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Integrating Energy Efficiency, Productivity, and Input Substitution for Sustainable Manufacturing in Nigeria: A Triangulated Econometric Analysis (1981–2025)

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Abstract

Nigeria's manufacturing sector faces a triple challenge: rising energy costs, declining productivity, and environmental pressures. Most studies address these issues in isolation, leading to fragmented policy advice. This paper provides an integrated analysis using a triangulated econometric approach on time-series data from 1981 to 2025. Recent evidence indicates that Nigerian manufacturers spent ₦676.6 billion on alternative energy in the first half of 2025 alone, with 18,935 job losses recorded in the same period. Against this backdrop, our empirical findings reveal that the sector operates at an average energy efficiency of 82.2%, with a worrying post-2017 decline to 54.7% by 2023. Nonlinear Autoregressive Distributed Lag (NARDL) estimation shows that energy efficiency improvements raise output by 0.93% per 1% efficiency gain, but efficiency losses reduce output by 2.24% – a loss aversion ratio of 2.4:1. Translog cost function estimates indicate that capital and energy are strong Morishima substitutes ($MES_{KE} = 3.66$), while capital and labour are complements ($MES_{KL} = -1.94$). These findings align with recent cross-country evidence on input substitution in developing economies and asymmetric environmental effectiveness. The paper makes four contributions: (i) first SFA-based efficiency scores for the sector; (ii) first evidence of long-run asymmetry; (iii) first MES estimates for Nigeria; and (iv) an integrated policy matrix linking each finding to specific actions. We recommend: (a) an Energy Efficiency Loss Prevention Fund to reverse the post-2017 decline; (b) capital subsidies for energy-efficient machinery (exploiting K-E substitution); (c) avoidance of capital taxes (to protect employment via K-L complementarity); and (d) a National Manufacturing Energy Dashboard for real-time monitoring.

Keywords: Energy Efficiency, Productivity, Input Substitution, Morishima Elasticity, NARDL,

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