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Technical Efficiency and Financial Sustainability of Private Waste Management Firms in Dar es Salaam, Tanzania: A System GMM Approach

Technical Efficiency and Financial Sustainability of Private Solid Waste Management Firms in Dar es Salaam, Tanzania: A System GMM Approach

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Abstract
This study examines the relationship between technical efficiency and financial sustainability among private solid waste management firms in Dar es Salaam, Tanzania, for which empirical evidence remains limited. The study uses an unbalanced panel of 36 private solid waste management firms covering the period 2016–2023. Technical efficiency is estimated using time-varying stochastic frontier analysis, while the relationship with financial sustainability is examined using a two-step System Generalised Method of Moments (GMM). Technical efficiency was positively and significantly associated with financial sustainability ($\beta = 0.095$, $p < 0.01$). Financial sustainability also showed significant persistence over time, while staff productivity was positively and significantly associated with it. The study was limited to 36 private solid waste management firms in Dar es Salaam, which may restrict the generalisability of the findings. Using estimated technical efficiency scores also introduces uncertainty that should be considered when interpreting the results. Private solid waste management firms should prioritise efficient resource utilisation and staff productivity to support financial sustainability, while municipal authorities should encourage efficient waste collection practices. The study provides firm-level longitudinal evidence linking technical efficiency with financial sustainability in urban solid waste management in a developing-country context.

Introduction

Efficient utilisation of productive resources is fundamental to firms' ability to control operating costs, maintain service delivery and achieve sustainable financial performance (Armah & Rodrigues, 2026). This relationship is particularly important in solid waste management (SWM), where service providers operate in a resource-intensive environment characterised by substantial labour requirements, vehicle and equipment costs, transportation expenses and continuous service obligations (Kwikima & Ngole, 2025; Zhang et al., 2024). Rapid urbanisation and population growth have further increased waste generation in developing countries, placing greater pressure on public authorities and, notably, private SWM firms to expand service coverage while maintaining technical efficiency and financial sustainability (Kapoor & Chakma, 2024; Lu et al., 2024).

Technical efficiency indicates how effectively firms convert productive inputs into output relative to the best-practice production frontier (Kumbhakar, 2025). Improvements in technical efficiency can reduce resource waste, increase output from existing inputs, and lower service-provision costs (Armah & Rodrigues, 2026). Evidence from across sectors shows that improvements in technical efficiency can enhance profitability and financial performance by improving resource utilisation and cost control (Adam, 2024; Rosko et al., 2020). However, whether such technical efficiency gains necessarily translate into financial sustainability remains less certain, particularly for private firms delivering regulated public services such as solid waste collection.

Private SWM firms incur substantial expenditures on salaries, vehicle maintenance, equipment maintenance and fuel, while collection fees, contractual arrangements, and service obligations still constrain revenue generation (Mpuya & Munishi, 2024). A firm may therefore collect waste efficiently but still experience weak financial sustainability if the additional revenue generated is insufficient to cover the costs of providing the service. This relationship raises an important empirical question: whether improvements in technical efficiency actually translate into stronger financial sustainability among private SWM firms. The issue is particularly relevant in developing countries, where SWM providers frequently operate under financial and operational constraints. Evidence from African cities indicates persistent challenges, including inadequate equipment, long transportation distances, limited cost recovery, weak infrastructure, and reliance on labour-intensive collection systems (Adedara et al., 2023; Ndiaye et al., 2021; Ntagisanimana et al., 2021). Such operational constraints may increase waste collection and transportation costs, thereby limiting the extent to which improvements in technical efficiency translate into financial sustainability.

These challenges are evident in Tanzania, particularly in Dar es Salaam, where rapid population growth and urbanisation continue to increase demand for solid waste collection services (Kitole et al., 2024; National Bureau of Statistics [NBS], 2025). Private firms play an important role in providing these services, yet they operate in an environment characterised by infrastructure challenges, low collection fees, and limited cost recovery (Kirama & Mayo, 2016; Mpuya & Munishi, 2024). Local government authorities have made efforts to improve solid waste collection services through public-private partnerships, municipal service contracts, licensing arrangements, enforcement of SWM by-laws, and monitoring of service delivery (Environmental Management Regulation [EMR], 2009). However, despite these efforts, financial sustainability remains a challenge for private SWM firms, particularly in generating sufficient revenue to cover their expenses and sustain service delivery.

Existing empirical literature has provided limited evidence on this relationship. Adam (2024) examined operational efficiency and revenue generation among private waste collectors in Nigeria, while Nan Wang et al. (2022) assessed technical and profitability efficiency among international waste management companies. Similarly, Parte and Alberca 2024 examined efficiency and risk-related characteristics among waste recycling firms. Although these studies provide important sector-specific evidence, they do not directly establish whether SFA-derived technical efficiency is associated with financial sustainability among private SWM firms within a dynamic panel framework. This dynamic dimension matters because financial sustainability may exhibit persistence (Baltagi, 2021). Firms with stronger financial positions in one period may be better positioned to maintain equipment, retain workers, finance operations, and meet subsequent service obligations, while financially constrained firms may continue to face difficulties in later periods. At the same time, reverse causality is possible because financially sustainable firms may have greater capacity to acquire productive resources and improve technical efficiency. Failure to account for such dynamics, unobserved firm heterogeneity and potential endogeneity may therefore produce biased estimates of the relationship between technical efficiency and financial sustainability (Arellano & Bover, 1995; Blundell & Bond, 1998).

In Tanzania, existing SWM studies have largely concentrated on private-sector participation, public-private partnerships, operational challenges, governance, cost recovery and recycling practices (Kamugisha et al., 2019; Kibonde, 2024; Likotiko et al., 2017; Mpuya & Munishi, 2024).

Limited firm-level evidence exists on whether technical efficiency translates into financial sustainability among private SWM service providers. Njiku and Nyamsogoro (2019), for example, found that technical efficiency was associated with financial sustainability among sunflower oil-processing firms using cross-sectional data. Other studies have reported positive relationships between operational efficiency and profitability or financial performance in different sectors (Chindengwike, 2024; Lyaro et al., 2025). These studies reveal an empirical gap in the technical efficiency–financial sustainability relationship and a methodological gap in examining it within a dynamic longitudinal framework that accounts for persistence, firm-specific heterogeneity, and potential endogeneity.

This study contributes to the literature by moving beyond the conventional view of technical efficiency as an operational outcome and assessing whether efficiency gains translate into financial sustainability, linking technical efficiency to firms' capacity to sustain their financial operations. It examines this relationship in the context of private urban waste collection services, where operational costs, collection fees and contractual obligations may influence financial outcomes. Methodologically, it uses longitudinal firm-level data to examine the relationship, accounting for the persistence of financial sustainability and potential endogeneity through a dynamic panel estimation approach. The findings may also inform municipal authorities in developing supportive measures to enhance efficient waste collection and the financial sustainability of private service providers, thereby promoting continuity of waste collection services.

Literature Review

Theoretical Framework

This study is grounded in Neoclassical Production Theory (NPT) and draws on the Cobb–Douglas production function developed by Cobb and Douglas (1928). NPT explains the relationship between productive inputs and output, providing a theoretical foundation for estimating technical efficiency. Its relevance to financial sustainability is established through resource utilisation and expenditure management. Firms operating closer to their production frontier may generate greater waste collection output from available resources without proportionate increases in expenses, potentially strengthening their financial self-sufficiency. However, this relationship also depends on collection fees, input prices, customer demand and contractual arrangements, which are not explicitly modelled but may influence firms' ability to recover expenses. Accordingly, a positive association between technical efficiency and financial sustainability is expected, although higher technical efficiency does not necessarily guarantee financial sustainability. Staff productivity is included as a control variable because variations in labour efficiency may independently influence financial outcomes. Although NPT assumes rational firm behaviour and simplifies production relationships without fully accounting for external operating conditions, these limitations do not undermine its relevance for examining input–output efficiency (AlFraj, 2024; Choi et al., 2025; Colther & Doussoulin, 2025). The relationship between technical efficiency and financial sustainability is therefore assessed empirically, as improvements in technical efficiency do not necessarily translate into greater financial sustainability.

Empirical Evidence and Hypothesis Development

Technical Efficiency and Financial Sustainability

Firms are more likely to achieve long-term financial sustainability by improving technical efficiency (Rahmiyati et al., 2024). In this context, financial sustainability is the ability of private

SWM firms to finance their operations entirely through self-generated revenues, achieve cost recovery, and maintain viability without external subsidies.

Njiku and Nyamsogoro (2019) investigated the relationship between technical efficiency and financial sustainability in small sunflower oil-processing firms in Tanzania. In particular, Ayeni and Aremu (2023), Ndubueze-Ogaraku and Anya (2023) and Velnamby and Ajanthan (2021) reported positive effects, suggesting that efficient resource utilisation is fundamental to long-term financial outcomes. However, some studies examining operational or cost efficiency have shown negative effects on financial sustainability (Aranda & Wardani, 2024; Nurmalasari & Carmelita, 2025; Septiani & Murwaningsari, 2024). These results may reflect differences in industrial settings, institutional environments, measures of financial sustainability, and analytical approaches adopted across studies. Additionally, cited studies have primarily used ratio analysis, multiple regression, data envelopment analysis, stochastic frontier analysis, and static panel regression techniques, with limited use of dynamic panel estimators (GMM) that can address persistence and endogeneity.

H1: Technical efficiency is positively associated with the financial sustainability of private SWM firms in the short run.

Staff productivity

Staff productivity is an essential determinant of service output, particularly in the labour-intensive service sector where service delivery relies heavily on manual labour (Makundi et al., 2025). Rehan et al. (2024) found that staff productivity strengthens the relationship between organisational productivity and financial sustainability. Likewise, Wanigasekara and Mendis (2021) found that higher staff productivity significantly improves firm profitability and overall financial performance. Conversely, Yousaf (2023) found that employee productivity positively affects the performance of non-certified firms but negatively affects the performance of EFQM-certified firms. Although these studies focus on different dimensions of firm performance, they collectively suggest that variations in staff productivity can influence firms' financial outcomes.

Conceptual framework

Figure 1 presents the framework, which illustrates the expected relationship between technical efficiency and financial sustainability among private SWM firms. The framework is grounded in neoclassical production theory, which argues that firms enhance financial sustainability by minimising input costs relative to output through efficient resource utilisation. Accordingly, firms that achieve higher technical efficiency are expected to convert inputs such as drivers, wheelbarrows, and trucks into waste collection at lower cost, thereby improving financial sustainability. The relationship between technical efficiency and financial sustainability is examined while controlling for staff productivity, which accounts for variations in workforce performance that may independently influence financial sustainability.

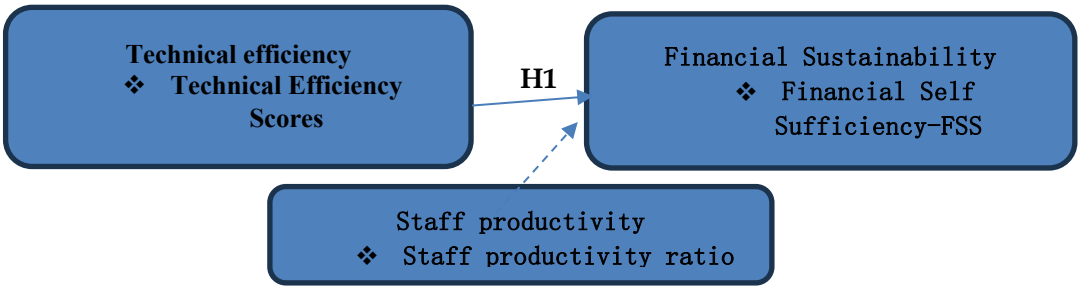


Figure 1: Conceptual framework
Source*: Authors' construction (2026)*

Methodology

Research Philosophy, Design and Approach

This study is grounded in the positivist philosophy, which supports objective measurement, empirical observation and hypothesis testing using quantitative data. Furthermore, a longitudinal panel research design was employed to construct a firm-level unbalanced panel dataset, capturing both cross-sectional differences across firms and temporal variations over the study period.

Study area

Dar es Salaam was chosen as the study area because it generates one of the highest volumes of solid waste, exceeding 4,000 tonnes per day (Abel, 2024). The city relies heavily on private-sector providers, which account for approximately 75% of solid waste management (SWM) services. (Biswas and Singh, 2021). These features provide a suitable context for the study, given the large number of private SWM firms involved, enabling sufficient observations for the empirical analysis of technical efficiency and financial sustainability.

Study Population, Sample Size and Sampling Procedures

The study population comprised private SWM firms operating in Dar es Salaam. Initially, 40 firms were identified from records obtained from the Department of Environment and SWM; however, 36 firms were included as eligible for the study after applying inclusion criteria requiring firms to have operated for at least 3 years and to maintain sufficient data for analysis. Two firms were excluded because of shorter operating periods, while the remaining two lacked adequate data for analysis. Because the population was relatively small, the study used a census sampling technique and included all eligible firms from 2016 to 2023. The year 2016 was selected as the base year following the establishment of Kigamboni and Ubungo Municipalities, which completed the administrative structure of the five municipalities in Dar es Salaam and ensured comprehensive geographical coverage of the study area (LGA, 1982).

Data and Data Collection Method

The study utilised firm-level unbalanced panel data covering 36 private SWM firms from 2016 to 2023. The panel data were unbalanced because some firms lacked complete records for all years during the study period. The panel structure ($N = 36$, $T \leq 8$) was consistent with the application of System GMM, which is designed for dynamic panel datasets with a relatively large cross-sectional dimension (N) and a short time dimension (T) (Ally et al., 2025). Secondary data were collected from firms' audited financial records, human resources records and operational records. These data sources provide reliable and consistent firm-level information necessary for the study.

Measurement and Operationalisation of Research Variables

Table 1: Operationalisation of key research variables

Variable	Definition and measurement	Initials	Reference
Input variables			
Capital	Measured as the annual value of capital assets by the firm during the year.	CAP	(Parte & Alberca, 2024; Njiku and Nyamsogoro, 2019)
Number of trucks	Number of operational vehicles used for waste collection during the year.	TRK	(Fan et al., 2020)
Number of wheelbarrows	Number of wheelbarrows actively used for waste collection during the year.	WB	(Chamwali et al., 2022)
Number of tricycles	Number of operational tricycles used for waste collection during the year.	TRI	(Volsuuri et al., 2023)
Vehicles drivers	Measured as the number of vehicle drivers employed for waste-collection operations during the relevant year.	VD	(Chamwali et al, 2022)
Waste collectors	Measured as the number of waste collectors employed for collection operations during the relevant year.	WC	(Singh & Malik, 2018)
Output-variables			
Total amount of waste collected	Measured in tonnes of total waste collected per year	WASTE_COL	(Chamwali et al., 2022,Fan et al., 2020)
Total number of staff	Measured by the total number of operational, administrative and managerial employees of a firm.	Num_Staff	(Njiku & Nyamsogoro, 2019)
Independent variable			
Technical Efficiency	Variable estimated using technical efficiency scores.	TE	(Rosko et al., 2020)
Control variable			
Staff productivity	Variable estimated using the ratio of waste collected over the number of staff.	STA_prod	(Wanigasekara and Mendis, 2021)
Dependent variable			
Financial sustainability	Estimated using financial self-sufficiency = revenue/expenses	FS	(Makwani et al., 2026)

Measurement of Technical Efficiency, Financial Sustainability and Staff Productivity.

Technical Efficiency

Technical efficiency was measured using stochastic frontier analysis (SFA) for an unbalanced panel from 36 private solid waste management firms in Dar es Salaam. SFA separates deviations from the production frontier into statistical noise and non-negative technical inefficiency (Belotti et al., 2013; Kumbhakar et al., 2015). The general stochastic frontier is expressed as:

$$Y_{it} = f(X_{it}; \beta)\, exp(v_{it} - u_{it}) \quad (1)$$

Here, Y denotes annual waste collected, X the production-input vector, β the technology parameters, v random statistical noise and u technical inefficiency. The Cobb–Douglas frontier was specified in logarithmic form to estimate conditional output elasticities:

$$ln\, WASTE_COL_{it} = \beta_0 + \beta_1\, ln\, WC_{it} + \beta_2\, ln\, VD_{it} + \beta_3\, ln\, WB_{it} + \beta_4\, ln\, TRI_{it} + \beta_5\, ln\, TRK_{it} + \beta_6\, ln\, CAP_{it} + v_{it} - u_{it} \quad (2)$$

WASTE_COL denotes annual waste collected (tonnes); WC, waste collectors; VD, vehicle drivers; WB, wheelbarrows; TRI, tricycles; TRK, trucks; and CAP, capital. Subscripts i and t denote firm

and year. The disturbance v is normally distributed with zero mean and variance σ_v^2 and is independent of the inefficiency term. The production-frontier estimates indicate positive, statistically significant coefficients for drivers (0.353), wheelbarrows (0.103), tricycles (0.267) and trucks (0.680), each at $p < 0.01$. Waste collectors are insignificant (0.016), while capital is marginally significant (0.058; $p < 0.10$). The insignificant coefficient for waste collectors (0.016) may reflect the complementary nature of labour and transport inputs, whereby additional collectors do not necessarily increase waste collection output independently of vehicle availability and capacity. These coefficients measure potential output responses, not direct efficiency changes. The sum of input elasticities was 1.477, indicating increasing returns to scale in solid waste collection operations.

To accommodate changes in technical inefficiency over time, the Kumbhakar (1990) model specifies inefficiency as a firm-specific non-negative component multiplied by a logistic time function:

$$u_{it} = g(t)u_i, \quad g(t) = [1 + exp(bt + ct^2)]^{-1} \tag{3}$$

The baseline inefficiency component follows a half-normal distribution; b and c govern the common time profile. The linear parameter is positive and marginally significant (b = 0.088; SE = 0.052), whereas the quadratic parameter is insignificant (c = 0.000; SE = 0.005). These estimates suggest, but do not establish without a joint test of b = c = 0, a declining inefficiency scaling factor over time. Firm-year technical efficiency is computed as:

$$TE_{it} = exp(-u_{it}) = exp[-g(t)u_i], \quad 0 < TE_{it} \leq 1 \tag{4}$$

Efficiency scores lie between zero and one, with values closer to one indicating greater proximity to the estimated production frontier.

For comparison, the Battese and Coelli (1988) time-invariant specification assumes firm-specific inefficiency remains constant over the observation period:

$$ln\, WC_{it} = \beta_0 + \sum_{k=1}^{6} \beta_k \ln X_{kit} + v_{it} - u_i \tag{5}$$

In this benchmark, the non-negative inefficiency component follows a truncated-normal distribution with pre-truncation mean μ and variance σ_u^2. Its positive and significant drivers, wheelbarrow, tricycle and truck coefficients corroborate the main production relationships.

Both models were estimated by maximum likelihood using sfpanel in Stata. Their relative fit was assessed using the maximised log-likelihood and the Akaike and Bayesian information criteria:

$$AIC = -2 \ln L + 2K; \quad BIC = -2 \ln L + K \ln N \tag{6}$$

The Kumbhakar model exhibited better relative fit than the Battese–Coelli benchmark (log-likelihood: −56.837 versus −76.936; AIC: 135.673 versus 173.872; BIC: 173.635 versus 208.382) and was therefore retained for technical efficiency estimation. As the models differ in both time structure and inefficiency distribution, this fit advantage cannot be attributed solely to temporal variation. The complete comparative frontier estimates, including standard errors and fit statistics, are reported in Appendix A.

Financial sustainability

Financial sustainability was operationally measured using the Financial Self-Sufficiency (FSS) ratio, which assesses firms' ability to generate sufficient revenue to cover their expenses. Although financial sustainability is a broader concept encompassing multiple financial dimensions, FSS was preferred over alternative indicators, such as profitability, liquidity, and cash-flow measures, because it directly assesses the extent to which revenue from waste collection services covers associated expenses. This measure aligns with the study's focus on firms' ability to sustain service

delivery through internally generated revenue over time. In this study, revenue comprised waste collection fees, while expenses included salaries, fuel, vehicle maintenance, rent and other waste collection service costs. This approach is consistent with Dutra and Siman (2024) and Mim et al. (2025). The ratio is calculated as;

$$FSS_{it} = Revenue_{it} / Expenses_{it} \quad (7)$$

Although conventional FSS measures may involve adjustments to revenues and expenses, this study used unadjusted financial figures, considering the operational characteristics of private SWM firms, which relied solely on waste collection fees without subsidies or external financial support, while most operating expenses were paid as incurred. This approach aligns with Marwa and Aziakpono (2015) and Njiku and Nyamsogoro (2019). A ratio greater than 1 indicates financial sustainability, whereas a ratio below 1 indicates financial unsustainability (Yasmin et al., 2024).

Staff Productivity

Staff productivity is measured to capture labour efficiency in the SWM service. It was calculated as the amount of waste collected per staff member as follows.

$$STA_Prod_{it} = \frac{Total\ Waste_COL_{it}}{Total\ Num_Staff_{it}} \quad (8)$$

This measure is particularly relevant in firms where labour is a key operational input (Njiku & Nyamsogoro, 2019). Staff productivity was calculated as total waste collected divided by total employees, whereas technical efficiency was estimated using multiple production inputs through SFA. Although these measures capture different aspects of operational performance, their shared production variables are acknowledged.

Model Specification

The model was selected because it can handle dynamic panel data, address firm-specific heterogeneity, and mitigate potential endogeneity concerns, particularly with lagged dependent variables (Blundell & Bond, 1998; Arellano & Bover, 1995). We use Least Squares (OLS) and Fixed Effects (FE) as benchmark models to compare with dynamic panel estimates from Two-Step Difference GMM and Two-Step System GMM. However, pooled OLS does not control for unobserved firm-specific heterogeneity, while FE is susceptible to Nickell bias arising from the correlation between the lagged dependent variable and the transformed error term in short panels (Nickell, 1981). The Two-Step System GMM was adopted as the preferred estimator because it combines equations in first differences and levels, potentially providing more efficient estimates than Difference GMM, particularly when variables are persistent over time (Blundell & Bond, 1998).

Potential endogeneity arising from dynamic relationships among model variables, reverse causality, and unobserved firm-specific characteristics was addressed using the System GMM instrumental variables approach. The lagged dependent variable (FSS) was treated as predetermined, while technical efficiency and staff productivity were classified as endogenous and instrumented using appropriate internal lags consistent with System GMM moment conditions. Instrument proliferation was controlled by restricting instrument selection, following Roodman (2009), while the Hansen test of overidentifying restrictions and the Arellano–Bond AR (2) test were used to assess instrument validity and the absence of second-order serial correlation, respectively.

After computing these measures, the financial self-sufficiency ratio was used as the dependent variable to measure financial sustainability; technical efficiency scores were the main explanatory variable; and the staff productivity ratio was included as a control variable. The econometric model is specified as:

$$FSS_{it} = \alpha + \rho FSS_{i,t-1} + \beta_1 TE_{it} + \beta_2 \ln(STA_prod_{it}) + \mu_i + \varepsilon_{it} \quad (9)$$

Where:FSS_{it}: Financial self-sufficiency of firm i at time t,FS_{it-1}: Lagged dependent variable, TE_{it}: Technical Efficiency, STA_prod_{it}: Staff Productivity Ratio, μ_i: unobserved firm-specific effects and ε_{it}: Idiosyncratic error term.

Diagnostic Tests

Fisher-Type Unit Root Test

The unit-root tests rejected the null hypothesis of unit roots at levels, I(0), for financial sustainability, technical efficiency and staff productivity, supporting their inclusion in the subsequent dynamic panel analysis. Given the short time dimension (T ≤ 8), the unit-root test results are interpreted cautiously.

Pairwise Correlations Matrix and Variance Inflation Factor

In addition, the mean VIF of 1.99 and tolerance values of approximately 0.503 indicate no serious multicollinearity, suggesting that the explanatory variables can be reliably included in the regression model.

Table 2: Panel unit-root tests, pairwise correlations and variance inflation factors

Panel A. Fisher-type panel unit-root tests (level: constant and trend)					
Variable	**Inverse χ^2 (72)**	**Inverse normal**	**Inverse logit t (179)**	**Modified inverse χ^2**	**Integration order**
FinancialSS	437.806***	−12.955***	−19.787***	30.484***	I (0)
Tef_Score	109.2151***	−3.6141***	−9.2092***	3.1013***	I (0)
ln STA_prod	173.9177***	−2.2625**	−5.1318***	8.4931***	I (0)
Panel B. Pairwise correlations and variance inflation factors					
Variable	**(1) FSS**	**(2) TE**	**(3) Staff productivity**	**VIF**	**1/VIF**
(1) FinancialSS	1.000				
(2) Tef_Score	0.025	1.000		1.99	0.503
(3) ln STA_prod	0.036	0.705***	1.000	1.99	0.503
Mean VIF				1.99	

*Source note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

Arellano Bond and Hansen and Sargan Tests

The Arellano–Bond AR (1) test is statistically significant for both Difference GMM (p = 0.005) and System GMM (p = 0.002), as expected. However, the AR (2) test is insignificant at the 5% level (p = 0.360 and p = 0.067, respectively), indicating failure to reject the null hypothesis of no second-order serial correlation. Similarly, the Hansen (p = 0.169 and p = 0.135) and Sargan (p = 0.077 and p = 0.398) tests fail to reject their respective null hypotheses of valid overidentifying restrictions at the 5% significance level, although these results do not conclusively establish instrument validity. Furthermore, the System GMM model employs 14 instruments for 36 firms, reducing concerns

about instrument proliferation. Overall, the post-estimation diagnostic results provide reasonable support for the adequacy of the GMM model specifications.

Findings

Descriptive Statistics

Financial sustainability has a mean of 0.894 (SD = 0.120), indicating that, on average, private SWM firms operated below the financial self-sufficiency threshold. Technical efficiency has a mean of 0.525(SD = 0.212), suggesting that firms achieved, on average, 52.5% technical efficiency, leaving scope for further improvement. The mean value of the natural logarithm of staff productivity is 6.033 (SD = 0.843), indicating variation in labour productivity across firms. Generally, the results indicate sufficient variation in the study variables, providing an appropriate basis for the subsequent panel regression analysis.

Table 4: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
FinancialSS	233	0.894	0.120	0.53	1.17
Tef Score	233	0.525	0.212	0.18	0.957
Ln STA_prod	233	6.033	0.843	2.913	7.637

Source: computation based on study data

Discussion of Two-Step System GMM Results

Relationship Between Technical Efficiency and Financial Sustainability

The Two-Step System GMM results indicate strong persistence in financial sustainability, as reflected in the positive and statistically significant coefficient on lagged financial sustainability ($\beta = 0.420$, $p < 0.01$). Firms that consistently generate sufficient revenue to cover expenses may be better positioned to maintain service delivery in subsequent periods. This result aligns with Budotela et al. (2023), who also report significant persistence effects in financial outcomes using lagged non-performing loans in a System GMM framework among commercial banks in Tanzania.

Technical efficiency is positively and significantly associated with financial sustainability ($\beta = 0.095$, $p < 0.01$), supporting hypothesis (H1). Economically, firms operating closer to their production frontier may generate greater waste-collection output from available resources, potentially reducing avoidable resource use and associated operating costs. The finding is consistent with Njiku and Nyamsogoro (2019), who reported a positive relationship between technical efficiency and financial sustainability. It is also consistent with neoclassical production theory, which holds that differences in firms' ability to transform productive inputs into output provide a basis for differences in productive performance. Staff productivity, included as a control variable, positively and significantly influences financial sustainability ($\beta = 0.020$, $p < 0.05$). The results complement Njiku and Nyamsogoro (2019), which showed that staff productivity is associated with increased financial sustainability. The findings suggest that financial sustainability among private SWM firms is associated with past financial performance, technical efficiency and staff productivity.

Table 5: Two-Step System GMM Panel regression results

Variables	(1) Pooled OLS	(2) FE	(3) 2Step Diff GMM	(4) 2Step Syst GMM
L.FinancialSS	0.516***	0.201***	0.389*	0.420***
	(0.021)	(0.073)	(0.206)	(0.090)
Technical efficiency	-0.061	-0.607**	-1.276***	0.095***
	(0.051)	(0.272)	(0.332)	(0.032)
Ln Staff Productivity	0.008	0.074**	0.053**	0.020**
	(0.013)	(0.031)	(0.027)	(0.009)
Constant	1.059***	0.907***		1.219***
	(0.089)	(0.202)		(0.087)
Observations	197	197	161	197
R-squared	0.758	0.122		
Number of firms		36	36	36
AR (1)			0.005	0.002
AR (2)			0.360	0.067
Hansen			0.169	0.135
Sargen			0.077	0.398
Number of Instruments			6.000	14.000

*Source note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

Conclusion

The study examined the relationship between technical efficiency and financial sustainability of private SWM firms in Dar es Salaam. The results confirm that technical efficiency, through better utilisation of input resources and reduced operating costs, is associated with improved firms' financial sustainability. In addition, staff productivity, a control variable, positively influences financial sustainability. This finding implies that firms with more productive labour are better able to generate and collect more tonnes and control service delivery costs.

Based on these findings, owners and managers of private SWM firms should prioritise the effective use of existing productive resources, including vehicles, collection equipment, and labour, to improve technical efficiency. They should also improve staff deployment and work organisation to increase the volume of waste collected per employee. Municipal authorities should support efficient service delivery by improving waste collection infrastructure and operational coordination, thereby creating favourable conditions for firms to utilise their productive resources effectively.

This study has some limitations. First, financial sustainability was measured using the Financial Self-Sufficiency (FSS) ratio, which captures firms' ability to cover reported expenses through internally generated revenue but does not fully reflect other dimensions of financial sustainability, such as liquidity, solvency, and long-term capital replacement. Second, technical efficiency was estimated using Stochastic Frontier Analysis (SFA) before its inclusion in the System GMM model, and the two-stage approach may not fully account for uncertainty in the estimated efficiency scores. Third, the study was limited to 36 private SWM firms in Dar es Salaam over 2016–2023, which may limit the findings' generalisability. Future studies may consider alternative financial sustainability indicators, examine the robustness of the relationship using alternative technical efficiency measures, and extend the analysis to other geographical settings and longer observation periods.

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Appendix A

VARIABLES	Kumbhakar	Battese and Coelli
ln_wastecollectors	0.016	0.082
	(0.070)	(0.077)
ln_number_vehicle_driver	0.353***	0.394***
	(0.081)	(0.085)
ln_wheelbarrow	0.103***	0.139***
	(0.026)	(0.029)
ln_tricycle	0.267***	0.167***
	(0.059)	(0.063)
ln_trucks	0.680***	0.685***
	(0.096)	(0.114)
ln_capital	0.058*	0.006
	(0.033)	(0.037)
b	0.088*	
	(0.052)	
c	0.000	
	(0.005)	
Constant	8.483***	9.076***
	(0.559)	(0.637)
Sigmau_2	11.313***	
	(3.314)	
Sigmav_2	0.051***	
	(0.005)	
lnsigma2		0.046
		(0.579)
Ilgtgamma		2.745***
		(0.616)
Mu		0.635
		(0.695)
Wald chi2	255.11***	311.15***
Log likelihood	-56.837	-76.936
AIC	135.673	173.872
BIC	173.635	208.382
Observations	233	233
Number of firms	36	36

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1