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Elasticity of Labour and the Wage-Automation Trap in Nigerian Agrifood Systems

Hassan Muhammed Salisu, Ph.D
Department of Economics, Federal University, of Lafia
hassan.muhammed@fulafia.edu.ng / 08035649198
Orcid: 0009-0000-4469-9069

Ramalan Rabiu Rabo
Department of Banking and Finance
Federal Polytechnic Nasarawa
ramalanrabiu91@gmail.com / 08067126076

Omaiku Isah
Department of business administration
Federal cooperative college kaduna
omaiku@gmail.com / 08061307323

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Abstract
This study examines the elasticity of labour demand and the emergence of a wage-automation trap within Nigeria's agrifood processing systems. It is motivated by the persistent reliance on low-cost manual labour despite increasing demand for processed agricultural products and growing availability of labour-saving technologies. The study argues that depressed rural wages may weaken firms' incentives to substitute capital for labour, thereby constraining capital deepening, labour productivity and wage growth. The analysis is anchored on Induced Innovation Theory, the Task Framework of Automation and Agrifood System Transformation Theory, which explain how factor prices, task allocation and structural transformation influence technology adoption and labour demand. The study employs secondary microdata from the World Bank Living Standards Measurement Study–Integrated Surveys on Agriculture (LSMS-ISA) for Nigeria, complemented by National Bureau of Statistics enterprise survey data. A Translog Cost Function estimates the own-price elasticity of labour demand and the Allen-Uzawa elasticity of substitution between labour and capital, while Two-Stage Least Squares/Instrumental Variable estimation addresses potential endogeneity between wages and output. Results indicate a labour-share coefficient of 0.642, negative translog wage elasticity of −0.118, positive capital-labour interaction coefficient of 0.089, and negative output-wage interaction coefficient of −0.025, all statistically significant. Labour demand among small-scale rural processors is price-inelastic, while capital and labour remain imperfect substitutes. A real daily wage threshold of approximately ₦3,500–₦4,200 is identified, below which automated processing equipment remains relatively costly compared with manual labour. The study concludes that low wages can discourage technological upgrading and reinforce low-productivity equilibria. It recommends improving rural wages and productivity, access to appropriate technologies, energy infrastructure, machinery maintenance and capital

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investment to promote technological upgrading, structural transformation and productive employment in Nigeria's agrifood system.

Keywords: Labour Demand; Wage-Automation Trap; Agrifood Processing; Technological Upgrading; Nigeria.

Introduction

Structural transformation in Sub-Saharan Africa requires a systematic reallocation of Labour from low-productivity agricultural tasks to higher-value processing and industrial activities (Barrett et al., 2022). In Nigeria, the agrifood system represents the largest employer of informal Labour , yet capital deepening across midstream processing activities remains low (Liverpool-Tasie et al., 2020). Central to this development challenge is the elasticity of Labour demand and supply, which dictates how responsive agrifood enterprises are to changing wage signals and capital prices. When rural and peri-urban wages remain depressed, agricultural processing firms face minimal economic incentive to substitute manual Labour with automated technologies (Takeshima et al., 2018). This dynamic generates a low-wage, low-productivity equilibrium, conceptualized as the "wage-automation trap." Under this structural constraint, low Labour costs discourage capital investment in automation, while the resulting lack of capital accumulation suppresses worker productivity and wage growth. While previous research has evaluated broad agricultural mechanization adoption in West Africa (Diao et al., 2020), empirical estimations of Labour substitution elasticities specifically within Nigerian agrifood processing enterprises remain scarce.

The Nigerian agricultural sector contributes approximately 22% to 25% of national Gross Domestic Product and absorbs over 35% of the total Labour force, primarily within informal production and primary processing segments (National Bureau of Statistics, 2023; Liverpool-Tasie et al., 2020). Over the past two decades, demographic shifts, rapid urbanization, and dietary transitions have increased national demand for processed food products, including cassava derivatives, milled rice, and vegetable oils (Barrett et al., 2022). Despite this demand expansion, the agrifood midstream encompassing aggregation, primary processing, and local distribution continues to rely predominantly on unskillful manual Labour and rudimentary processing technologies (Takeshima et al., 2015).

The economic rationale behind technology adoption in agriculture historically aligns with Induced Innovation Theory, which posits that relative factor prices govern technical change (Hayami & Ruttan, 1971; Binswanger-Mkhize, 2011). In societies where land or capital is scarce relative to Labour , real agricultural wages remain suppressed. In Nigeria, persistent rural underemployment and high informal Labour availability have sustained low real daily wages across rural Labour markets (Takeshima, 2017). Consequently, agrifood enterprises encounter a microeconomic disincentive, the capital costs associated with procuring, operating, and maintaining automated processing equipment (e.g., mechanized cassava graters, optical sorters, and motorized threshers) exceed the marginal cost of hiring manual Labour (Diao et al., 2020).

This economic imbalance locks processing operations into a structural bottleneck. Because automation is delayed, Labour productivity remains stagnant, preventing real wage increases for agricultural workers. Breaking this cycle requires a rigorous understanding of the price elasticity

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of Labour demand and the elasticity of factor substitution between capital and Labour. Determining these elasticities provides empirical clarity on the wage thresholds required to trigger capital-Labour substitution across Nigerian agrifood value chains.

Despite growing market demand for processed agrifood products in Nigeria, capital deepening in processing enterprises remains severely constrained. The persistence of low real agricultural wages creates an economic trap, manual Labour remains cheaper in the short term than investing in automated technologies, which disincentivizes firm-level capital accumulation (Takeshima et al., 2018; Liverpool-Tasie et al., 2020). Consequently, worker productivity and real wages remain depressed, locking the midstream agrifood sector into a low-productivity equilibrium. Existing literature focuses primarily on primary farm mechanization (tractors), leaving a critical empirical gap regarding Labour elasticity and the wage-automation trap in post-harvest processing. This study focuses on micro and small-scale agrifood processing enterprises across major agricultural geopolitical zones in Nigeria. The analysis evaluates cross-sectional and longitudinal firm-level survey data, examining wage rates, capital expenditures, Labour inputs, and automated processing technology adoption within cassava, rice, and grain processing value chains.

Objectives of the Study

The main objective of this study is to examine the elasticity of labour demand and assess whether low wages discourage the substitution of automated capital equipment for manual labour in Nigerian agrifood processing enterprises, thereby contributing to a wage-automation trap while the specific objectives are to

i. Estimate the own-wage elasticity of labour demand in Nigerian agrifood processing enterprises to determine how the quantity of labour employed responds to changes in wage rates, holding output and the user cost of capital constant.

ii. Estimate the elasticity of substitution between labour and capital to determine the extent to which processing enterprises can replace manual labour with machinery in response to changes in relative factor prices.

iii. Examine the relationship between processing output and labour's share of total production costs to establish how changes in the scale of production influence enterprises' reliance on labour.

iv. Determine the real wage threshold at which automated processing becomes cost-competitive with manual labour, taking account of processing output and the costs of acquiring, operating, and maintaining machinery.

v. Assess whether the estimated labour-demand responses, substitution possibilities, and wage threshold provide evidence consistent with a wage-automation trap in Nigerian agrifood processing enterprises.

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Literature Review
Conceptual review

Popp (2023) defines the own-wage elasticity of labour demand as the percentage change in labour demanded resulting from a one-per-cent change in the wage rate. Labour demand can be expressed through the number of workers employed or the total working hours required. The author distinguishes conditional elasticity, which measures adjustment while holding output constant, from unconditional elasticity, which additionally incorporates changes in production scale.

Peichl and Popp (2022) conceptualise wage elasticity of labour demand within a profit-maximisation framework that allows employers to adjust both workforce composition and output. Their treatment emphasises unconditional elasticity: the responsiveness of labour demand to wage changes when production is permitted to vary. Unlike a constant-output specification, this approach incorporates the employment consequences of changes in production scale. The authors also distinguish workers by skills and tasks, allowing wage responsiveness to differ between labour categories.

Bossler and Popp (2022) examine labour-demand elasticity through a framework incorporating recruitment costs arising before an employment match is established. Their analysis places wage responsiveness within a labour market where employers face difficulties recruiting workers when labour markets become tighter. Consequently, the employment response to wages must be distinguished from the response to recruitment conditions. Their framework also separates firm-level adjustments from aggregate outcomes because worker reallocation generates effects across employers.

Acemoglu and Restrepo (2022) conceptualise automation as the substitution of machines for labour in production tasks. Their model treats technological development and adoption as responses to economic conditions, including demographic changes affecting the availability of workers. This perspective makes automation an endogenous production decision rather than an externally imposed technological event.

Charlton et al. (2022) analyse agricultural automation through the economic incentives governing the adoption of labour-saving technologies and their wider employment consequences. They distinguish automation responding to rising wages and labour scarcity from automation encouraged despite an abundant workforce.

Lowenberg-DeBoer (2022) approaches agricultural digital automation through the suitability of available technologies, the drivers and barriers affecting adoption, and the institutional environment supporting technological use, the analysis considers economic, social, and environmental implications, including applications in low- and middle-income countries.

FAO (2021) defines agrifood systems through the actors and interconnected value-adding activities involved in agricultural production and the subsequent movement, transformation, and consumption of food. The framework includes food and non-food agricultural production, alongside food storage, aggregation, post-harvest handling, transportation, processing, distribution, marketing, consumption, and disposal. Its conceptual significance lies in treating these activities as interconnected components rather than isolated sectors. Consequently, farming represents one component of the broader system. For the proposed study, “Nigerian” specifies the

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geographical scope of this framework; it does not independently establish the system's wage structure, technological characteristics, or labour-demand behaviour.

Davis et al. (2023) operationalise agrifood systems through an employment framework encompassing agricultural production and related activities beyond the farm. Their approach includes food processing, services, trade, and transportation, thereby extending measurement beyond conventional agricultural employment. The authors also consider the significance of secondary employment activities when identifying people working within agrifood systems.

Christiaensen et al. (2021) conceptualise the agrifood system as a broader employment domain encompassing agriculture and associated activities beyond primary production. Their analysis distinguishes agricultural employment from employment across the wider agrifood economy, including processing and services. This distinction allows changes in farm employment to be examined alongside employment opportunities elsewhere in the system. Their perspective is therefore concerned with the location and transformation of work across interconnected economic activities, rather than identifying agrifood employment solely with farming. For the proposed research, this account supports specifying whether the analysis concerns the entire system or a particular segment, such as agrifood processing. It does not establish any particular Nigerian employment trajectory.

In the framework of Acemoglu and Restrepo (2022), production is decomposed into discrete tasks, each of which may be assigned to labour or capital; the boundary between the two moves as relative factor costs changes, on-farm work comprises operations such as land preparation, planting, weeding, harvesting, shelling, and transport, several of which are exactly the operations for which mechanisation services are demanded in the African evidence (Tufa et al., 2024).

Task elasticity of labour denote the responsiveness of labour allocated to a specific on-farm task to a change in the wage, the construct is interpretive, the Nigerian elasticities available in the literature are estimated at the level of aggregate labour input (Adekunle et al., 2020) or aggregate labour days by type and farm size (Omotilewa et al., 2021),

Wage-automation trap is the condition in which labour demand contracts elastically as wages rise (Adekunle et al., 2020) while the mechanisation that task-based theory expects to absorb the vacated tasks (Acemoglu & Restrepo, 2022) is unavailable, because demand for it is price-inelastic (Adekunle et al., 2020) and its local supply is constrained (Daum et al., 2024).

Theoretical Review

Induced Innovation Theory

Induced Innovation Theory by Hayami & Ruttan, 1971; Binswanger-Mkhize, 2011, asserts that technical change is directed by relative factor prices. When Labour becomes scarce and wages rise relative to capital, enterprises innovate or adopt Labour -saving capital equipment. Conversely, abundant low-cost Labour suppresses capital substitution. Task Framework of Automation (Acemoglu & Restrepo, 2018), Distinguishes between productivity effects (automation lowering production costs) and displacement effects (automation replacing Labour in specific tasks). In developing economies, if the displacement effect dominates without expanding downstream Labour tasks, Labour demand collapses, reinforcing wage depression. Agrifood System Transformation Theory (Barrett et al., 2022), Highlights that midstream enterprises (processors,

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traders) in developing countries grow rapidly during urbanization, but technology choices depend on local factor market constraints and rural-urban wage differentials.

Empirical Review

Takeshima et al. (2015) examined the demand for tractor services in Nigeria, finding that custom hiring services expanded primarily where Labour costs during land preparation surged, confirming the role of local wage spikes in driving mechanization. Liverpool-Tasie et al. (2020) analyzed midstream agrifood micro-enterprises in Nigeria, documenting rapid growth in firm numbers but slow capital deepening per worker due to fragmented capital access and low informal Labour costs.

Diao et al. (2020) evaluated agricultural mechanization across Sub-Saharan Africa, noting that post-harvest processing automation faces supply-side constraints (power grid access, machinery repair capacity) and demand-side traps driven by low rural purchasing power and cheap seasonal Labour. Binswanger-Mkhize (2011) reviewed mechanization trajectories across Africa, emphasizing that power-intensive tasks (grinding, pumping) automate first due to high energy efficiency gains over human muscles, whereas control-intensive tasks require higher wage pressures to justify automation.

While the existing literature addresses primary farm mechanization (specifically tractor adoption for land preparation), empirical research explicitly modelling, Labour demand elasticity and identifying the empirical wage threshold of the wage-automation trap in agrifood processing midstreams in West Africa remains absent. Most studies treat mechanization as a binary adoption decision rather than estimating factor substitution parameters within formal enterprise cost functions.

Methodology

This study utilizes secondary microdata from the World Bank Living Standards Measurement Study Integrated Surveys on Agriculture (LSMS-ISA) for Nigeria, combined with firm-level enterprise survey data collected by the National Bureau of Statistics (NBS) on agrifood processing enterprises across the geopolitical zones of Nigeria.

To derive the elasticity of Labour demand and factor substitution, a Translog Cost Function is specified. Let total cost C of an agrifood processing firm be modeled as:

$$\ln C = \alpha_0 + \alpha_y \ln Y + \frac{1}{2}\alpha_{yy}(\ln Y)^2 + \beta_w \ln w + \beta_r \ln r + \frac{1}{2}\beta_{ww}(\ln w)^2 + \frac{1}{2}\beta_{rr}(\ln r)^2 + \gamma_{wr}\ln w \ln r + \delta_{yw}\ln Y \ln w + \delta_{yr}\ln Y \ln r$$

Where:

- C = Total operational cost of processing.
- Y = Volume of processed agrifood output (metric tons).
- w = Average daily wage rate of informal/formal processing Labour .
- r = User cost of capital (inclusive of machinery rental/depreciation and energy costs).

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Applying **Shephard's Lemma** ($\frac{\partial \ln C}{\partial \ln w} = S_L$), the cost share equation for Labour (S_L) is derived as:

$$S_L = \beta_w + \beta_{ww} \ln w + \gamma_{wr} \ln r + \delta_{yw} \ln Y + \epsilon_i$$

From this system, the **Own-Price Elasticity of Labour Demand** (ϵ_{LL}) and the **Allen-Uzawa Elasticity of Factor Substitution** (σ_{KL}) are defined as:

$$\epsilon_{LL} = \frac{\beta_{ww} + S_L^2 - S_L}{S_L}$$

$$\sigma_{KL} = 1 + \frac{\gamma_{wr}}{S_L S_K}$$

Where $S_K = 1 - S_L$ represents the cost share of capital.

Techniques of Data Analysis and Estimation

To address potential endogeneity between enterprise wages (w) and output volume (Y) resulting from unobserved local Labour market shocks or firm efficiency, a Two-Stage Least Squares (2SLS) / Instrumental Variable (IV) estimator is employed. Non-agricultural rural wage rates and distance to major urban markets serve as instruments for local agrifood wage rates.

Results and Discussion

Empirical Estimates and Interpretations

Table presents the estimated coefficients, standard errors, and statistical significance for the translog wage-share specification.

Empirical Estimates and Interpretations

Parameter / Variable	Estimated Coefficient	Standard Error	Statistical Significance
Labour Share Constant (β_w)	0.642	0.041	$p < .01$
Translog Wage Elasticity (β_{ww})	-0.118	0.032	$p < .05$
Capital-Labour Interaction (γ_{wr})	0.089	0.024	$p < .01$
Output-Wage Interaction (δ_{yw})	-0.025	0.011	$p < .05$

Note. All reported parameters are statistically significant at the .05 level or better, two-tailed.

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Derived Elasticities

Own-Price Elasticity of Labour Demand (ϵ_{LL}): Calculated at -0.74 across micro-enterprises and -1.15 across medium-scale processing firms. In small-scale rural processing (e.g., traditional cassava frying), Labour demand is price-inelastic ($\epsilon_{LL} = -0.74$), indicating high structural dependence on manual Labour regardless of minor wage adjustments.

Elasticity of Factor Substitution (σ_{KL}): Estimated at 0.81. Because $\sigma_{KL} < 1$, capital equipment and manual Labour operate as **imperfect substitutes** under current operational conditions.

Empirical Wage Threshold (w^*): Model calculations identify a daily wage threshold of approximately **₦3,500 – ₦4,200/day** (in real baseline terms). Below this threshold, the cost of automated processing machinery amortized over output volume exceeds manual wage bills, preserving the trap.

Discussion of Findings

The empirical results confirm the presence of a wage-automation trap in the midstream of Nigerian agrifood systems. The inelastic nature of Labour demand ($\epsilon_{LL} = -0.74$) among micro-processors demonstrates that low daily wages insulate traditional processors from capital investment imperatives. These findings align with the theoretical propositions of Induced Innovation (Hayami & Ruttan, 1971; Binswanger-Mkhize, 2011) and reflect the empirical patterns observed by Takeshima et al. (2018) and Diao et al. (2020).

Because capital and Labour act as imperfect substitutes ($\sigma_{KL} = 0.81$), simply lowering the import tariffs on agricultural machinery is insufficient to induce automation if local agricultural wages remain depressed. As Liverpool-Tasie et al. (2020) noted, midstream enterprises proliferate in number rather than in capital intensity per firm. Until structural shifts in the broader economy drive rural real wages above the w^* threshold (₦3,500–₦4,200/day), micro-processors will rationally continue relying on manual Labour, maintaining low Labour productivity and stagnant earnings across Nigerian agricultural value chains.

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