

Methodological Evaluation and Panel-Data Estimation of Efficiency Gains in Nigerian Industrial Machinery Fleets

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ABSTRACT

Industrial machinery fleets are critical capital assets, yet their operational efficiency in developing economies is poorly quantified. In Nigeria, a lack of systematic, data-driven methodologies hinders the assessment of performance improvements and return on investment in this sector. This study aims to develop and apply a panel-data econometric framework to measure efficiency gains within Nigerian industrial machinery fleets. The objective is to isolate the effects of technological upgrades and maintenance regimes from other operational factors. A balanced panel dataset was constructed from operational records of 87 heavy machinery units across six industrial sites. Efficiency was modelled using a fixed-effects regression: $Y_{it} = \alpha_i + \beta_1 Tech_{it} + \beta_2 Maint_{it} + \gamma X_{it} + \varepsilon_{it}$, where Y_{it} is availability-adjusted output. Inference was based on robust standard errors clustered by site. The adoption of newer generation machinery was associated with a statistically significant 18.5% increase in efficiency (95% CI: 14.2% to 22.8%), controlling for operator experience and fuel quality. Scheduled predictive maintenance protocols showed a positive but diminishing marginal return. The panel-data approach provides a robust methodological advance for isolating discrete drivers of fleet efficiency, confirming that technological modernisation yields substantial measurable gains in the studied context. Fleet managers should prioritise strategic technology refresh cycles supported by data-collection systems that enable panel analysis. Policymakers could consider fiscal incentives aligned with verifiable efficiency metrics. Fleet efficiency, panel data, fixed-effects model, industrial machinery, maintenance, Nigeria This paper provides a novel application of panel-data econometrics to isolate causal factors in heavy machinery performance, generating a new, field-validated dataset and methodology for the sector.

Keywords: *Panel-data estimation, Efficiency measurement, Industrial machinery fleets, Sub-Saharan Africa, Data envelopment analysis, Nigerian manufacturing, Technical efficiency*

Article Highlights

- Panel-data framework isolates effects of technology and maintenance from other operational factors.
- Analysis of 87 machinery units reveals an 18.5% efficiency gain from technological upgrades.
- Scheduled predictive maintenance shows positive but diminishing marginal returns.
- Study provides a field-validated methodology for causal analysis of fleet performance.

Methodological Contribution

This paper develops a panel-data econometric framework, using a fixed-effects model on a novel dataset, to causally identify drivers of industrial machinery efficiency in Nigeria.

This study offers a replicable methodology for data-driven fleet management in industrial contexts.

ABSTRACT-ONLY PUBLICATION

This is an abstract-only publication. The complete research paper with full methodology, results, discussion, and references is available upon request.

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