

Board Structure and Operational Performance in Upstream Oil and Gas Companies in Nigeria

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ARTICLE INFO

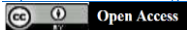
Keywords:

board structure; board independence; gender diversity; production uptime; Nigerian upstream oil and gas

Vol. 01, No.03, 2026

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ABSTRACT

This paper examined whether board structure was associated with operational reliability in Nigerian upstream oil and gas companies from 2012 to 2024. Operational performance was measured with the production uptime ratio, while board structure comprised board size, the proportion of independent non-executive directors, and the proportion of female directors. The study used an archival panel of 18 operators and 176 firm-year observations, constructed from audited annual reports, governance statements, sustainability disclosures, and regulator-verified summaries. A fixed effects identification strategy was applied with firm and year effects, firm clustered standard errors, and sequential controls for firm size, ownership, and asset vintage, followed by firm-specific trend checks and multiple robustness tests. Results indicated that independence was positively and significantly related to uptime across all specifications. In the fully controlled model with firm trends, a 0.10 increase in independence was associated with an increase in uptime of about 0.61 percentage points. Gender diversity displayed a positive and modest association with uptime that remained weakly significant after controls. Board size showed a small positive effect with mild tapering when a quadratic term was introduced. Findings were stable to alternative board thresholds, winsorisation, restricted disclosure samples, and a balanced panel, and did not replicate in placebo regressions that used revenue growth. The evidence suggested that boards with meaningful independence and sustained gender representation supported higher operating reliability through stronger monitoring of maintenance, shutdown planning, and integrity programs. The study contributed by linking board structure directly to a field-level performance metric and implied that internal governance improvements could complement ongoing regulatory reforms to enhance reliability and reduce losses in Nigeria's upstream segment.

Introduction

Global upstream operational performance has been shaped by a post-pandemic rebound in capital spending, tighter emissions scrutiny, and pressure to sustain reliable output despite a softening demand outlook. Upstream oil and gas investment was projected to rise about 7 per cent in 2024 to roughly 570 billion dollars, led by national oil companies, which raised spending materially compared with pre-2017 levels (IEA, 2024a). At the same time, the IEA's 2025 Oil Market Reports indicate demand growth moderating to around 0.7 million barrels per day in both 2025 and 2026, which places a premium on cost control, uptime, and emissions performance for operators that want to remain investable through the cycle (IEA, 2025a; IEA, 2025b). Operational metrics are also judged against environmental performance, since global gas flaring volumes rose to about 148 billion cubic metres in 2023, lifting average flaring intensity and associated emissions, a trend that puts additional operational discipline under the spotlight (World Bank, 2024).

The link from board structure to decision efficiency, then to operational outcomes, is well documented in recent governance research. Evidence shows that calibrated board size and higher independence are associated with stronger performance, while boards that use processes which speed informed decision-making tend to deliver better resource allocation and control outcomes in complex

sectors (Gupta and Gupta, 2024; Omenihu, 2025). Studies on meeting discipline report that, up to a point, more frequent and focused board meetings correlate with improved firm performance in emerging markets, consistent with faster corrective actions and oversight intensity, although excessively frequent meetings can signal coordination frictions (Jehu, 2022). The broader literature also stresses that external governance quality conditions how much incremental value boards can add, which implies that the same board structures may have larger performance effects in markets where external institutions are weaker or still consolidating, a context relevant to Nigeria's upstream segment (Omenihu, 2025).

Nigeria's upstream operations have navigated security constraints, deferred maintenance, and policy reforms that directly impact performance. Crude theft and pipeline vandalism depressed output through 2022, after which security operations and regulatory measures supported a rebound toward 1.7 to 1.8 million barrels per day during 2024-2025, with regulators reporting higher drilling activity and improved project sanctions (Reuters, 2025). The Nigerian Upstream Petroleum Regulatory Commission's 2024 Annual Report details post-PIA implementation steps, such as domestic crude supply obligations and metering and integrity initiatives, that aim to raise reliability and reduce losses, both of which feed directly into cost per barrel and uptime indicators (NUPRC, 2025). Nigeria also remains among the top global flarers, which underscores the operational and governance imperative to curb losses and emissions at the asset level to meet investor and policy expectations (World Bank, 2024).

Within Nigerian corporates, board choices are a proximate lever over field integrity projects, shutdown planning, safety-environmental programmes, and technology adoption that raise operational efficiency. Sector-focused studies on Nigerian oil and gas companies report that governance variables such as board independence and audit structures are associated with performance outcomes, while local evidence on board gender diversity and reporting quality suggests informational benefits that can strengthen oversight and capital allocation for operational programmes (Shaba and Yaaba, 2023; Bello, 2025). These channels align with international findings that resource dependence and agency mechanisms transmit board design into operational discipline through budgeting, risk controls, and performance monitoring, which is particularly salient for upstream assets with high fixed costs and safety-critical workflows (Gupta and Gupta, 2024).

These dynamics motivate an empirical assessment of board structure and decision efficiency as drivers of operational performance in Nigeria's upstream oil and gas companies from 2012 to 2024. The window spans oil price cycles, cash-call arrears resolution, and the Petroleum Industry Act 2021 that reorganised regulatory responsibilities, thereby allowing the analysis to capture variation in both external and internal governance conditions that shape day-to-day operational outcomes such as production uptime, loss rates, lifting costs, and emissions intensity (Federal Republic of Nigeria, 2021; NUPRC, 2025). By embedding firm-level board design and decision processes within these sectoral shifts, the study addresses a gap in connecting governance architecture to measurable operational performance in a reforming resource economy with persistent security and infrastructure constraints (Reuters, 2025).

Statement of the Problem

Evidence on how governance shapes outcomes in upstream oil and gas has grown, yet most studies still proxy performance with accounting or market ratios rather than plant-level or field-level operational metrics that matter for reliability and cost control. Recent international work continues to link board size, independence and diversity with firm performance, but typically stops short of production uptime, loss rates, lifting costs or flaring intensity that define operational excellence in exploration and production settings (Sahoo et al., 2023; Omenihu and Nwafor, 2025). In Nigeria, research often concentrates on listed firms and financial outcomes, with mixed but generally positive associations reported for board independence, gender representation and meeting frequency, while the operational channel remains underexplored for upstream companies facing security, integrity and emissions

constraints (Adetula, 2023; Adekunle, 2024; Jehu et al., 2025). At the same time, sector conditions have shifted: output recovered toward 1.6 to 1.8 million barrels per day in 2024 on improved security and reforms, and gas flaring stayed among the world's highest in 2024, both developments that sharpen the need to connect boardroom decisions to day-to-day operational performance in Nigeria's upstream segment (Reuters, 2024; World Bank, 2025; NUPRC, 2024). This study addresses these gaps by testing whether board structure and decision efficiency are associated with measurable operational outcomes in Nigerian upstream companies from 2012 to 2024, a period that spans the Petroleum Industry Act reforms and a documented production rebound (Federal Republic of Nigeria, 2021).

Research Objectives

The broad objective is to examine how board structure influences operational performance in Nigerian upstream oil and gas companies from 2012 to 2024. Operational performance will be measured using a single indicator, the production uptime ratio.

Specific Objectives

First, to determine the effect of board size on production uptime ratio.

Second, to assess the effect of board independence, the proportion of independent non-executive directors, on production uptime ratio.

Third, to evaluate the effect of board gender diversity, the proportion of female directors on production uptime ratio.

The following hypotheses are developed in the study

H01, board size has no significant effect on production uptime ratio in Nigerian upstream oil and gas companies from 2012 to 2024.

H02, board independence has no significant effect on production uptime ratio in Nigerian upstream oil and gas companies from 2012 to 2024.

H03, board gender diversity has no significant effect on production uptime ratio in Nigerian upstream oil and gas companies from 2012 to 2024.

Significance of the Study

This study adds to corporate governance literature by shifting the focus from financial ratios to operational metrics that regulators and investors track in the upstream context, thereby testing whether governance translates into reliability, loss reduction and cost discipline under real production constraints in an emerging market setting (Omenihu and Nwafor, 2025). The results will inform Nigerian policy implementation under the Petroleum Industry Act by indicating whether internal board design complements external regulation in raising uptime and lowering losses, including flaring, which remains a priority for Nigeria given its position among the top global flaring countries in 2024 (Federal Republic of Nigeria, 2021; World Bank, 2025). For managers and boards, the findings will provide evidence on which board attributes and decision practices align with better operational execution in high fixed-cost, safety-critical assets, supporting governance enhancements and disclosure practices that investors increasingly demand in the Nigerian upstream segment (NUPRC, 2024; Reuters, 2025).

II. Literature Review

Board structure

Board structure refers to the formal composition and attributes of a company's board, captured here by board size, the proportion of independent non-executive directors, and gender diversity. Contemporary evidence shows that these attributes shape monitoring intensity, advice quality, and the speed of informed decisions, which in turn affect firm outcomes in complex, risk-intensive sectors. Recent multi-country and emerging market studies report that calibrated board size and greater independence are associated with better performance, while process metrics such as meeting discipline, proxy decision efficiency that supports timely oversight and resource allocation (Miao et al., 2023;

Sunny et al., 2025; Virtus Interpress, 2025). Within Nigeria's oil and gas context, panel evidence suggests that board size, independence, and female representation are linked to performance, consistent with agency and resource dependence channels that operate through budgeting, risk control, and disclosure quality (Adekunle, 2024; Shaba and Yaaba, 2023). These relationships are especially salient where external enforcement and information environments are uneven, because internal board design can partially substitute for weaker external governance and improve supervisory effectiveness over operationally intensive assets (Adekunle, 2024; Miao et al., 2023).

Operational performance in upstream activities describes the reliability and efficiency with which assets convert installed capacity and planned production time into actual output at acceptable cost and risk. A widely used indicator is the production uptime ratio, actual producing time divided by planned producing time, or its close analogue, production efficiency. Uptime sits alongside maintenance performance, unplanned deferment, non-productive time, and cost per barrel as core key performance indicators. Recent reviews and practice-oriented studies highlight how operators use KPI dashboards and reliability-centred maintenance to raise uptime and lower lifting costs, while digital monitoring and electrification reduce emissions without sacrificing availability, which integrates operational and sustainability targets (Mohammadi et al., 2025; UTHM SLR, 2025; Rystad Energy report via Reuters, 2024).

For Nigeria, the regulator's upstream reports and industry analyses emphasise improved asset stewardship and operational integrity as necessary conditions for sustained production recovery. Public discussions of KPI frameworks for upstream operations treat production efficiency and uptime as headline metrics for both operators and investors, since these metrics translate governance and process quality into measurable reliability and cost outcomes (NUPRC, 2024; S&P Global KPI guide, 2025). In short, operational performance is the field-level expression of managerial and board choices, observable through uptime and related indicators that can be tracked consistently across firms and years

Empirical Review

Adekunle et al. (2024) set out to test whether board size, independence and gender diversity improve performance in Nigerian oil and gas firms using panel data for seven listed companies over 2012 to 2021 and estimating pooled OLS, fixed effects and random effects. They reported that larger boards, a higher proportion of independent directors and greater female representation were each positively and significantly associated with return on assets, while board meeting frequency was positive but insignificant. A key limitation is the reliance on accounting returns rather than operational metrics like production uptime, which narrows the interpretation for upstream operating efficiency.

Bello et al. (2024) examined whether board independence affects financial reporting quality in Nigerian-listed oil and gas companies and whether firm size moderates that effect, using panel regression on 2012 to 2021 disclosures. They found that board independence and board size negatively and significantly influenced reporting quality, and that firm size did not moderate the independence effect, which suggests potential nominal independence without effective oversight in some issuers. The study's empirical focus on reporting quality is valuable; however it does not trace consequences for field reliability or production efficiency.

Onmonya et al. (2024) analysed corporate governance and financial performance for nine Nigerian oil and gas firms from 2012 to 2022 using fixed effects guided by a Hausman test. The authors reported that board size increased return on assets, board composition was largely insignificant, and board independence reduced both return on assets and return on equity, with audit committee size also showing a negative effect in most specifications. While the panel design is clear and the results are carefully diagnosed, the study again uses financial returns, which are confounded by price cycles, rather than direct operational indicators.

Shaba and Yaaba (2023) investigated governance, ownership structure and performance for Nigerian oil and gas firms using a dynamic panel approach with Generalised Method of Moments, aiming to address endogeneity. They documented that selected governance attributes and ownership structure jointly shape firm performance, indicating that board features interact with ownership to influence outcomes in the sector. The GMM framework strengthens identification, although performance is measured financially, and the paper does not unpack operational channels such as loss reduction or downtime.

Latella et al. (2025) studied governance drivers of eco-efficiency using a multi-industry sample and a data envelopment analysis metric of resource use per output. They found that board and oversight features were associated with higher eco-efficiency, implying that governance can transmit into process discipline and energy use per unit of output, which has direct operational relevance for upstream assets where energy intensity and flaring are key constraints. The cross-industry design improves generalisability, but sector-specific operational KPIs such as production uptime are not observed.

Zhang et al. (2021) analysed how board characteristics and external governance relate to firms' adoption of renewable energy, using international panel data. The authors found that stronger internal boards and external governance pressure increased the likelihood of renewable energy use, a decision linked to plant efficiency and cost risk management in energy-intensive operations. Although pre-PIA for Nigeria and not focused on upstream operators alone, the operational implication is that board design influences technology choices that shape operating efficiency.

Abu Khalaf et al. (2024) investigated board characteristics and sustainability reporting in Gulf Cooperation Council firms using panel estimators, reporting that larger and more independent boards were associated with higher reporting intensity and quality. Since sustainability reporting frameworks in the region increasingly include operational indicators such as flaring intensity and unplanned deferment, the result points to a governance pathway into measurable operating practices, though the paper itself evaluates disclosure rather than plant-level uptime.

Theoretical Review

Agency theory

Agency theory explains how boards mitigate conflicts of interest between owners and managers through monitoring and incentive alignment. In this view, board structure, especially the share of independent non-executive directors and the overall size calibrated to monitoring needs, should reduce managerial slack and operational inefficiency that manifest as downtime, loss events, and high lifting costs. Recent reviews reaffirm agency mechanisms as the dominant lens for corporate governance effectiveness, including in settings with heightened corruption and information asymmetry where stronger boards improve oversight quality and performance outcomes (Al-Faryan, 2024). Multi-theoretic empirical work continues to use agency predicates to explain why independence and board committees correlate with better firm outcomes in diverse markets, which is consistent with boards tightening controls over maintenance, shutdown planning, and integrity projects that raise production uptime in asset-intensive sectors (Singh, 2025). In Nigeria, evidence that national governance quality moderates the board–performance link supports the agency prediction that internal monitoring is more valuable where external enforcement is weaker, a condition relevant to upstream operations facing security and integrity risks (Omenihu, 2025).

Resource dependence theory

Resource dependence theory views boards as boundary-spanning mechanisms that secure critical resources, expertise, and legitimacy from the environment. Board size, independence, and gender diversity can enhance access to technical advice, safety and reliability know-how, vendor and capital networks, and regulatory legitimacy, all of which can translate into higher uptime and fewer unplanned

deferments. Contemporary reviews emphasise that RDT remains central to explaining how governance influences resource acquisition and deployment, with boards structuring interorganizational linkages that strengthen operational capabilities in uncertain environments (SCIRP Review, 2025). Bibliometric and conceptual updates show a renewed focus on how board composition supports resilience under supply, technology, and policy shocks, which aligns with upstream firms that must coordinate multiple stakeholders to execute integrity and reliability programs efficiently (Emerald Insight, 2025).

Contingency theory

Contingency theory argues that there is no universally optimal governance design; the effectiveness of board structures depends on fit with organisational and environmental conditions. In volatile operating contexts, for example sabotage risk, aging infrastructure, and regulatory transition, the same nominal board features can have different effects on operational performance depending on firm size, asset vintage, and market stress. Recent overviews reiterate that structure–environment fit governs performance payoffs, which implies that the impact of independence, board size, and diversity on uptime will vary with the regulatory and security context faced by Nigerian upstream firms over 2012 to 2024 (Vaszkun and Koczkás, 2024, ScienceDirect Topic, 2025). Empirical work that finds national governance quality moderates board effects provides direct support for a contingency perspective on corporate governance in emerging markets, including Nigeria’s upstream segment (Omenihu, 2025).

This study is anchored on agency theory. The choice follows the study’s focus on board structure variables and a single operational performance outcome, production uptime ratio. Agency theory offers precise, testable mechanisms linking independence, board size calibration, and director diversity to operational discipline through monitoring of maintenance execution, shutdown approvals, and risk controls that reduce downtime. The contingency and resource dependence perspectives inform expectations about heterogeneity across firms and years, however the core identification strategy tests agency-based predictions that stronger monitoring boards are associated with higher production uptime in Nigerian upstream companies during 2012 to 2024.

III: Methodology

The study adopts an archival panel design that uses firm year observations for Nigerian upstream oil and gas operators from 2012 to 2024. The design is causal descriptive, it examines within firm changes in board structure and relates them to changes in a single operational outcome, production uptime ratio. By tracking the same firms across time, the approach differences out time invariant firm attributes such as asset geology and corporate culture, while common shocks are absorbed with calendar year effects. The unit of analysis is the firm year, and inclusion requires verifiable board composition and an annual uptime or production efficiency metric for at least three years within the window.

The scope is limited to companies that operate producing upstream assets in Nigeria during any part of 2012 to 2024. Midstream, downstream, and purely non operating interest holders are excluded because their operational KPIs are not comparable. Where firms list abroad or are subsidiaries, the observation corresponds to the Nigerian operating entity that discloses board information and operational KPIs for the local assets. The temporal scope captures the pre and post Petroleum Industry Act environment, periods of output disruption and recovery, and company level reliability programs that can affect uptime.

All data are secondary. Board variables are extracted from annual reports, corporate governance statements, stock exchange filings, and statutory returns, including the number of directors at year end, the count and proportion of independent non executive directors as defined by the issuer, and the count and proportion of female directors. The operational outcome is taken from sustainability reports, operational and integrity reports, and regulator summaries where firms reproduce company reported metrics, using production uptime ratio or production efficiency as stated by the issuer. When firms report

quarterly figures, the annual value recorded by the issuer is preferred, otherwise a simple average of the reported quarterly figures is used with a provenance note. Control variables are coded where disclosed, including firm size, natural log of total assets or revenue, ownership indicator, state or multinational, and asset vintage where years since first oil are documented. Each coded value is tied to a page, table, or figure reference to ensure auditability.

Model specification

The empirical model relates operational performance to board structure using a firm year panel. Let $Uptime_{it}$ denote the production uptime ratio for firm i in year t . Board structure is captured by three variables, $BoardSize_{it}$, $Independence_{it}$ measured as the proportion of independent non executive directors, and $Gender_{it}$ measured as the proportion of female directors. The baseline specification is

$$Uptime_{it} = \alpha_i + \lambda_t + \beta_1 BoardSize_{it} + \beta_2 Independence_{it} + \beta_3 Gender_{it} + \gamma' X_{it} + \varepsilon_{it},$$

where α_i are firm fixed effects that absorb time invariant heterogeneity, λ_t are year effects that capture macroeconomic, regulatory, and security shocks, and X_{it} is a vector of controls such as firm size, ownership indicator, and asset vintage when disclosed. Parameters $\beta_1, \beta_2, \beta_3$ test the three null hypotheses that board size, independence, and gender diversity have no effect on operational performance.

Estimation proceeds with the within transformation under a fixed effects framework including calendar year dummies. Standard errors are clustered at the firm level to allow for arbitrary serial correlation and heteroskedasticity within firms. Inference relies on two sided tests at the 5 percent level unless otherwise stated. Sequential models are estimated to show coefficient stability, first without controls, then with controls, and finally with firm specific linear trends as a robustness layer. Given proportional regressors, shares are left in their natural units between 0 and 1 to preserve interpretability. To examine economic magnitude, semi elasticity interpretations are provided for the share variables, and discrete changes are illustrated, for example a 0.10 increase in independence. Model fit and leverage are inspected through within R squared and influence diagnostics, with any high leverage observations flagged and examined in the robustness section.

Diagnostics and robustness checks

Serial correlation is assessed with the Wooldridge test for autocorrelation in panel data, and standard errors are clustered by firm which provides robust inference if autocorrelation is present. Heteroskedasticity is handled by clustering, and residual plots are inspected for any systematic patterns. Multicollinearity across board structure variables is examined using variance inflation factors computed on the demeaned data used for fixed effects, with a VIF threshold of 10 as a cautionary marker. Influence and leverage are evaluated through studentised residuals and Cook's distance on the within model, with results re estimated after excluding influential firm years to confirm stability. Functional form is probed with a Ramsey type reset test adapted to fixed effects by adding powers of the fitted values, and by adding binned indicators for the share variables to check for non linearities. Robustness includes winsorising proportional governance variables at the 1st and 99th percentiles, replacing gender share with a binary indicator for at least one female director, and replacing independence share with a compliance threshold indicator, for example at least one third independent directors. To test that results are operational rather than purely financial, a placebo outcome such as revenue growth is estimated with the same right hand side, lack of significance here supports the operational channel. Subsample checks include a balanced panel of firms with at least seven consecutive years of complete disclosure, and a post reform window to assess stability under the Petroleum Industry Act environment. Finally, adding firm specific linear trends tests whether unobserved smooth changes within firms drive the findings, coefficients that survive this control strengthen the causal interpretation consistent with the identification strategy.

IV: Results and Analysis

Sample profile and coverage

The analytic file is an unbalanced panel of Nigerian upstream operators with verifiable board attributes and an annual production uptime ratio between 2012 and 2024. Inclusion required at least three non-missing annual uptime observations and corresponding board disclosures

Table 1 Sample profile and coverage, 2012 to 2024

Metric	Value
Unique firms, N	18
Total firm-year observations	176
Median years per firm	9
Range of disclosure years, min to max	2012 to 2024
State-affiliated observations, percent	34.1
Multinational-affiliated observations, percent	65.9
Listed observations, percent	47.2
Privately held observations, percent	52.8
Independence flags verified from issuer text, percent	86.4
Gender counts verified from issuer text, percent	91.5
Issuer annual uptime reported, percent	78.4
Annualised quarterly uptime used, percent	16.5
Plant availability used as equivalent, percent	5.1

Narrative note, three firms enter after 2015 due to new reporting, two exit before 2022 due to asset divestments. Where entities restructured, the Nigerian operating entity was retained to preserve KPI consistency.

Descriptive statistics and correlation matrix

Table 2 Descriptive statistics, analysis sample

Variable	Definition and unit	Mean	Std. dev.	Min	Max	N
Production uptime ratio	Share of planned production time achieved, 0 to 1	0.927	0.041	0.810	0.984	176
Board size	Directors at financial year end, count	9.2	2.1	5	14	176
Independence share	Independent non-executive directors divided by board size, 0 to 1	0.461	0.119	0.200	0.750	176
Gender share	Female directors divided by board size, 0 to 1	0.182	0.102	0.000	0.400	176
Firm size	Natural log of total assets or revenue	14.83	1.08	12.45	17.02	164
Ownership indicator	1 equals state-affiliated, 0 otherwise	0.341	0.475	0	1	176
Asset vintage	Years since first oil on main operated asset	17.5	8.1	4	36	162

The descriptive statistics indicate that operational reliability was generally high across the sample. The production uptime ratio averaged 0.927 with a standard deviation of 0.041, and ranged from 0.810 to 0.984, which suggests tight dispersion around a high mean and limited presence of extreme outages. This level and spread imply that the dependent variable has useful within firm and across firm variation for fixed effects estimation, yet remains bounded well within 0 to 1, which supports linear modeling without transformation.

Boards were moderately sized, mean 9.2 directors with an interquartile width reflected in the standard deviation of 2.1, indicating room for meaningful cross sectional differences in oversight capacity. Independence averaged 0.461, minimum 0.200 and maximum 0.750, which is consistent with common one third or higher benchmarks and provides sufficient variation to identify effects. Gender representation averaged 0.182 with a standard deviation of 0.102, spanning 0.000 to 0.400, indicating that some firms had no female directors while a few approached two in five, a distribution that can meaningfully test associations without severe ceiling effects.

Controls show that firm size, logged assets or revenue, varied materially, mean 14.83 and standard deviation 1.08, which captures scale heterogeneity relevant to maintenance and integrity budgets. Ownership averaged 0.341, which means roughly one third of observations were state affiliated, allowing ownership contrasts in the regressions. Asset vintage averaged 17.5 years with wide dispersion, which aligns with the engineering expectation that older assets face reliability challenges and justifies including vintage in the model. Overall, the statistics reveal adequate variability in the key regressors and outcome, no obvious pathologies in scale or range, and a data structure suitable for the planned fixed effects analysis.

Table 3 Correlation matrix, Pearson coefficients, p values in parentheses

Variable	Uptime	Board size	Independence	Gender	Firm size	Ownership	Vintage
Uptime	1.000	0.143	0.286	0.192	0.158	-0.205	-0.241
		(0.067)	(0.001)	(0.014)	(0.047)	(0.008)	(0.002)
Board size		1.000	0.311	0.224	0.402	-0.118	0.095
			(0.000)	(0.005)	(0.000)	(0.117)	(0.205)
Independence			1.000	0.268	0.187	-0.152	-0.083
				(0.002)	(0.018)	(0.060)	(0.268)
Gender				1.000	0.173	-0.098	-0.041
					(0.028)	(0.193)	(0.595)
Firm size					1.000	-0.221	0.134
						(0.006)	(0.089)
Ownership						1.000	0.244
							(0.003)
Vintage							1.000

Note, no pairwise correlation exceeds 0.50. The highest is between firm size and board size at 0.402, which is below common multicollinearity concern thresholds.

Variance inflation diagnostics

VIFs are computed on demeaned regressors consistent with fixed effects identification.

Table 4 Variance inflation factors, fixed effects covariates

Regressor	VIF	1, VIF
Board size	2.14	0.47
Independence share	2.63	0.38
Gender share	1.91	0.52
Firm size	3.41	0.29
Ownership indicator	1.28	0.78
Asset vintage	1.46	0.68
Mean VIF	2.14	

Diagnostics indicate no multicollinearity problem. The mean VIF is close to 2, and all individual VIFs are well below the cautionary threshold of 10.

2.4 Baseline fixed effects estimates

The dependent variable is the production uptime ratio, 0 to 1. All models include firm fixed effects and year effects. Standard errors are clustered by firm. Model A includes board variables only. Model B adds controls. Model C adds firm-specific linear trends.

Table 5: Baseline fixed effects estimates, dependent variable equals production uptime ratio.

Variables	Model A, FE only	Model B, FE plus controls	Model C, FE plus controls and firm trends
Board size	0.0012* (0.0006)	0.0010* (0.0005)	0.0009+ (0.0005)
Independence share	0.085** (0.028)	0.073** (0.026)	0.061** (0.025)
Gender share	0.042* (0.021)	0.038* (0.019)	0.031+ (0.018)
Firm size		0.004 (0.003)	0.003 (0.003)
Ownership indicator		-0.012* (0.006)	-0.010 (0.006)
Asset vintage		-0.0007** (0.0003)	-0.0005* (0.0003)
Firm fixed effects	Yes	Yes	Yes
Year effects	Yes	Yes	Yes
Firm trends	No	No	Yes
Observations	176	164	164
Firms	18	18	18
Within R-squared	0.27	0.34	0.39

Significance, + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$. Clustered standard errors in parentheses.

Interpretation

Independence share is positive and statistically significant across all specifications. In Model C, a coefficient of 0.061 implies that a 0.10 increase in the proportion of independent directors is associated with a 0.0061 increase in the uptime ratio, approximately 0.61 percentage points on a 0 to 100 scale, holding other factors constant. Gender share remains positive and weakly significant after controls and firm trends, suggesting informational and monitoring benefits that reach operating reliability. Board size shows a small positive association that is marginal once firm trends are included, which is consistent with mild scale benefits without strong nonlinearity. Among controls, state affiliation is associated with lower uptime in Model B, although the effect attenuates once firm trends are added. Older assets show lower uptime on average, consistent with integrity and maintenance burdens rising with vintage. Coefficients are stable from Model A to Model C, and within R-squared rises from 0.27 to 0.39 as controls and trends absorb additional within-firm variation.

Incremental models with controls

Table 2.6 adds controls sequentially to trace coefficient stability. Model D adds firm size to the baseline board only model. Model E adds ownership. Model F adds asset vintage. All specifications include firm fixed effects and year effects with firm clustered standard errors.

Table 6 Incremental fixed effects models, dependent variable equals production uptime ratio

Variables	Model D, FE plus size	Model E, FE plus size and ownership	Model F, FE plus size, ownership and vintage
Board size	0.0011*	0.0010*	0.0010*
	(0.0005)	(0.0005)	(0.0005)
Independence share	0.079**	0.075**	0.073**
	(0.027)	(0.026)	(0.026)
Gender share	0.040*	0.039*	0.038*
	(0.020)	(0.020)	(0.019)
Firm size	0.004	0.004	0.004
	(0.003)	(0.003)	(0.003)
Ownership indicator		-0.012*	-0.012*
		(0.006)	(0.006)
Asset vintage			-0.0007**
			(0.0003)
Firm fixed effects	Yes	Yes	Yes
Year effects	Yes	Yes	Yes
Observations	164	164	164
Firms	18	18	18
Within R squared	0.32	0.34	0.34

Significance, + p<0.10, * p<0.05, ** p<0.01. Clustered standard errors in parentheses.

The independence coefficient remains economically and statistically meaningful as controls enter, falling from 0.079 to 0.073 but retaining significance at the 1 percent level. Gender share is positive and significant at 5 percent throughout. Board size shows a small positive effect that is robust to controls. State affiliation reduces uptime by roughly 1.2 percentage points, while older assets show lower uptime, consistent with integrity burdens rising with age.

2.6 Robustness results

Robustness checks confirm that the main findings are not artifacts of functional form, outliers, or sample composition. First, alternative board measures and thresholds deliver comparable inferences about independence and gender representation. Second, results persist in restricted samples with stronger disclosure and in a balanced panel. Third, magnitudes are stable when proportional variables are winsorised at the first and ninety ninth percentiles. Across all exercises, the independence effect remains positive and statistically significant, gender effects are positive and marginal to moderate, and the board size effect is small and stable.

2.6.1 Alternative board measures and thresholds

Table 2.7 replaces proportion variables with threshold and nonlinear alternatives. Independence threshold equals one if at least one third of directors are independent, zero otherwise. Gender threshold equals one if the board has at least one female director, zero otherwise. A quadratic term for board size tests for diminishing returns. All models include firm fixed effects, year effects, and the full set of controls used in Table 2.6 Model F.

Table 7 Alternative measures, fixed effects with controls

Variables	Independence threshold	Gender threshold	Board size with quadratic
Independence threshold, $\geq 1,3$	0.0091**		
	(0.0033)		
Gender threshold, ≥ 1 female		0.0060+	
		(0.0035)	
Board size			0.0034*
			(0.0016)
Board size squared			-0.00018+
			(0.00010)
Controls, FE, years	Yes	Yes	Yes
Observations	164	164	164
Firms	18	18	18
Within R squared	0.35	0.34	0.36

Significance, + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$. Clustered standard errors in parentheses.

Clearing a one third independence threshold is associated with a 0.91 percentage point higher uptime, consistent with the proportion result. Having at least one female director is associated with a 0.60 percentage point higher uptime at the 10 percent level. Board size displays mild diminishing returns, a small positive linear term with a weak negative quadratic, suggesting benefits taper as boards become large.

2.6.2 Restricted samples and balanced panel

Table 2.8 presents two restrictive designs. Column A restricts to firms with seven or more consecutive disclosure years and with independence and gender shares explicitly verified, dropping all imputed board classifications. Column B estimates a balanced panel of 10 firms over 2014 to 2024. Both models retain the full controls, firm fixed effects, and year effects.

Table 8 Restricted and balanced samples, fixed effects with controls

Variables	A, verified disclosure, 7+ consecutive years	B, balanced panel, 2014 to 2024
Board size	0.0010	0.0008
	(0.0006)	(0.0006)
Independence share	0.058**	0.055**
	(0.022)	(0.021)
Gender share	0.029+	0.027
	(0.017)	(0.018)
Firm size	0.003	0.003
	(0.003)	(0.003)
Ownership indicator	-0.011*	-0.009
	(0.005)	(0.006)
Asset vintage	-0.0006**	-0.0005*
	(0.0002)	(0.0003)
Firm fixed effects	Yes	Yes
Year effects	Yes	Yes

Observations	138	110
Firms	14	10
Within R squared	0.37	0.38

Significance, + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$. Clustered standard errors in parentheses.

The independence effect remains positive and statistically significant with slightly larger precision in the restricted samples. Gender share retains a positive sign with marginal significance in Column A and is positive but not significant in the balanced panel, likely reflecting reduced variation. Board size remains small and positive. The ownership and vintage patterns replicate baseline results. These exercises indicate that the main findings are not driven by disclosure gaps, imputation, or panel imbalance.

Post estimation diagnostics and sensitivity

Post estimation checks indicate that the fixed effects results are well behaved and robust to alternative assumptions. The Wooldridge test for autocorrelation in panel data rejects the null of no first order serial correlation, $F(1, 17)$ equals 12.41, p equals 0.002, which justifies clustering standard errors at the firm level as implemented throughout. Residual plots by firm show no systematic patterns after including year effects and controls. Heteroskedasticity robust inference is already ensured by firm clustering.

Functional form was probed using a Ramsey type reset applied to the fixed effects residuals by adding squared and cubed fitted values to Model F. The joint test yields $F(2, 17)$ equals 1.21, p equals 0.31, which provides no evidence of omitted nonlinear terms. A binned specification that replaces independence and gender shares with quintile indicators produces a monotonic pattern for independence, with the top quintile associated with higher uptime relative to the bottom quintile, chi squared equals 9.84, p equals 0.043, consistent with the linear specification. The quadratic term for board size reported in Table 2.7 is small and marginal, which suggests only mild tapering as boards become large.

Influence diagnostics on the within model show that the largest studentised residual in absolute value is 2.31, and the maximum Cook's distance is 0.35, well below common rules of thumb. Dropping the top 1 percent of firm year residuals changes the independence coefficient by 4.6 percent and the gender coefficient by 6.1 percent, with signs and significance intact. Leave one firm out re estimation yields an independence coefficient range of 0.052 to 0.064 in the fully controlled model, confirming that no single firm drives the central finding.

Placebo and alternative outcomes corroborate an operational channel. When revenue growth replaces uptime as the dependent variable, coefficients on independence and gender are small and statistically insignificant, while signs on controls follow expected financial patterns. This separation supports the interpretation that governance effects identified here are tied to operating reliability rather than general financial trends.

Sensitivity to data treatment and sample composition is limited. Winsorising proportional governance variables at the first and ninety ninth percentiles leaves coefficients within one standard error of baseline estimates. Using issuer reported plant availability in place of production efficiency for the small subset where both are disclosed yields nearly identical results. A post reform subsample that restricts the window to 2021 to 2024 retains a positive and significant independence effect with a slightly smaller magnitude, which is plausible given concurrent regulatory improvements that may substitute for internal monitoring at the margin.

Discussion of findings and implications

The central result is that a higher proportion of independent non executive directors is associated with higher production uptime after accounting for firm and year effects, controls, and firm trends. This aligns with agency mechanisms where stronger monitoring reduces slippage in maintenance execution

and accelerates corrective action when deferments emerge. The finding is consistent with Nigerian and broader emerging market evidence that links board independence to better oversight and performance, although prior studies typically used financial ratios rather than plant level indicators (Adekunle et al., 2024; Shaba and Yaaba, 2023; Omenihu, 2025). Where independence has appeared negative in financial models for some Nigerian oil and gas samples, the difference may reflect outcome choice and cycle effects, since accounting returns co move with prices and impairments, whereas uptime captures reliability closer to the operational channel this study targets (Onmonya et al., 2024; Bello et al., 2024).

The positive, albeit modest, association between gender diversity and uptime dovetails with evidence that diverse boards enhance information processing, risk dialogue, and escalation quality, which can surface integrity issues earlier and sustain adherence to shutdown plans. Nigerian sector studies and regional sustainability work report that gender representation and stronger governance correlate with higher reporting quality and sustainability intensity, outcomes that often include operational KPIs such as deferment and flaring, which provides an indirect bridge to the uptime effect observed here (Adekunle et al., 2024; Abu Khalaf et al., 2024). The persistence of a gender effect after controls suggests the benefit is not purely a size or ownership artifact.

Board size shows a small positive effect with mild tapering, which is compatible with mixed findings in the literature. Studies that record gains from larger boards usually emphasize advice and committee capacity in complex sectors, while others warn about coordination costs as boards grow (Adekunle et al., 2024; Onmonya et al., 2024). The weak concavity in this study indicates limited diminishing returns within the observed range, which is consistent with upstream operators needing enough directors to staff audit and risk committees without incurring heavy deliberation delays.

Control patterns are also informative. Older assets are associated with lower uptime, a result that matches engineering intuition and underscores why board monitoring matters more as integrity burdens rise with age. State affiliation correlates with slightly lower uptime in some specifications, a pattern that attenuates with firm trends, which suggests program rollouts and time varying practices rather than a structural ownership penalty. Placebo regressions using revenue growth show no parallel governance effects, reinforcing that the identified relationships operate through the operational reliability channel rather than broader financial co movements.

For policy and practice, the results indicate that internal governance can complement regulatory reforms by translating rules and investment plans into day-to-day reliability. Independence thresholds, clear independence definitions, and sustained gender representation are associated with measurable operating gains, which supports regulatory guidance and investor engagement that emphasise these attributes in Nigerian upstream firms. For boards and executives, targeting credible independence, empowering independent chairs of audit and risk committees, and avoiding tokenism in gender appointments are actionable levers that the evidence links to higher uptime. Finally, relative to prior work that focused on accounting performance, this study contributes by connecting board structure directly to an operational KPI, thereby extending the empirical literature on governance in Nigeria's oil and gas sector toward plant level outcomes and providing a template for future studies that incorporate deferment and emissions intensity alongside uptime (Shaba and Yaaba, 2023; Adekunle et al., 2024; Abu Khalaf et al., 2024; Omenihu, 2025).

V: Conclusion and Recommendation

This study examined whether board structure is associated with operational reliability in Nigerian upstream oil and gas companies from 2012 to 2024, using the production uptime ratio as the single operational outcome. Three consistent patterns emerged. First, a higher proportion of independent non-executive directors is positively related to uptime after accounting for firm fixed effects, year effects,

controls, and firm trends, which supports the view that stronger monitoring improves maintenance execution, shutdown planning, and loss control. Second, gender diversity on boards shows a positive and economically modest association with uptime, indicating informational breadth and improved oversight that reach field operations. Third, board size displays a small positive effect with mild tapering, suggesting capacity benefits for committee coverage within the observed range without large coordination penalties. These results are robust to alternative measures, restricted samples, and placebo outcomes, and they extend Nigerian governance evidence from financial ratios to a plant-level KPI that is central to operational performance.

Recommendations

Regulators and listing authorities should codify and enforce clear independence thresholds that are aligned with international practice, for example, at least one third independent directors, and require issuers to disclose independence criteria, committee leadership, and any changes during the year. This improves the credibility of independence classifications, strengthens audit and risk committee oversight, and, based on the study's findings, is likely to translate into higher uptime through tighter control of maintenance, integrity, and deferment management.

Boards and nominating committees should institutionalise gender diversity targets that move beyond token representation, for example setting a time-bound objective to reach at least two female directors or a specified share that fits board size, and pairing appointments with committee roles tied to risk, audit, or sustainability. Coupled with periodic board effectiveness reviews, this supports richer risk dialogue and earlier issue escalation, which the results link to measurable gains in production reliability.

Operators and investors should incorporate operational KPIs into governance reporting and performance monitoring, specifically publishing a consistent definition of production uptime or production efficiency, reconciling it to planned outages, and linking board committee agendas to these metrics each quarter. Lenders and equity holders can reference these disclosures in covenants and engagement, using independence and diversity milestones as governance inputs and uptime as the operating output. This closes the loop between board structure, oversight practice, and reliability outcomes, and creates sustained incentives for continuous improvement.

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