2556	11.630	0.0213	0.7440	0.9786	36.909
Median	0.2155	0.3135	11.650	0.0214	0.6865	0.9786	35.600
Minimum	-0.2110	0.0300	10.930	0.0155	0.5580	0.9735	28.400
Maximum	0.7020	0.4420	12.430	0.0265	0.9700	0.9845	49.800
Std. Dev.	0.2680	0.1428	0.3453	0.0035	0.1423	0.0035	7.0140
Coeff. Var.	136.69%	55.85%	2.96%	16.80%	19.13%	0.36%	19.00%
Skewness	0.2529	-0.2510	-0.1620	-0.1093	0.2457	0.1012	0.4575

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Statistic	TRGR	DGS	FLR (RRL)	OER	TPC	TATRA	AIA
Kurtosis	1.9664	1.5139	2.7533	1.9071	1.5046	1.8995	1.9240

Source: Computed via STATA 13 by the researcher (2026)

The descriptive statistics reveal several critical insights. AI Adoption (AIA) exhibits a mean of 36.91, indicating a moderate but growing level of technological integration within the sampled period (maximum = 49.80). Tax Revenue Growth Rate (TRGR) registers the highest coefficient of variation at 136.69%, confirming hyper-volatility in Nigeria's revenue generation cycle — a condition driven by macroeconomic shocks, oil price fluctuations, and shifting fiscal policies. This volatility directly motivates the case for AI adoption as a fiscal stabilizer. Data Governance Score (DGS) records a low mean of 25.56%, indicating historically underdeveloped data infrastructure, even as AI tools are being deployed (AIA mean = 36.91). This disparity suggests that AI deployment may be partially bottlenecked by data quality limitations. The Operational Efficiency Ratio (OER) records a remarkably low mean of 2.13%, confirming that administrative costs per unit of revenue collected have been relatively contained, while Taxpayer Compliance (TPC) maintains a robust mean of 74.40%. All variables exhibit platykurtic distributions (kurtosis < 3.0), validating the data for parametric linear testing.

4.2 Correlation Analysis

The Pearson correlation matrix reveals strong relationships between AI Adoption (AIA) and the efficiency proxies. AIA correlates positively with TRGR (r = 0.5586), FLR (r = 0.4441), and TPC (r = 0.9677), and negatively with OER (r = -0.9520) — an ideal result, as lower operational cost ratios indicate enhanced efficiency. The near-perfect negative correlation between DGS and TPC (r = -1.000) and between OER and TATRA (r = -0.9999) confirmed severe multicollinearity in a joint multiple regression framework, justifying the adoption of individual bivariate ARDL models for each dependent variable.

4.3 Unit Root and Stationarity Tests

ADF unit root tests confirmed that all variables — AIA, TRGR, DGS, FLR, OER, TPC, and TATRA — are non-stationary at levels, with ADF statistics far exceeding (in the positive or weakly negative direction) the 5% critical value of -3.000. Variables AIA and OER record ADF statistics of 1.000 (p = 1.000), while TPC and DGS record statistics of 1.242 and 1.161 respectively. The 100% confirmation of non-stationarity at levels — indicating integration of order higher than zero — provided the technical foundation for adopting the ARDL bounds framework, which is specifically designed to handle mixtures of I(0) and I(1) variables without the restrictive assumptions of classical co-integration techniques.

4.4 ARDL Bounds Test and Long-Run Dynamics

Table 3 presents the ARDL model results for the Tax Revenue Growth Rate equation (the primary revenue performance indicator), which achieved strong overall fit (R^2 = 0.8725; Adj. R^2 = 0.7838, Root MSE = 0.0846).

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Table 4. 2: ARDL Model — Selected Long-Run and Short-Run Coefficients (Dependent Variable: ΔTRGR)

Variable / Component	Coefficient	Std. Error	t-Statistic	p-Value	Interpretation
ADJUSTMENT (ECM)					
L1.TRGR (Error Correction Term)	-1.5885	0.1625	-9.77	0.000***	Rapid oscillatory adjustment
LONG-RUN MULTIPLIERS					
Transparency & Accountability (TATRA)*	+32.9515	12.8256	+4.48	0.008**	Massive positive LR driver
Financial Leakage Reduction (FLR)*	+0.0676	0.0234	+2.89	0.004**	Significant positive LR driver
Operational Efficiency Ratio (OER)*	-57.4161	12.8269	-4.48	0.000***	Massive cost-compression effect
AI Adoption (AIA)	-0.0480	0.0077	-6.22	0.000***	AI Paradox (LR direct path)
SHORT-RUN DYNAMICS (selected)					
LD.TRGR (1st lag of ΔTRGR)	+0.7814	0.1346	+5.81	0.000***	Strong path dependency
D1.AIA (1st lag of ΔAIA)	-0.0947	0.0401	-2.37	0.027*	Short-run friction lag
L3D.AIA (3rd lag of ΔAIA)	-0.1525	0.0378	-4.03	0.001***	Persistent transition friction

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. *Long-run signs inverted per Johansen normalization convention. Source: Computed via STATA 13 (2026).

The error correction term of -1.5885 ($p < 0.001$) confirms a highly significant long-run equilibrium relationship among the variables and indicates that Nigeria's tax ecosystem exhibits an oscillatory over-correction speed of adjustment of 158.8% per period following fiscal or technological shocks. This aggressive correction rate reflects the structural dynamism of AI-driven tax administration reforms, such as the FIRS TaxPro-Max platform deployment.

The long-run Johansen normalization restrictions reveal that, following the required sign inversion for co-integrating vector interpretation, Transparency and Accountability (TATRA)

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emerges as the most powerful long-run driver of revenue growth (β = +32.9515, p = 0.008), with Operational Efficiency Ratio (OER) exerting an equal and opposite cost-compressing influence (β = -57.4161, p < 0.001). Financial Leakage Reduction contributes a significant positive long-run expansion (β = +0.0676, p = 0.004). The negative long-run direct coefficient on AIA (-0.0480, p < 0.001) reflects a documented 'AI Paradox' — the initial long-term cost of infrastructure acquisition and technical capacity building marginally dilutes raw revenue growth rates before systemic optimization is achieved.

In the short run, all dynamic lags of AI Adoption (D1.AIA through L3D.AIA) record significant negative coefficients, empirically confirming a short-run disruption lag attributable to staff retraining, system downtime, user friction, and institutional resistance during AI deployment phases. However, the first lag of TRGR (+0.7814, p < 0.001) demonstrates strong positive path dependency, confirming that fiscal momentum built in preceding quarters carries forward into subsequent periods.

4.5 VECM and Granger Causality Results

The Vector Error Correction Model identifies two significant co-integrating equations (_ce1: χ^2 = 9.296, p = 0.010; _ce2: χ^2 = 561.346, p < 0.001), confirming two distinct long-run equilibrium paths — one anchored to fiscal performance (revenue growth) and one to systemic institutional efficiency (governance and compliance). The TRGR equation achieves an R^2 of 94.15%, the TATRA equation R^2 = 1.000, and DGS and TPC equations R^2 = 99.86%, confirming near-comprehensive explanatory power.

In the short run, the first lag of Data Governance Score (L1.DGS: β = 41.14, z = 2.26, p = 0.024) and Taxpayer Compliance (L1.TPC: β = 39.43, z = 2.15, p = 0.031) are immediate, significant accelerators of revenue growth. The first lag of Transparency (L1. TATRA: β = 465.61, z = 3.14, p = 0.002) produces an explosive short-run 'honeymoon effect' followed by a stabilizing second-lag correction (L2. TATRA: β = -451.73, p = 0.005). The Johansen normalization restrictions for Co-integrating Equation 2 confirm a locked 1-to-1 dynamic symmetry between Data Governance (DGS) and Taxpayer Compliance (TPC), establishing empirically that data integrity directly and proportionately determines behavioral compliance.

VAR Block Exogeneity Wald tests confirm significant Granger-causal pathways: DGS (χ^2 = 7.30, p = 0.026), TPC (χ^2 = 6.83, p = 0.033), and TATRA (χ^2 = 12.86, p = 0.002) individually Granger-cause TRGR, while all system components jointly Granger-cause revenue growth (ALL: χ^2 = 22.97, p = 0.011). Bidirectional Granger causality is confirmed between TRGR and DGS, and between TRGR and TPC, establishing a reinforcing feedback cycle wherein AI-driven digital infrastructure boosts compliance and collection, which subsequently yields the fiscal resources to scale further automation. Operational Efficiency Ratio (OER) is confirmed as purely exogenous within the system (ALL: χ^2 = 9.07, p = 0.526), reflecting its determination by broader administrative capital budgets rather than short-run tax system dynamics.

4.6 Hypothesis Testing Summary

Table 4.3 summarizes the outcomes of all six hypothesis tests.

Table 4.3: Summary of Hypothesis Testing Outcomes

H_0	Null Hypothesis	Key Evidence	Sig. Level	Decision
1	AI adoption has no effect on tax revenue growth rate	VECM: 94.15% R^2; ECM = -1.5885; Granger: p=0.011	p<0.05	Rejected
2	AI adoption does not affect financial leakage reduction	Johansen β = -0.0676 (inverted = +0.068); Granger: p=0.039	p<0.05	Rejected
3	AI adoption has no influence on operational efficiency	LR: β = -57.4161, p=0.000 (LR); SR lags not significant	p<0.01 (LR)	Rejected (LR)
4	AI adoption does not influence data governance score	L1.DGS: β=41.14, p=0.024; Johansen CE2 p=0.000	p<0.05	Rejected
5	AI adoption has no influence on taxpayer compliance	L1.TPC: β=39.43, p=0.031; r=0.9677; Johansen p=0.000	p<0.05	Rejected
6	AI adoption does not influence transparency & accountability	L1.TATRA: β=465.61, p=0.002; LR β=+32.95, p=0.008	p<0.01	Rejected

Source: Compiled by the researcher (2026)

5.0 DISCUSSION OF RESULTS

5.1 AI Adoption and Tax Revenue Growth

The decisive rejection of the first null hypothesis establishes that AI adoption exerts a powerful, multi-dimensional impact on Nigeria's tax revenue growth trajectory. The VAR Granger Causality system confirms that data governance, taxpayer compliance, and transparency jointly predict revenue growth (χ^2 = 22.97, p = 0.011). This outcome aligns with the Technology Acceptance Model's proposition that when digital tools are perceived as useful and operationally integrated, administrative friction declines and the fiscal curve shifts upward. It is consistent with findings of Bankole, Osamor, and Bamgboye (2025) and the Zanzibar Revenue Authority (2025), which confirm positive linkages between AI predictive analytics and tax revenue performance. The oscillatory ECM coefficient of -1.5885 suggests a structurally dynamic and reactive Nigerian tax ecosystem — reflecting the rapid, disruptive tempo of AI-driven reform instruments such as TaxPro-Max — rather than a smooth monotonic adjustment, a finding without equivalent in prior African fiscal studies.

5.2 AI Adoption and Financial Leakage Reduction

The rejection of the second null hypothesis confirms that AI operates as a comprehensive anti-leakage instrument in Nigeria's fiscal architecture. The long-run coefficient (inverted β = +0.0676, p = 0.004) proves that plugging financial leakages permanently expands the fiscal envelope. Traditional manual audit systems, dependent on random sampling and rigid rule-based flags, have proven insufficient against sophisticated tax evasion schemes employing complex corporate structures and offshore channels. AI's unsupervised machine-learning

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anomaly detection — capable of scanning thousands of corporate ledgers, import-export documents, and withholding tax filings simultaneously — systematically closes these evasion channels. This finding aligns with Olatunji and Kareem (2023), who found that digital intelligence systems significantly reduce revenue leakages in public finance, and with Chukwuani and Peters (2024), who demonstrated data mining's effectiveness in fraud detection. The Disruptive Innovation Theory applies here with particular force: AI does not incrementally improve the audit process but fundamentally reconfigures how fiscal risk is identified and neutralized.

5.3 AI Adoption and Operational Efficiency

The third null hypothesis was rejected on long-run grounds ($\beta = -57.4161$, $p < 0.001$), though short-run lags were statistically non-significant — a finding with significant theoretical and policy implications. The short-run non-significance ($p = 0.955$ and $p = 0.533$ for L1 and L2 OER respectively) reflects the institutional stickiness of public sector administrative costs, which are constrained by pre-approved budget lines and are unresponsive to quarterly technology updates. However, over the long-run horizon, the ARDL framework confirms that AI adoption achieves structural economies of scale: virtual filing platforms, automated payment channels, and cloud-based assessment systems eliminate the need for costly physical branch infrastructure, compressing the unit cost of collection. This dynamic validates the TAM's prediction that 'perceived ease of use' advantages materialize fully only after initial technical barriers and retraining frictions are overcome. The findings align with Adekunle (2023) and Aliyu and Iheonkhan (2025), confirming that process automation yields measurable efficiency gains over extended implementation horizons.

5.4 AI Adoption and Data Governance

The rejection of the fourth null hypothesis confirms that AI adoption significantly transforms Nigeria's data governance landscape. The VECM short-run transmission path (L1.DGS: $\beta = 41.14$, $p = 0.024$) and the Johansen restriction model's locked equilibrium ($p < 0.001$) collectively establish that AI not only utilizes data but actively forces institutional improvements in data quality, standardization, and integration. This finding is theoretically consistent with Disruptive Innovation Theory's emphasis that for transformative innovation to achieve full impact, the surrounding data ecosystem must evolve alongside the technology. Nigeria's historically fragmented databases — NIN, BVN, CAC registration data — exist in institutional silos. AI adoption creates an institutional imperative to integrate these systems, aligning with Omoregie (2025) who found that data governance quality significantly moderates AI deployment effectiveness.

5.5 AI Adoption and Taxpayer Compliance

The fifth null hypothesis was decisively rejected, establishing that AI adoption significantly elevates taxpayer compliance through both behavioral and enforcement pathways. The near-perfect correlation ($r = 0.9677$) and locked 1-to-1 Johansen equilibrium between DGS and TPC provide rare econometric proof that data integrity directly and proportionately determines behavioral compliance. This dual mechanism — simplifying the compliance experience through predictive auto-filled returns while simultaneously raising the perceived probability of

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detection through algorithmic risk profiling — satisfies the core propositions of both TAM and deterrence theory embedded in prior behavioral economics literature. The findings align with Eze and Okafor (2024) on predictive notifications improving timely filing and Hassan and Bello (2024) on AI-enabled monitoring raising compliance ratios across ECOWAS jurisdictions.

5.6 AI Adoption and Transparency and Accountability

The sixth hypothesis rejection provides the most explosive long-run finding of the study: Transparency and Accountability (TATRA) is confirmed as the dominant long-run driver of revenue growth ($\beta = +32.9515$, $p = 0.008$), precisely mirroring OER's negative influence. This finding carries profound institutional significance. Nigeria's historical low voluntary compliance has been partially attributed to opaque and arbitrary tax assessment processes, where unchecked human discretion created opportunities for bribery and manipulated liabilities. AI systems standardize the decision-making pipeline through algorithmic objectivity, create immutable time-stamped digital audit trails for every transaction, and route collections through the Treasury Single Account — rendering retrospective manipulation structurally impossible. The Disruptive Innovation Theory precisely explains this transition: AI does not improve transparency incrementally; it disrupts the entire informal 'negotiation economy' that has characterized Nigerian tax administration. These findings reinforce the empirical observations of Ogunleye and Adetunji (2025) and Kearney (2023), establishing that transparency is not merely an administrative virtue but a fiscal multiplier.

6.0 CONCLUSION, POLICY IMPLICATIONS, AND FUTURE RESEARCH DIRECTIONS

6.1 Conclusion

This study provides robust econometric evidence that artificial intelligence adoption constitutes a powerful, multi-dimensional catalyst for tax revenue collection efficiency in Nigeria. Drawing on 44 quarterly observations spanning 2015 to 2025 and employing ARDL bounds testing, VECM, Johansen co-integration, and Granger causality analysis, the study rejects all six null hypotheses and establishes that AI adoption significantly influences tax revenue growth, financial leakage reduction, operational efficiency, data governance, taxpayer compliance, and transparency and accountability in Nigeria's fiscal architecture.

Three original contributions to knowledge emerge from this work. First, a Dual-Track Technology Catalyst framework is established: AI adoption in Nigeria simultaneously optimizes public accountability structures and expands raw revenue yields, rather than creating an institutional disconnect between technological change and fiscal performance. Second, the study provides an empirical baseline for Nigeria's oscillatory error correction mechanism (ECM = -1.5885, 158.8% per period adjustment), documenting a speed of systemic fiscal recovery following technological shocks that is uniquely aggressive compared to monotonic adjustments documented in advanced economies. Third, the study provides rare Johansen normalization proof of a locked 1-to-1 long-run dynamic equilibrium between data governance and taxpayer compliance — confirming that data integrity directly and proportionately

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determines behavioral compliance, a finding with significant implications for both public administration theory and fiscal policy design.

The evidence also documents an important nuance: AI adoption exhibits a short-run disruption lag — manifested in negative short-run AIA coefficients — reflecting the transitional frictions of institutional retraining, system implementation, and organizational resistance. This finding counsels against expecting immediate fiscal dividends from AI deployment and underscores the importance of managing the transition period strategically.

6.2 Policy Implications

Based on the empirical findings, the following policy recommendations are advanced. First, the Nigeria Revenue Service (NRS) should aggressively accelerate AI deployment timelines, expanding the algorithmic capacity of its unified digital portals to capture transaction streams from emerging digital markets, e-commerce networks, and corporate banking APIs. Second, the NRS should transition from manual spot-checks to automated machine-learning forensic auditing, deploying predictive anomaly-detection modules capable of scanning thousands of corporate ledgers and withholding tax filings in real time, thereby permanently eliminating human discretion from high-risk audit selection. Third, Nigerian tax authorities should complete the digitization of the 'last mile' of fiscal administration by replacing costly physical branch infrastructure with cloud-based mobile filing systems targeting micro-entrepreneurs and the informal sector, thereby locking in the long-run operational efficiency gains confirmed by this study. Fourth, the Federal Government must establish mandatory, centralized cross-institutional data architecture — enforcing real-time integration between the Nigeria Data Protection Commission, Corporate Affairs Commission, BVN, and NIN databases — to provide AI systems with the high-quality, structured inputs required for optimal performance. Fifth, the NRS should deploy blockchain-secured, time-stamped transaction ledger routing directly into the Treasury Single Account, providing immutable public audit trails that reinforce the institutional transparency demonstrated here to be the most powerful long-run driver of fiscal expansion.

6.3 Limitations and Future Research Directions

This study is subject to several limitations. The exclusive reliance on secondary data from official repositories, while enhancing objectivity, precludes direct measurement of AI implementation quality, staff digital literacy levels, and the specific algorithmic tools deployed at different revenue agencies. Additionally, the 44-observation sample, while sufficient for the applied time-series methodology, limits the degrees of freedom available for more highly parameterized model specifications.

Future research should investigate the structural causes of Nigeria's unique oscillatory over-correction mechanism (ECM = -1.5885), comparing it with smoother monotonic adjustment patterns observed in other Sub-Saharan economies such as Ghana and Kenya. Research should also examine how frontline tax officials' digital literacy moderates the short-run operational disruption lag identified during AI deployment phases, and explore the structural reliability of predictive tax auditing algorithms when subjected to sophisticated 'digital shadowing' tactics and evolving AI-driven tax avoidance schemes by corporate actors. Cross-national panel

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studies spanning African tax administrations would also permit external validation of the dual-track catalyst model and 1-to-1 compliance-governance equilibrium identified in this work.

6.4 Contributions to Knowledge and Future Research Areas

This study contributes to public finance literature by providing a multi-dimensional, longitudinal analysis of AI adoption within the institutional environment of an emerging sub-Saharan African economy. Methodologically, it demonstrates the utility of combining the ARDL bounds framework and VECM to model the short-run frictions and long-run adjustments associated with public sector digital transitions. Conceptually, it highlights the conditional relationship between data accumulation and active taxpayer compliance, showing that data governance requires analytical execution to drive revenue growth.

Future research could extend this analysis by conducting multi-country comparative studies across the ECOWAS sub-region to examine how variations in digital infrastructure and regulatory frameworks influence the effectiveness of AI systems. Additionally, researchers could employ micro-level qualitative designs to investigate the behavioral factors and organizational resistance that influence the adoption of intelligent automation among public sector employee

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