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Fiscal Metering Efficiency and Economic Performance in Nigeria's Gas Sector through an Econometric Analysis of the Nigerian Gas Transportation Network Code

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Abstract
This study evaluates the economic implications of fiscal metering efficiency under the Nigerian Gas Transportation Network Code (NGTNC). Using a longitudinal dataset covering July 2015 to December 2024, the research applies econometric modeling—including multiple regression and Vector Autoregression (VAR) —to quantify the financial and operational impact of metering inaccuracies in the Eastern Gas Network. Results show persistent metering deviations ranging from 2.8% to 11.6%, driven by aging infrastructure, weak calibration routines, and inconsistent regulatory enforcement. Econometric estimates reveal that a 1% improvement in metering accuracy increases monthly revenue by 0.42%–0.61%. The study concludes that metering accuracy is central to revenue assurance, market transparency, and investor confidence. Strengthened regulatory oversight, digital metering upgrades, and harmonized data governance are recommended to enhance NGTNC implementation and sectoral efficiency.

Keywords: *Fiscal metering; Gas transportation; Econometric modeling; Measurement uncertainty; NGTNC; Energy economics; Nigeria.*

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I. Introduction

Natural gas has become a central pillar of Nigeria's energy transition strategy, industrialization agenda, and long-term economic diversification efforts. With proven reserves exceeding 200 trillion cubic feet, Nigeria possesses one of the largest gas endowments in Africa. Yet, persistent inefficiencies in midstream infrastructure, measurement systems, and regulatory governance continue to constrain the sector's performance. The Nigerian Gas Transportation Network Code (NGTNC), launched in 2020, was designed to address these structural weaknesses by establishing a transparent, rules-based framework for gas transportation, capacity allocation, system balancing, and commercial settlement. At the heart of this framework lies fiscal metering, the mechanism through which gas volumes are measured, allocated, and monetized across the value chain.

Fiscal metering is not merely a technical subsystem; it is the economic backbone of gas market operations. In gas markets, measurement accuracy directly influences revenue allocation, tariff settlement, and system balancing (Bhattacharyya, 2019). Accurate measurement determines the financial flows between producers, shippers, network operators, and industrial off-takers. It underpins tariff calculations, balancing charges, invoicing, and revenue assurance. Inaccurate metering, by contrast, introduces uncertainty, distorts commercial transactions, and undermines the credibility of regulatory institutions(Oladokun & Akinyemi, 2020). In gas markets characterized by high volumes and thin margins, even small measurement deviations can translate into substantial financial losses (Li et al., 2022). This is particularly true in developing economies where infrastructure is aging, calibration practices are inconsistent, and regulatory enforcement is uneven. Studies in mature gas markets show that metering uncertainty below 1% is typically required to maintain commercial integrity (Arpino et al., 2014).

In Nigeria, fiscal metering inefficiencies have long been recognized as a major source of revenue leakage, commercial disputes, and operational imbalance. However, despite widespread acknowledgment of the problem, empirical evidence quantifying the economic magnitude of metering inaccuracies remains limited. Existing studies tend to focus on technical descriptions of metering systems, engineering performance, or regulatory commentary, with little emphasis on the econometric evaluation of measurement errors or their financial implications. This gap is significant because the success of the NGTNC—and, by extension, the broader gas sector reforms under the Petroleum Industry Act (PIA) 2021—depends on the integrity of fiscal metering systems.

The study is motivated by three key considerations. First, the Nigerian gas market is undergoing rapid transformation driven by the PIA 2021, which seeks to reposition gas as a transition fuel and attract private investment into midstream infrastructure. Accurate metering is essential for achieving these objectives. Second, the NGTNC introduces market-based mechanisms—such as capacity trading, balancing charges, and cash-out processes—that depend on precise measurement. Without accurate metering, these mechanisms cannot function effectively. Third, Nigeria's industrial gas demand is expanding, particularly in fertilizer, petrochemicals, and power generation. As demand grows, the economic consequences of metering inaccuracies become more pronounced.

1.1 Gas Market Regulation and the Role of Network Codes

Gas network codes are regulatory instruments that define the rules governing access, capacity allocation, balancing, and commercial settlement in gas transmission systems. The European Network Code (ENC) and the UK's Uniform Network Code (UNC) are widely cited as benchmarks for transparency and efficiency (Joskow, 1997). These codes rely heavily on accurate metering to support nomination processes, imbalance charges, and cash-out mechanisms.

In Nigeria, the NGTNC was introduced to replicate these global best practices. It establishes a hub-based transportation system, third-party access, and market-based balancing arrangements. However, unlike in mature markets, Nigeria's implementation environment is characterized by infrastructural deficits, fragmented institutional responsibilities, and limited digitalization (Iledare, 2022). The literature on African gas markets highlights that regulatory reforms often fail when technical systems—such as metering—are not upgraded to support new commercial frameworks (Mutezo&Mulopo, 2022). This study contributes to this discourse by empirically examining how metering performance affects NGTNC implementation.

1.2 Metering Accuracy, Revenue Assurance, and Economic Performance

Revenue assurance in gas markets depends on the accuracy of custody-transfer measurements. Studies in the Middle East and North America show that metering errors can lead to revenue losses ranging from 0.5% to 5% of annual throughput (Al-Mansoori &Elkamel, 2019). These losses arise from volumetric discrepancies, pressure-temperature deviations, and flow-profile distortions. In pipeline systems, measurement uncertainty also affects system balancing, leading to operational inefficiencies and increased balancing charges.

In Nigeria, anecdotal evidence suggests that metering inaccuracies contribute significantly to unaccounted-for gas (UFG), but empirical quantification has been limited. Prior studies have focused on technical diagnostics, such as flow-meter performance, calibration intervals, and instrumentation reliability (Jami & Raghunathan, 2021). Few studies have examined the economic consequences of these technical deficiencies. This research fills that gap by linking metering accuracy to revenue performance using econometric modeling.

1.3 Regulatory Enforcement and Institutional Capacity

Regulatory enforcement is a critical determinant of metering performance. Comparative studies show that strong regulatory institutions—such as Ofgem in the UK and FERC in the United States—enforce strict metering standards, audit requirements, and data-governance protocols (Hauge et al., 2020). In contrast, weak enforcement environments allow operators to defer calibration, underinvest in metering infrastructure, and maintain inconsistent reporting practices.

Nigeria's regulatory landscape has undergone significant restructuring under the PIA 2021, which created the Nigerian Upstream Petroleum Regulatory Commission (NUPRC) and the Nigerian Midstream and Downstream Petroleum Regulatory Authority (NMDPRA). However, overlapping mandates and capacity constraints continue to affect the consistency of enforcement. The literature highlights that regulatory fragmentation increases transaction costs, reduces compliance incentives, and weakens market confidence

(Adewuyi & Awodumi, 2020). This study extends this line of inquiry by demonstrating how regulatory weaknesses contribute to metering deviations and economic losses.

1.4 Econometric Approaches to Measurement Uncertainty

Econometric modeling has been widely used to analyze measurement uncertainty, system losses, and operational efficiency in energy systems. Regression models are commonly applied to quantify the relationship between measurement errors and financial outcomes (Brito et al., 2022). Vector autoregression (VAR) models capture dynamic interactions among variables such as flow rates, pressure deviations, and revenue performance. These models are particularly useful in gas systems where operational variables exhibit temporal interdependence.

II. Methodology

2.1 Research Design

This study adopts a **quantitative, longitudinal, and explanatory research design** to evaluate the economic implications of fiscal metering efficiency in Nigeria's gas transportation system. The longitudinal approach is appropriate because metering performance, system imbalances, and revenue outcomes evolve and exhibit temporal dependencies. The explanatory dimension enables the identification of causal relationships among metering accuracy, revenue performance, and investment confidence. This design aligns with established econometric practices in energy market analysis, where time series data are used to model operational variability, regulatory impacts, and financial outcomes.

2.2 Study Area and Operational Context

The empirical analysis focuses on the Eastern Gas Network, one of Nigeria's major transmission corridors that supplies industrial off-takers and power plants. Within this network, a metering station, which serves as a critical custody-transfer point where gas volumes are measured for allocation between the operator and an off-taker, was used as a case study.Thestation was selected for three reasons: high fiscal exposure, Operational complexity, and Data availability.

2.3 Data Sources and Variables

2.3.1 Data Sources

The study uses complete monthly operational data from July 2015 to December 2024, obtained from custody-transfer logs, off-take records,Pipeline flow-rate and pressure-temperature logs, meter calibration and maintenance reports, and compliance documentation. Using a census of all available data eliminates sampling bias and enhances internal validity.

2.3.2 Variable Definitions

Dependent Variables

i. **Revenue Performance (REV):** Monthly revenue retained after accounting for metering deviations.
ii. **Investment Confidence Index (ICI):** A composite index reflecting investor perceptions of commercial certainty, regulatory stability, and measurement reliability.

Independent Variables

i. **Metering Error (ME):** Percentage deviation between operator-recorded volumes and off-taker-recorded volumes.
ii. **Production Loss (PL):** Difference between expected and actual throughput.
iii. **System Imbalance (SI):** Net difference between injected and withdrawn gas volumes.
iv. **Calibration Interval (CI):** Number of months since last meter calibration.

Control Variables: Gas price index

i. Seasonal demand variation
ii. Pipeline pressure fluctuations
iii. Regulatory events (dummy variables)

2.4 Econometric Modeling Framework

The study employs multiple regression, vector autoregression (VAR), and diagnostic tests to evaluate relationships among variables.

Model 1: Revenue Performance Model

$$REV_t = \alpha_0 + \alpha_1 ME_t + \alpha_2 PL_t + \alpha_3 SI_t + \alpha_4 CI_t + \epsilon_t \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where:

REV_t= revenue performance
ME_t= metering error

PL_t= production loss
SI_t= system imbalance
CI_t= calibration interval
ϵ_t= error term
This model tests the hypothesis that metering inaccuracies significantly reduce revenue.
Model 2: Investment Confidence Model
$ICI_t = \beta_0 + \beta_1 ME_t + \beta_2 SI_t + \beta_3 REV_t + \beta_4 CI_t + u_t$ ....…… (2)
This model evaluates how metering accuracy influences investor confidence.
Model 3: Vector Autoregression (VAR)
A VAR model is used to capture dynamic interactions among metering error, revenue performance, system imbalance, and investment confidence.
The general VAR(p) specification is:
$Y_t = A_0 + A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + e_t$ ………….. (3)
Where Y_t is a vector of endogenous variables.
The VAR model helps identify lagged effects, shock propagation, and system-wide interactions.

III. Results

This section presents the empirical findings from the econometric models. The results are organized into three major components: (1) metering error trends and descriptive statistics, (2) regression results for revenue performance, and(3) regression results for investment confidence. Together, these results provide a comprehensive assessment of the economic implications of fiscal metering efficiency in the Eastern Gas Network.

3.1 Descriptive Analysis of Metering Error Trends

The descriptive analysis reveals persistent and economically significant metering deviations across the 10-year study period. Monthly discrepancies between operator-recorded volumes and off-taker-recorded volumes ranged from **2.8% to 11.6%**, with an average deviation of approximately **7.2%**. These deviations were not random; instead, they exhibited structural patterns consistent with equipment degradation, calibration lapses, and operational inconsistencies.
Three key observations emerge:

3.1.1 Persistent Upward Drift in Measurement Error

The data show a gradual upward drift in metering error over time, particularly between 2018 and 2022. This trend aligns with periods of reduced calibration frequency and aging of the primary metering units. The drift suggests that metering inaccuracies accumulate when calibration intervals exceed recommended standards.

3.1.2 Seasonal Variability

Metering deviations were higher during months with elevated throughput, particularly in the third quarter of each year. This pattern is consistent with flow profile distortions that occur when meters operate near or beyond their optimal capacity ranges.

3.1.3 Correlation with System Imbalance

A strong positive correlation (r ≈0.68) was observed between metering error and system imbalance. This indicates that measurement inaccuracies directly contribute to operational discrepancies in the network, affecting balancing charges and allocation accuracy.
These descriptive findings provide the foundation for the econometric analysis that follows.

3.2 Regression Results: Revenue Performance Model

The first econometric model evaluates the relationship between metering accuracy and revenue performance. The regression results indicate that metering error is a statistically significant predictor of monthly revenue outcomes.

3.2.1 Key Coefficients

Variable	Coefficient	Significance	Interpretation
Metering Error (ME)	−0.54	$p < 0.01$	A 1% increase in metering error reduces monthly revenue by 0.54%
Production Loss (PL)	−0.31	$p < 0.05$	Higher production losses reduce revenue
System Imbalance (SI)	−0.22	$p < 0.10$	Imbalances negatively affect revenue
Calibration Interval (CI)	−0.17	$p < 0.10$	Longer intervals worsen revenue performance

The negative coefficient for metering error confirms the hypothesis that measurement inaccuracies significantly reduce revenue. The magnitude of the coefficient (−0.54) indicates a strong economic sensitivity: even small improvements in metering accuracy yield measurable financial gains.

3.2.2 Model Fit and Diagnostics

i. **R^2 = 0.71**, indicating that the model explains 71% of the variability in revenue.
ii. **Durbin-Watson statistic ≈ 1.95**, suggesting no autocorrelation.
iii. **VIF values < 3**, confirming absence of multicollinearity.
iv. **Breusch-Pagan test** indicates mild heteroskedasticity, corrected using robust standard errors.

These diagnostics confirm the reliability of the regression estimates.

3.2.3 Interpretation

The results demonstrate that metering accuracy is a major determinant of revenue performance. The strong negative relationship suggests that improving metering systems could significantly enhance revenue retention for both operators and the government. This finding aligns with global evidence that fiscal metering is a critical revenue-assurance mechanism in gas markets.

3.3 VAR Model Results: Dynamic Interactions

The VAR model provides insights into the dynamic relationships among metering error, revenue performance, system imbalance, and investment confidence.

3.3.1 Impulse Response Functions (IRFs)

The IRFs show that:

i. A **shock to metering error** produces a **persistent negative effect** on revenue for 4–6 months.
ii. A **shock to the system imbalance** increases metering error in subsequent periods, indicating feedback loops.
iii. A **positive shock to revenue** improves investment confidence for up to 8 months.

These dynamic effects highlight the interconnected nature of operational and economic variables in gas networks.

3.3.2 Variance Decomposition

Variance decomposition reveals that:

i. Metering error explains **42%** of revenue variability after 12 months.
ii. System imbalance explains **28%** of metering error variability.

These results underscore the central role of metering accuracy in shaping system-wide outcomes.

Summary of Key Findings

i. Metering errors are persistent, systemic, and economically significant.
ii. A 1% reduction in metering error increases revenue by 0.42%–0.61%.
iii. Dynamic interactions show that metering errors propagate through the system.

IV. Discussion

The results of this study provide strong empirical evidence that fiscal metering efficiency is a central determinant of economic performance, regulatory credibility, and investment attractiveness in Nigeria's gas sector. This section interprets the findings in the context of existing literature, theoretical frameworks, and the operational realities of the Nigerian Gas Transportation Network Code (NGTNC). The discussion is organized around five thematic areas: (1) technical and operational implications, (2) revenue assurance and economic performance, (3) regulatory governance and enforcement, (4) investment confidence and market stability, and (5) broader implications for gas-sector reform under the Petroleum Industry Act (PIA) 2021.

4.1 Technical and Operational Implications of Metering Inaccuracy

The descriptive and econometric results demonstrate that metering inaccuracies in the Eastern Gas Network are persistent, systemic, and structurally embedded. The upward drift in measurement error over the study period reflects the cumulative effects of aging metering infrastructure, inconsistent calibration practices, and inadequate maintenance regimes. These findings align with global evidence showing that metering systems deteriorate over time when calibration intervals exceed recommended standards (Arpino et al., 2014; Jami & Raghunathan, 2021).

The strong correlation between metering error and system imbalance underscores the operational consequences of measurement drift. System imbalances increase the difficulty of maintaining pipeline pressure stability, complicate nomination and scheduling processes, and distort balancing charges. In the context of the NGTNC, where balancing and cash-out mechanisms depend on accurate measurement, persistent metering deviations undermine the integrity of the entire operational framework.

The VAR results further reveal that shocks to metering error propagate through the system, affecting revenue performance and investment confidence for several months. This dynamic interaction highlights the interconnected nature of technical and economic variables in gas networks. It also reinforces the argument that metering accuracy is not an isolated technical issue but a system-wide determinant of operational efficiency.

4.2 Revenue Assurance and Economic Performance

One of the most significant findings of this study is the strong negative relationship between metering error and revenue performance. The regression results show that a 1% increase in metering error reduces monthly revenue by approximately 0.54%. This magnitude is consistent with international studies indicating that measurement inaccuracies can lead to revenue losses of 0.5%–5% of annual throughput (Al Mansoori &Elkamel, 2019; Li et al., 2022).

The results also show that production loss and system imbalance negatively affect revenue performance. These findings are consistent with the literature on pipeline operations, which emphasizes the role of accurate measurement in reducing operational losses and improving allocation efficiency (Brito et al., 2022). Together, these results demonstrate that metering accuracy is a critical revenue-assurance mechanism in Nigeria's gas sector.

4.3 Regulatory Governance and Enforcement

The findings have important implications for regulatory governance under the NGTNC and PIA 2021. The persistent metering deviations observed in the dataset reflect weaknesses in regulatory enforcement, institutional coordination, and compliance monitoring. The literature on energy-sector regulation highlights that strong enforcement mechanisms are essential for maintaining measurement integrity and ensuring market transparency (Hauge et al., 2020; Iledare, 2022).

In Nigeria, regulatory responsibilities for metering oversight are split between the Nigerian Upstream Petroleum Regulatory Commission (NUPRC) and the Nigerian Midstream and Downstream Petroleum Regulatory Authority (NMDPRA). This fragmentation creates enforcement gaps, reduces accountability, and weakens compliance incentives. The results of this study suggest that harmonizing regulatory oversight and strengthening enforcement mechanisms are essential for improving metering performance.

The negative relationship between calibration interval and both revenue performance and investment confidence further underscores the importance of regulatory enforcement. When operators are not compelled to adhere to strict calibration schedules, measurement drift increases, leading to economic losses and reduced market confidence. This finding supports the argument that investments in institutional capacity and digital monitoring systems must accompany regulatory reforms.

4.4 Implications for Gas-Sector Reform Under PIA 2021

The findings of this study have broader implications for gas-sector reform in Nigeria. The PIA 2021 seeks to reposition gas as a transition fuel, attract private investment, and improve regulatory governance. However, the success of these reforms depends on the integrity of technical systems such as fiscal metering.

The results show that metering accuracy is a foundational requirement for achieving the objectives of the NGTNC and PIA 2021. Without accurate measurement, capacity allocation becomes unreliable, balancing mechanisms become ineffective, and tariff settlement becomes contentious. These deficiencies undermine market transparency, reduce investor confidence, and limit the effectiveness of regulatory reforms.

The study also highlights the importance of digitalization in improving metering performance. Modern metering technologies—such as ultrasonic and Coriolis meters—offer real-time diagnostics, automated calibration alerts, and enhanced data accuracy. Integrating these technologies into Nigeria's gas infrastructure could significantly improve measurement reliability and support the digital governance objectives of the PIA 2021.

V. Conclusion

This study provides a comprehensive econometric and policy analysis of fiscal metering efficiency in Nigeria's gas transportation system, focusing on the implementation of the Nigerian Gas Transportation Network Code (NGTNC). Using a longitudinal dataset covering 2015–2024, the research demonstrates that metering inaccuracies are persistent, systemic, and economically significant. Metering deviations ranging from 2.8% to 11.6% were observed across the study period, driven by aging infrastructure, inconsistent calibration, and weak regulatory enforcement.

The study concludes that fiscal metering is not merely a technical requirement but a core economic and governance pillar essential for the successful implementation of the NGTNC and the broader gas-sector reforms under the Petroleum Industry Act (PIA) 2021. Accurate metering underpins revenue assurance, market transparency, system balancing, and investment attractiveness. Without substantial improvements in metering infrastructure, calibration practices, and regulatory enforcement, Nigeria will struggle to achieve the objectives of its gas-market reforms.

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