



Household Participation and Positive Monthly Quarry-Related Income in Mvomero District, Tanzania: A Two-Part Analysis

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Abstract: Quarrying may provide rural cash income while also involving occupational, environmental, and economic risks. This study examines whether the characteristics associated with reported quarry participation differ from those associated with reported positive monthly quarry-related income in Kinyenze and Lugono villages, Mvomero District, Tanzania. The survey included 142 households; 137 provided direct participation responses, and 8 of the 87 participants had no recorded income. The questionnaire recorded an estimated amount in Tanzanian shillings; the analysis treats it as self-reported monthly quarry-related income, although the recall period, costs, and net profit were not separately documented. A two-part strategy estimates participation with Probit and the log of observed positive income with robust ordinary least squares in separate equations. Education and farming experience were negatively associated with participation. Farming experience was negatively associated with income among participants with observed positive amounts; estimates for age and land access were imprecise, and the adjusted village contrast was not statistically distinguishable from zero. The small cross-sectional sample and missing income responses limit precision and generalisability. These are adjusted associations, not causal effects or measures of welfare. Future surveys should define the income recall period, document sampling and consent procedures, and record revenues, costs, labour inputs, and seasonality separately.

Keywords: Quarry mining, rural livelihoods, household participation, positive monthly quarry-related income, Mvomero District, Tanzania.

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1.0 INTRODUCTION

Rural households commonly combine agriculture with non-farm and extractive activities to manage cash needs and livelihood constraints. In Mvomero District, the documented economic base includes agriculture, livestock keeping, forestry, mining, beekeeping, fisheries, processing, and trade (Mvomero District Council, 2024). The district had 421,741 residents in the 2022 Population and Housing Census (National Bureau of Statistics, 2022). In this context, quarry mining may offer an accessible source of cash while also exposing households to unstable earnings and occupational or environmental risks.

Tanzanian evidence documents the livelihood relevance of mining and quarrying alongside institutional, health, environmental, and income-related risks (Fisher et al., 2009; Kitole et al., 2025). Yet household-level evidence from Mvomero remains limited on whether characteristics associated with entering quarry work are also associated with the amount participants report. This distinction matters because a missing income response is not equivalent to non-participation or to a zero amount.

Quarry participation and the amount reported after participation are distinct livelihood margins. A household may have no recorded quarry income because it did not participate, because an income response is missing, or because no positive amount was recorded. Separating these outcomes allows the analysis to describe participation and observed positive income without treating either as a direct measure of household welfare.

This study examines Kinyenze and Lugono villages in Mvomero District, Morogoro Region. It uses a two-part analytical strategy: a Probit model for reported participation and a separate robust log-linear model for observed positive monthly quarry-related income. Cragg's framework (1971) motivates the conceptual distinction between entry and a positive outcome, but the estimated equations do not form a jointly estimated double-hurdle model or a sample-selection correction. The contribution is a locally defined, covariate-adjusted comparison of these two margins, not a causal or welfare assessment.

Income was taken from the questionnaire field "Quarry activities – Estimated Amount in TZS" and operationalised as monthly quarry-related income. The supplied questionnaire wording does not specify a monthly recall period or distinguish between gross revenue, net profit, and individual versus household earnings. Income nonresponse was retained as missing, not recoded as zero; full sample construction and missing-data accounting are reported in the Methods section.

1.1 Study Aim and Research Questions

To address the local, two-margin evidence gap identified in Section 2.2.4, this study examines household characteristics associated with reported quarry participation and with observed positive monthly quarry-related income among participants in Kinyenze and Lugono villages, Mvomero District. It also assesses whether descriptive village differences persist after adjusting for covariates. The aim concerns conditional associations, not causal determinants or the welfare impact of quarrying.

The study addresses the following research questions:

1. Which household characteristics are associated with participation in quarry mining?
2. How do quarry participation and positive monthly quarry income differ between Kinyenze and Lugono villages?

Which household characteristics are associated with observed positive monthly quarry-related income among participants after adjustment?

1.2 Empirical Literature, Research Gap, and Theoretical Framing

1.2.1 Empirical Literature from Tanzania

Fisher et al. (2009) examined artisanal and small-scale mining and poverty reduction using evidence from gold and diamond mining in Tanzania's Mwanza Region. People working in mining or related services were less likely to be poor than those in other occupations, and mining income could buffer livelihood shocks. Nevertheless, difficulty obtaining or effectively exploiting formal mineral claims, along with the marginal role of small-scale mining in governance and district planning, contributed to insecurity (Fisher et al., 2009). The study establishes that extraction can be economically important without producing secure livelihoods for every participant. This paper motivates studying mining-related economic choices and returns. However, its poverty focus and gold-and-diamond setting do not directly answer which household characteristics are associated with participation in construction-stone quarrying and positive monthly quarry income in Kinyenze and Lugono.

More directly, Kitole et al. (2025) examined the risks, challenges, and socioeconomic implications of quarrying among 300 households in Mzumbe, Mlali, and Melela villages in Mvomero District, using a quantitative approach. They documented quarrying's livelihood relevance, along with health, environmental, and income-related challenges (Kitole et al., 2025). This is substantive prior quarrying research from the same district; consequently, the present paper cannot claim that quarrying or its socioeconomic implications have not been studied in Mvomero. Instead, it complements that evidence through a separately specified

analysis of direct participation responses and observed positive monthly income in Kinyenze and Lugono. Differences in village coverage and analytical outcomes matter when comparing the studies, and the earlier findings should not be assumed to describe all villages identically.

Achandi and Mujawamariya (2016) offer a relevant Tanzanian methodological comparison, although they focus on rice marketing rather than quarrying. Using an effective sample of 676 rice-growing households, they applied a double-hurdle model to market participation and quantities sold. Cropped area and yield were positively associated with participation, while distance to market and growing an improved variety were negatively associated with it. In the conditional quantity equation, improved varieties and market distance had positive coefficients, and the existence of a village market also mattered (Achandi & Mujawamariya, 2016). Thus, a characteristic can relate differently to participation and to the amount observed after participation. This supports separating the two margins in the present study, but the rice-marketing coefficients do not establish expected signs for quarrying. Nor is the present robust log-OLS positive-income equation equivalent to their double-hurdle estimation and unconditional partial-effect calculations.

The Tanzanian evidence therefore offers complementary insights: mining-related poverty and insecurity, quarrying opportunities and risks, and the empirical value of separating participation from conditional intensity (Fisher et al., 2009; Kitole et al., 2025; Achandi & Mujawamariya, 2016). What remains to be examined here is the pattern of household-level associations across those two margins in the selected quarrying villages. This is a sector- and location-specific extension, not a new model or a claim that all prior Tanzanian work used a single equation.

1.2.2 Empirical Literature from Sub-Saharan Africa

In Ghana, Asante et al. (2014) studied quarrying and livelihood transformation in Nkukua Buoho and Ntiri Buoho near Kumasi. They used questionnaires and in-depth interviews with 110 respondents in communities where both small- and large-scale quarrying were important economic activities. Despite quarrying's prominence, socioeconomic and environmental outcomes were judged unsatisfactory, with limited socioeconomic improvement in the resource-rich communities (Asante et al., 2014). This illustrates why participation in an economically important sector should not automatically be interpreted as livelihood success. Its community-level analysis provides context for household choices, but it does not estimate the adjusted correlates of entry and positive monthly household quarry income in rural Mvomero.

Hilson and Garforth (2012) examined artisanal mining expansion through experiences from southwest Mali and

southeast Ghana. Their empirical argument linked entry into mining to 'agricultural poverty', highlighting how hardship associated with dependence on agriculture can encourage diversification into extraction (Hilson & Garforth, 2012). This makes the agriculture–mining relationship central to the present study's inclusion of farming experience and land access. However, farming experience is not itself a measure of agricultural poverty, and the regional argument does not establish the sign or causal meaning of either coefficient in Mvomero. Households may combine activities, specialize in farming, or face unobserved constraints; empirical investigation, rather than an assumed universal mechanism, is needed.

Geenen et al. (2021) investigated earnings among artisanal gold miners in Kamituga, Democratic Republic of Congo. Their survey covered 453 miners sampled within selected mining zones and pits, using multiple questions to triangulate reported earnings and perceived economic alternatives. Earnings differed markedly by mining function and by whether a pit was in preparation or active production. The study also emphasized measurement difficulties arising from income variability, reluctance to report earnings, and differences in payment arrangements (Geenen et al., 2021). This is directly relevant to the positive-income margin: membership in the mining workforce does not imply a uniform income level, and the meaning of a reported amount depends on the worker's role and production context. Nevertheless, their sample concerns miners already working in gold pits, not a household participation comparison that includes nonparticipants. It is also distinct from this paper's household-head characteristics and single reported monthly income item.

These regional studies distinguish livelihood context, entry pressures, and earnings heterogeneity rather than treating extraction as one homogeneous outcome (Asante et al., 2014; Hilson & Garforth, 2012; Geenen et al., 2021). They motivate separate equations and careful outcome definitions in the present paper. They also identify information the current analysis cannot recover: mining roles, output, labour time, production phases, and detailed payment arrangements. The present study adds a local two-margin assessment but does not claim to supersede the richer earnings measurement in the Congolese research.

1.2.3 International Empirical Literature: Evidence Beyond Africa

In Bangladesh, Hoque and Aktar (2022) explored the environmental and social consequences of stone quarrying in Jaflong, Sylhet. Their qualitative study purposively selected 15 respondents from the Khasi community and 15 from the mainstream or settler Bengali community, alongside interviews with officials and other stakeholders and observations of quarrying-related events. The findings

described migration into quarry-related work, environmental degradation, dispossession, and disruption of traditional Khasi livelihoods (Hoque & Aktar, 2022). This shows how entry into quarrying can occur alongside constraints or losses affecting other livelihood activities. It is relevant for interpreting place of birth, location, and household livelihood portfolios, but it does not quantify adjusted participation probabilities or associations with positive monthly income. The present study cannot assume that its birthplace indicator captures the same migration and dispossession processes.

Verbrugge and Besmanos (2016) examined mining formalization and labour arrangements using empirical evidence from the southern Philippines, particularly South Cotabato. Between 2012 and 2014, they conducted field research using qualitative methods, including key-informant interviews, participant observation, and oral histories. The study documented a differentiated workforce, complex revenue-sharing arrangements, and the limited protection afforded to workers by formalization centred on mineral tenure. It distinguished financiers, skilled workers, and low-paid labourers, whose shares and security differed (Verbrugge & Besmanos, 2016). This contributes to an explanation of why participation need not lead to similar returns: organizational position, financing, deductions, and labour rights can shape earnings. For Mvomero, this implies that household demographics and generic association membership cannot fully capture the institutions governing income. The Philippine evidence concerns gold mining and cannot be directly transferred as a quarry-income coefficient or used to show that association membership raises earnings.

Together, the international studies show that participation may be shaped by migration and livelihood disruption, while returns can depend on labour hierarchy and institutional arrangements (Hoque & Aktar, 2022; Verbrugge & Besmanos, 2016). These are selected international comparisons, not an exhaustive review of every world region. Their qualitative evidence helps identify plausible omitted mechanisms, whereas the present paper estimates household-level conditional associations. The distinction is important: the modified two-part analysis supplies numerical evidence for its selected villages but does not measure dispossession, labour exploitation, or all the costs determining net livelihood returns.

1.2.4 Synthesis, Identified Research Gap, and Study Contribution

The reviewed literature establishes that mining and quarrying provide economic opportunities under unequal and sometimes insecure conditions. Tanzanian and regional evidence examines poverty, quarry-related risks, agricultural diversification, and miners' earnings, while international studies reveal migration, livelihood disruption, and labour

arrangements (Fisher et al., 2009; Kitole et al., 2025; Asante et al., 2014; Hilson & Garforth, 2012; Geenen et al., 2021; Hoque & Aktar, 2022; Verbrugge & Besmanos, 2016). A Tanzanian rice-marketing study also demonstrates that participation and conditional intensity can have different correlates (Achandi & Mujawamariya, 2016). The gap addressed here is the combination of local quarry-household coverage, separate analytical margins, and transparent income observation—not an absence of mining research or two-part methods.

First, the contextual gap concerns quarry-household evidence in Kinyenze and Lugono. Prior work on gold and diamond mining in Mwanza and quarrying in Mzumbe, Mlali, and Melela is informative but does not substitute for village-specific analysis in these two communities (Fisher et al., 2009; Kitole et al., 2025). This study addresses that gap using the retained survey of 142 households, directly reporting participation and income patterns for Kinyenze and Lugono and including village in the adjusted equations. It extends within-district evidence without claiming national representativeness or demonstrating that these villages have never previously been researched.

Second, the analytical gap concerns distinguishing which characteristics are associated with reported participation from those associated with income among positive-income participants. Broader livelihood findings do not answer both questions, while conditional earnings studies of existing miners do not by themselves explain household nonparticipation (Asante et al., 2014; Geenen et al., 2021). The present study addresses this distinction through a Probit participation equation and an HC1-robust log-OLS income equation. Education, age, household-head gender, marital status, household size, birthplace, farming experience, land access, association membership, and village are examined across the two margins where data permit. The contribution lies in comparing their patterns, not in claiming that every earlier study ignored separate decisions.

Third, the measurement gap concerns distinguishing observed nonparticipation from missing participation or income information. The earnings literature identifies variability and reporting difficulties as important obstacles to interpretation (Geenen et al., 2021). This paper makes the observation process explicit: 137 households answered the direct participation item, 87 reported participation, and 79 of those supplied positive income amounts; eight participants had missing income. Missing income is not recoded as zero. Complete-covariate samples of 136 and 78 observations enter the participation and income models, respectively. This transparent accounting improves the interpretation of the available evidence, but excluding missing income does not remove possible nonresponse bias. The reported amount is treated as monthly quarry income; the study does not

independently establish whether it is gross revenue, net income, or income from a typical month.

Fourth, the model-comparison contribution concerns presenting conditional estimates together with diagnostics and sensitivity checks. Tanzanian evidence supports the possibility of different relationships across participation and positive intensity (Achandi & Mujawamariya, 2016). Here, participation is also assessed with a Logit specification, while positive income is examined without the village indicator and under a Gamma model with a log link. These comparisons reveal whether reported directions depend on link, contextual adjustment, or positive-outcome specification. However, fitting separate equations does not test the full joint Cragg model, prove independence of the margins, or correct unobserved sample selection.

This study addresses the local and two-margin gap by providing a covariate-adjusted account of reported quarry participation and observed positive monthly quarry-related income in Kinyenze and Lugono. It contributes transparent sample accounting and sensitivity analysis. Cross-sectional data cannot establish causal or temporal relationships; missing-income selection, labour inputs, prices, production roles, costs, and seasonal transitions are not fully addressed. The outcomes must not be interpreted as household welfare or the net livelihood impact of quarrying.

1.2.5 Household and Local Factors in Livelihood Choices

A household's decision to undertake quarry work may reflect its available labour, skills, productive assets, agricultural commitments, local opportunities, and social connections. Education may be associated with access to non-quarry opportunities, while farming experience and land access may reflect agricultural commitments or asset positions that shape labour allocation. Household demographic characteristics can influence labour availability and livelihood choices. Village location may capture differences in access to quarry sites, markets, transport, labour demand, or local regulation. Because these mechanisms are not directly measured in the survey, the variables are treated as correlates rather than causal determinants.

Evidence from Mvomero documents livelihood relevance as well as material risks (Kitole et al., 2025). A positive participation or income association is therefore not an unqualified welfare gain, and a negative association does not establish that a characteristic harms livelihoods. The outcomes studied here are reported participation and estimated monthly quarry-related income—not household welfare, health, food security, or environmental quality.

1.2.6 Two-Part Analytical Framework

This study uses a two-part analytical framework to distinguish reported quarry participation from observed

positive monthly quarry-related income among participants. Cragg's framework (1971) provides the conceptual rationale for separating a discrete entry decision from a positive outcome. The present analysis estimates a Probit participation model and a separate robust log-linear model for observed positive income. It is not a jointly estimated Cragg model, a Tobit model, or a sample-selection correction; the second equation does not correct for unobserved selection into participation or income reporting.

Conceptually, household characteristics and local context—including education, demographic characteristics, farming experience, land access, association membership, and village location—may be associated with reported participation, which is distinct from observed positive monthly quarry-related income. Agricultural commitments, quarry access, market conditions, and labour allocation may influence both margins but are not directly observed. The analysis therefore estimates adjusted associations and does not impose directional hypotheses unsupported by the survey.

2.0 MATERIALS AND METHODS

2.1 Study Setting and Data Source

The study used a cross-sectional household survey of 142 respondents from Kinyenze and Lugono villages in Mvomero District, Morogoro Region, Tanzania. The questionnaire was piloted before the main survey. The Prime Minister's Office–Regional Administration and Local Government (PMO-RALG) granted permission to collect data, and the authorisation was presented to the relevant local authorities. The manuscript describes respondents as randomly selected villagers, but does not report the sampling-frame source, randomisation procedure, eligibility criteria, fieldwork dates, number approached, refusals or unavailable respondents, or response rate. It also does not state whether the respondent was always the household head. Representativeness and the respondent's relationship to the household-head measures therefore cannot be fully assessed from the available study documentation.

The manuscript records PMO-RALG permission and local-authority authorisation but does not report institutional ethics review or waiver or describe the informed-consent procedure; these procedures should be verified and reported by the study team. Questionnaires and responses were translated between English and Kiswahili to facilitate communication and interpretation. The manuscript gives inconsistent accounts of the analytical software: this section names SPSS, whereas the reproducibility section lists Python libraries. The author should reconcile this before submission. The questionnaire covered household demographics, migration, income sources, expenditure, quarry awareness and participation, mining experience and regulation, land and housing, assets, finance, associations,

environmental issues, market access, infrastructure, and open-ended responses. This article uses variables required for the participation and positive-income equations.

2.2 Outcome Definitions and Sample Construction

The participation outcome is 1 for a direct “Yes” response and 0 for a direct “No” response. Of the 142 respondents, 137 provided direct participation responses: 87 affirmative and 50 negative. Five retained records had no direct participation response and were not forced into either category. One additional direct-response record had missing covariate information, so the complete-covariate Probit model used 136 observations.

The income outcome was taken from the questionnaire field “Quarry activities – Estimated Amount in TZS.” The analysis operationalised the reported amount as monthly quarry-related income, but the supplied instrument wording does not document a monthly recall period. It also does not

separately record gross revenue, operating costs, labour days, or net profit; the measure is therefore interpreted as self-reported estimated income, not verified household profit. Of the 87 affirmative participants, 79 reported a positive amount and eight had missing income. Missing amounts were retained as missing, not recoded as zero, and excluded from the positive-income equation.

A total of 87 households reported participation. Seventy-nine had non-missing positive amounts: 39 in Kinyenze and 40 in Lugono. All eight participants with missing income were in Lugono. The positive-income model used 78 observations with complete covariate data. The available aggregate results do not permit a fuller comparison of participants with observed versus missing income; village comparisons in the conditional income model may consequently be sensitive to non-random income nonresponse. Table 1 summarises sample construction.

Table 1: Analytical sample construction for Kinyenze and Lugono

Stage	Records retained	Records excluded or unavailable	Analytical implication
Raw workbook records	142	None at import	Starting survey file
Retained Kinyenze and Lugono records	142	No Mlali records in this workbook	Geographic scope
Direct participation responses	137	5 missing responses	87 Yes; 50 No
Affirmative participants with income	79	8 missing monthly income	Positive-income sample
Participation Probit sample	136	1 direct-response record missing covariates	Participation model
Positive-income model sample	78	1 positive-income record missing covariates	Positive-income model

Note. Source: Data collected

2.3 Explanatory Variables

The participation model includes age in 10-year units, female household head, married household head, years of formal education, household size, born in the village, farming experience in 10-year units, land access or ownership, association membership, and a Lugono indicator. Binary variables are interpreted against the reference categories specified in the regression-table notes and Appendix A. The participation model uses direct Yes/No responses with complete covariates.

The positive-income model includes the same covariates and is estimated only for participants with an observed positive amount and complete covariates.

2.4 Econometric Strategy

The two-part strategy is conceptually motivated by the distinction between entry and positive outcomes, but its equations are estimated separately. The first part estimates direct reported participation using a Probit link with HC1 heteroskedasticity-robust standard errors. Results are reported as Probit coefficients and sample-average derivative-based marginal effects, including for binary variables and village. The complete-covariate participation sample contains 136 observations.

The second part estimates the natural logarithm of positive monthly quarry-related income for 78 Kinyenze and Lugono participants with complete covariates. Ordinary least squares is used with HC1 robust standard errors. Exponentiated

coefficients are reported as percentage associations. This conditional equation is neither jointly estimated with the participation model nor corrected for selection into observed positive income. The amount is self-reported and treated as monthly, although its recall period and gross/net definition are not established by the supplied instrument.

The participation diagnostics include McFadden's pseudo-R-squared, the ROC area, the Brier score, and variance-inflation factors. The positive-income diagnostics include ordinary and adjusted R-squared, the Breusch–Pagan heteroskedasticity test, and the Jarque–Bera residual-normality test.

2.5 Sensitivity Analyses

Sensitivity checks used a Logit link for the direct participation responses, a positive-income model without the village indicator, and a Gamma generalised linear model with a log link for the 78 complete positive-income observations. These checks assess whether the main directions depend on the choice of link, contextual adjustment, or the assumed positive-outcome distribution.

2.6 Software and Reproducibility

Data management and analysis were conducted in Python using pandas, statsmodels, openpyxl, and the household workbook. Village labels were normalised before filtering.

Variable definitions and available model diagnostics are reported in the manuscript and Appendix A. The supplied materials did not include model syntax or the complete regressor-level VIF output, so these are not reproduced. Household-level data are subject to data-custodian permissions and applicable ethical requirements; any de-identified release or code supplement should follow those restrictions.

3.0 RESULTS

3.1 Household Profile and Village Participation

The 142-household sample had a mean household head age of 40.8 years and a mean of 5.3 years of formal education. Female-headed households accounted for 40.8% of the sample. 65.5% of heads were married, and the mean household size was 3.42 members. About 60.6% of heads were born in the surveyed village, 82.4% reported land access or ownership, and 9.9% reported association membership. Mean farming experience was 8.44 years.

Among the 79 positive monthly-income reports, the mean was approximately TZS 337,342 and the median was TZS 200,000. Together with the TZS 2,000,000 maximum, this mean-median difference is consistent with a right-skewed distribution and supports examining log income.

Table 2: Participation and monthly positive income by village

Village	Retained households	Direct responses	Participants	Participation rate	Positive monthly-income cases	Mean / median monthly income (TZS)
Kinyenze	70	67	39	58.2%	39	350,000 / 250,000
Lugono	72	70	48	68.6%	40	325,000 / 155,000
Total	142	137	87	63.5%	79	337,342 / 200,000

Note. The questionnaire recorded an estimated amount in TZS, operationalised here as monthly quarry-related income; the recall period is not documented. Participation rates are based on direct Yes/No responses. Eight affirmative participants had missing income.

3.2 Participation: Adjusted Associations

Table 3 reports the primary Probit estimates. Each additional year of formal education was associated with a 2.08-percentage-point lower adjusted probability of reported participation (95% CI: −3.78 to −0.38 percentage points; $p = 0.016$). An additional 10 years of farming experience was associated with an 11.55-percentage-point lower adjusted probability (95% CI: −20.27 to −2.82; $p = 0.009$). The estimated age association was positive but imprecise (marginal effect 1.49 percentage points per 10 years; 95%

CI: −6.37 to 9.34; $p = 0.711$), as was the land-access association (14.30 percentage points; 95% CI: −8.30 to 36.91; $p = 0.220$). The adjusted Lugono contrast was also positive but imprecise (marginal effect 9.74 percentage points; 95% CI: −5.86 to 25.35; $p = 0.221$).

Female-headed households and being born in the village showed weaker negative associations with participation, while land access showed a positive association; none reached the 5% level in the primary specification. The estimates are adjusted associations and should not be interpreted as causal effects.

Table 3: *Probit participation model with HC1 robust standard errors*

Variable	Coefficient	Robust SE	p value	Average marginal effect	95% CI for marginal effect
Lugono	0.296	0.247	0.231	0.0974	-0.0586, 0.2535
Age, per 10 years	0.045	0.122	0.711	0.0149	-0.0637, 0.0934
Female household head	-0.416	0.254	0.102	-0.1370	-0.2963, 0.0223
Married household head	-0.089	0.312	0.776	-0.0292	-0.2301, 0.1718
Formal education, years	-0.063	0.028	0.024	-0.0208	-0.0378, -0.0038
Household size	-0.060	0.089	0.501	-0.0197	-0.0769, 0.0375
Born in village	-0.395	0.243	0.105	-0.1298	-0.2821, 0.0225
Farming experience, per 10 years	-0.351	0.144	0.015	-0.1155	-0.2027, -0.0282
Land access or ownership	0.435	0.355	0.220	0.1430	-0.0830, 0.3691
Association member	-0.430	0.459	0.349	-0.1414	-0.4327, 0.1499

Note. Reference categories: Kinyenze; male-headed household; not married; not born in the village; no land access or ownership; and non-membership. Continuous variables are scaled as labelled. N = 136 direct-response households with complete covariates. Average marginal effects are derivative-based dy/dx values averaged over the sample.

The participation model had an ROC area of 0.734, a Brier score of 0.198, and McFadden's pseudo-R-squared of 0.119. The largest variance inflation factor was 12.43 for age,

reflecting its scaling relationship with household and livelihood variables. This indicates that collinearity should be considered when interpreting individual coefficients.

Table 4: *Primary model diagnostics*

Diagnostic	Participation Probit	Positive-income model
Analytical N	136	78
McFadden pseudo-R-squared	0.119	N/A
ROC area under the curve	0.734	N/A
Brier score	0.198	N/A
Maximum variance inflation factor	12.43	N/A
Squared-index link-test p-value	Not re-estimated	N/A
R-squared	N/A	0.207
Adjusted R-squared	N/A	0.088
Breusch-Pagan p-value	N/A	0.172
Jarque-Bera p value	N/A	0.800

Note. HC1 robust standard errors were used in both primary models. The positive-income model uses 78 observations with complete covariates. The maximum participation-model VIF was 12.43.

3.3 Positive Monthly Quarry-Related Income: Adjusted Associations

The positive-income equation is limited to 78 complete-covariate observations from Kinyenze and Lugono. It estimates conditional associations among participants with an observed positive amount. The questionnaire's estimated amount was operationalised as monthly, but the recall period is not specified in the available instrument.

An additional 10 years of farming experience was associated with 38.1% lower reported monthly quarry-related income (coefficient = -0.479 ; $p = 0.001$; transformed 95% CI: -53.8% to -17.0%). The age estimate was imprecisely positive: approximately 27.5% per 10 years, with a 95% confidence interval spanning -0.3% to 63.1% ($p = 0.053$). The estimated association for land access was also imprecise (approximately 102.0%; 95% CI: -9.5% to 353.4% ; $p = 0.086$). The adjusted Lugono–Kinyenze association was -24.6% (95% CI: -54.5% to 24.9% ; $p = 0.272$).

Table 5: HC1-robust log model of positive monthly quarry-related income

Variable	Coefficient	Robust SE	p value	95% confidence interval	Approximate percentage association
Lugono	-0.283	0.257	0.272	-0.787, 0.222	-24.6%
Age, per 10 years	0.243	0.125	0.053	-0.003, 0.489	27.5%
Female household head	0.284	0.240	0.237	-0.187, 0.756	32.9%
Married household head	0.432	0.373	0.247	-0.300, 1.164	54.1%
Formal education, years	0.008	0.032	0.791	-0.054, 0.071	0.9%
Household size	-0.124	0.090	0.172	-0.301, 0.054	-11.6%
Born in village	-0.134	0.277	0.629	-0.678, 0.409	-12.5%
Farming experience, per 10 years	-0.479	0.150	0.001	-0.772, -0.186	-38.1%
Land access or ownership	0.703	0.410	0.086	-0.100, 1.506	102.0%
Association member	-0.555	0.654	0.396	-1.838, 0.727	-42.6%

Note. Reference categories: Kinyenze; male-headed household; not married; not born in the village; no land access or ownership; and non-membership. The model contains an intercept. Percentage associations use the exact exponential transformation of log coefficients. They are adjusted conditional associations, not causal effects. The amount is self-reported and operationalised as monthly.

The positive-income model explained 20.7% of the log-income variance; adjusted R-squared was 8.8%. The Breusch–Pagan test did not reject homoskedasticity ($p = 0.172$), and the Jarque–Bera test did not reject residual normality ($p = 0.800$).

3.4 Sensitivity Results

Under the Logit sensitivity model, education and farming experience remained negatively associated with

participation. The negative farming-experience association persisted in the positive-income models without the village indicator and under the Gamma model with a log link. The age estimate was statistically distinguishable from zero only in the Gamma-log specification. These checks support cautious directional interpretation, not stable causal magnitudes.

Table 6: *Selected sensitivity estimates*

Part and specification	N	Term	Coefficient	Robust SE	p value
Participation: Logit	136	Formal education, years	-0.107	0.049	0.028
Participation: Logit	136	Farming experience, per 10 years	-0.578	0.246	0.019
Income: no village indicator	78	Farming experience, per 10 years	-0.518	0.138	< 0.001
Income: no village indicator	78	Association member	-0.550	0.663	0.407
Income: Gamma-log	78	Age, per 10 years	0.302	0.119	0.011
Income: Gamma-log	78	Farming experience, per 10 years	-0.557	0.141	< 0.001
Income: Gamma-log	78	Association member	-0.561	0.420	0.182

Note. Reference categories for binary indicators are Kinyenze; male-headed household; not married; not born in the village; no land access or ownership; and non-membership. Coefficients are on each model's link scale and should not be compared directly across Probit, Logit, log-OLS, and Gamma-log models. Sensitivity estimates use the retained two-village data.

4.0 DISCUSSION

4.1 Participation as a Distinct Livelihood Margin

In the two surveyed villages, education and farming experience were negatively associated with reported participation, while farming experience was also negatively associated with observed positive monthly quarry-related income. The equations estimate different conditional associations; their significance patterns do not constitute a formal test that coefficients differ across margins.

Education was negatively associated with participation but was not statistically associated with positive monthly income. One possible explanation is that education is associated with access to alternatives to quarry work, but employment opportunities were not measured and the cross-sectional survey cannot establish this mechanism.

Farming experience was negatively associated with both outcomes. It may proxy age, agricultural attachment, or unmeasured labour allocation; the high maximum VIF and cross-sectional design counsel against treating this coefficient as a causal effect. The distinction between participation and a conditional amount is consistent in broad logic with the Tanzanian rice-marketing study by Achandi and Mujawamariya (2016), but the outcomes and estimators differ.

The distinction between the two margins is comparable in logic, though not in outcome or estimator, to Achandi and Mujawamariya's (2016) Tanzanian rice-marketing study. Their evidence showed that the participation decision and conditional quantities could have different correlates. In this quarry study, the education association is negative for participation but statistically imprecise for positive income.

That pattern reinforces the usefulness of examining entry separately from reported earnings. It does not establish that the population coefficients differ statistically across equations, and the reported significance patterns are not a formal cross-equation test.

Prior Tanzanian and Ghanaian studies show that economic opportunities can coexist with insecurity or unsatisfactory community outcomes (Fisher et al., 2009; Kitole et al., 2025; Asante et al., 2014). These findings reinforce the need not to interpret participation or a positive reported amount as a welfare gain after occupational, environmental, or opportunity costs.

4.2 Village Heterogeneity and Awareness Coding

The raw participation rate was higher in Lugono than in Kinyenze, but the adjusted Lugono–Kinyenze association was not statistically distinguishable from zero. The raw difference therefore does not demonstrate an adjusted village effect. Because all eight missing income reports were in Lugono, the conditional village comparison may be sensitive to income nonresponse.

Five retained records lacked a direct participation response. Future surveys should distinguish “not participating,” “not aware,” and “not asked,” and should follow up with a clearly defined monthly income question.

4.3 Positive-Income Intensity and Association Membership

Among participants with observed positive income, the adjusted Lugono–Kinyenze estimate was imprecise despite the descriptive difference in village medians. Association membership was not statistically associated with the positive-income outcome; this does not establish that

membership has no livelihood relevance. The mean income exceeded the median and the maximum was comparatively high, consistent with right-skew. The age association was not robust to the choice between log-OLS and Gamma-log specifications.

4.4 Limitations

This study is cross-sectional and restricted to two villages, so it cannot establish causal or temporal relationships or support generalisation to all quarrying communities. The income measure is self-reported and estimated; its recall period and whether it represents gross revenue, net profit, or household versus individual earnings are not established by the supplied instrument. Five participation responses and eight income reports were missing, and all eight missing income cases were in Lugono. The modest analytic samples, ten covariates, adjusted R-squared of 0.088 in the income model, wide confidence intervals, and maximum reported VIF of 12.43 limit precision; age and farming experience may capture overlapping life-course or livelihood patterns. Results should be treated as exploratory adjusted associations. The available manuscript also omits sampling-frame and randomisation details, response-rate accounting, fieldwork dates, participant-consent and ethics-review reporting, full model syntax, and complete regressor-level diagnostics. These gaps limit assessment of representativeness, ethical procedures, and reproducibility and should be resolved by the study team where records permit.

4.5 Contribution to the Identified Gap

The study adds village-specific, covariate-adjusted evidence on reported participation and observed positive monthly quarry-related income in Kinyenze and Lugono. Its contribution is the explicit comparison of these two margins, transparent sample accounting, and sensitivity analysis—not a new econometric estimator or a claim to represent Tanzania nationally. Larger longitudinal studies with complete income, cost, labour, production-role, and seasonal measurements are needed to assess livelihood transitions and net welfare.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

In Kinyenze and Lugono, reported quarry participation and observed positive monthly quarry-related income were associated with different household characteristics. Education and farming experience were negatively associated with participation, while farming experience was negatively associated with reported income among participants with observed positive amounts. These cross-sectional associations should not be interpreted as causal effects or evidence that quarrying improves household welfare.

The analysis used separate Probit and robust log-linear equations, conceptually motivated by the distinction between participation and a positive outcome. It is not a jointly estimated double-hurdle or sample-selection model. Income was self-reported, treated as monthly, and subject to missing responses; its recall period and net/gross definition are uncertain. The small samples and possible collinearity further limit precision.

The estimates describe adjusted associations in the surveyed households only. The study does not establish causal effects, selection-corrected income differences, or broad livelihood effects of quarry mining.

5.2 Recommendations

First, future quarry surveys should define the income recall period and record gross revenue, operating costs, labour input, and net earnings separately. Respondents should also be asked whether the reported period was typical or exceptional.

Second, future designs should collect measures of exposure and access that may explain village-level differences, including distance to quarry sites, transport access, local labour demand, market arrangements, and regulatory conditions.

Third, policy responses should recognise household heterogeneity. Education and farming-experience associations should not be used as instructions for or against quarry participation without evidence on employment alternatives and labour allocation.

Fourth, association membership should be examined by organisation type, purpose, membership selection, services, and quarry relevance. The nonsignificant income coefficient should not be used to discourage collective action.

Finally, a larger multi-village study should use a documented sampling frame and randomisation procedure, report fieldwork and response-rate details, and transparently describe ethics review or waiver and informed-consent procedures. Complete repeated income observations would support stronger inference about livelihood transitions and seasonality.

6.0 AUTHOR DECLARATIONS

6.1 Consent for Publication

The manuscript does not reproduce identifiable individual information.

6.2 Funding

No specific funding supported this study.

6.3 Competing Interests

The author declares no competing interests.

6.4 Data Availability

The household-level data contain potentially sensitive survey information and are not included in this manuscript. Availability is subject to the original data custodian's permissions and to applicable ethical requirements.

6.5 Author Contributions

Nehemia Dauson Kaaya: Conceptualisation, resources, supervision, and writing, review and editing. He defined the

study objective and substantive focus, provided the research data and study-design clarifications, and is responsible for critically reviewing and approving the submitted version.

6.6 Use of AI-Assisted Tools

Generative AI tools assisted with data-audit scripting, statistical programming, and language editing.

Appendix A. Variable Coding and Reference Categories

The following coding reflects the model variables and reference categories reported in the manuscript and comments. Age and farming experience enter in 10-year units; formal education is measured in years. Reference categories apply to binary indicators.

Variable	Coding / scale	Reference category
Age	Years, scaled per 10 years	—
Female household head	Binary indicator	Male-headed household
Married household head	Binary indicator	Not married
Formal education	Years	—
Household size	Number of members	—
Born in village	Binary indicator	Not born in the village
Farming experience	Years, scaled per 10 years	—
Land access or ownership	Binary indicator	No access or ownership
Association member	Binary indicator	Not a member
Village	Lugono indicator	Kinyenze

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