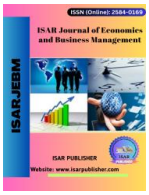
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Household Participation and Positive Monthly Quarry-Related Income in Mvomero District, Tanzania: A Two-Part Analysis

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1.0 Abstract: The quarrying operation may generate cash income for people in rural areas, but also carry risks for the citizens, environment, and economy. The study aims to investigate whether there are differences between the characteristics associated with reported quarry participation and reported positive monthly income from quarrying in Kinyenze and Lugono villages of Mvomero district in Tanzania. A total of 142 households were surveyed, with 137 households giving direct participation responses and 8 out of 87 households not having an income recorded. The amount of money estimated on the questionnaire was in Tanzanian shillings and is regarded as the monthly income from the quarry, as the person estimated it, but the date of the event and the net profit did not have to be recorded separately. The study employed a quantitative method approach. A two-part approach was used to estimate participation, using Probit and the log of observed positive income in separate equations. The negative association was between education and participation, as well as between farming experience and participation. For those participants who had positive experience in farming, the income was found to be negatively related to them, with imprecise estimates for age and land access, and the adjusted contrast for village was not significantly different from zero. Poor precision and generalisability due to the small sample of cross sections and lack of income responses. These are set connections, not causal effects or measures of welfare. Further surveys should specify the income recall period, record the sampling and consenting process and separately account for labour inputs, seasonality and costs and revenues.

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

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2.0 INTRODUCTION

Farm households often engage in multiple livelihood strategies, both rural and non-farm, to address livelihood challenges and cash requirements. The documented economic base in Mvomero District is: Agriculture, Livestock keeping, Forestry, Mining, Beekeeping, Fisheries, Processing, and trade (Mvomero District Council, 2024). According to the 2022 Population and Housing Census (PHC) by the National Bureau of Statistics (NBS), the district was home to 421,741 people in the census. In this context, quarry mining can be a readily available source of money for a household, but may also involve irregular sources of income, risks to health and safety from the job and/or the environment.

The livelihood relevance of mining and quarrying (MQ) has been documented in Tanzania, as well as institutional, health, environmental and income-related risks (Fisher et al., 2009; Kitole et al., 2025). However, there is little evidence at the household level that could shed light on household-level characteristics that are associated with reporting amounts of participation in quarry work for Mvomero. This is important as a zero income response is not the same as not responding to the survey at all.

The two livelihood margins of quarry participation and the amount reported after participation are different. There are a number of reasons why a household may not be recorded with a quarry income, such as: no recorded income response, no positive amount recorded, or the household did not participate in the quarry. These outcomes can be separated and used to describe participation and income observed as some sort of a measure of household welfare.

This study focuses on two villages in Mvomero District, Morogoro Region, namely Kinyenze and Lugono villages. It adopts a two-stage approach for analysis—first, a Probit model to examine reported participation and, second, a robust log-linear model to examine observed positive monthly income generated by the quarry. The theoretical and conceptual separation of entry and positive outcome is motivated by the framework of Cragg (1971), but the estimated equations do not constitute a jointly estimated double-hurdle model or a sample-selection correction. The contribution is a local, covariate-adjusted comparison of these two margins, and is not an economic or welfare measure.

The field in the questionnaire that asked about the "Estimated Amount in TZS" for the quarry activities was extracted and operationalised as the monthly income from the quarry activities. The wording of the questionnaire provides no indication of whether it is a monthly recall period, or whether it talks about gross income, net profit or individual income, versus household income. Income nonresponse was not recoded as zero, but retained as missing; full sample construction and accounting for missing data are reported in the Methods section.

2.1 Study Aim and Research Questions

This study focuses on the characteristics of household-reported participation in the quarries as well as on the characteristics of household-observed monthly positive income from quarries among those who participated in the quarries in Kinyenze and Lugono villages in Mvomero District. It also examines whether there are any village differences described after controlling for any covariates. The purpose is not to determine causality or the effects of quarrying on welfare, but to examine conditional associations.

The following research questions are discussed:

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?

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

2.2 Empirical Literature, Research Gap, and Theoretical Framing

2.2.1 Empirical Literature from Tanzania

Fisher et al. (2009) looked at the relationship between artisanal and small-scale mining and poverty alleviation, based on empirical evidence of gold and diamond mining in Mwanza Region of Tanzania. The likelihood of poverty among people engaged in mining or related services was lower than among those engaged in other activities, and mining income might help to moderate the effects of livelihood shocks. However, a lack of access to and effective use of formal mineral claims and a lack of their significance in governance and district planning led to increased insecurity (Fisher et al., 2009). The study confirms that extraction does not necessarily provide secure livelihoods for all participants and that it can be economically significant without providing secure livelihoods. This paper encourages research into economic decisions and returns associated with mining. Nevertheless, the poverty focus and the gold and diamond context do not directly address the relationship between participation in construction-stone quarries and positive monthly income from the stone quarry in Kinyenze and Lugono and between the characteristics of households and these types of stone quarries.

Directly, Kitole et al. (2025), in their study of 300 households in the villages of Mzumbe, Mlali and Melela in Mvomero District of Morogoro Region in Tanzania, employed quantitative research methodology to investigate

the risks, challenges and socioeconomic implications of quarrying. They captured the livelihood relevance of the quarrying activity as well as health, environmental, and income-related issues (Kitole et al., 2025). The present paper does not claim that quarrying or its socio-economic implications have not been studied in Mvomero, as this is substantive research conducted before the quarries were ever taken on the district. Rather, this adds to that evidence with an additional analysis of direct participation responses and observed positive monthly income in Kinyenze and Lugono. The studies differ in terms of their coverage of the villages and the results of the analyses, and it would not be appropriate to assume that all villages are the same in terms of these results.

A relevant methodological comparison exists in Tanzania in relation to rice marketing, between Achandi and Mujawamariya (2016), but not in relation to quarrying. They applied the double-hurdle model to participation in the market and quantity sold to a representative sample of 676 rice growers' households. The cropped area and yield were positively related to participation, while the distance to market and growing an improved variety were negatively related to participation. The effects of both improved varieties and market distance were positive in the conditional quantity equation, and the presence of a village market was also significant (Achandi & Mujawamariya, 2016). Therefore, there can be different relationships between a characteristic and participation and the amount of observation after participation. This justifies separation of the two margins in the current work, but the rice-marketing coefficients do not give a clear indication of the signs of the expected quantity. Neither is the present model a strong log-OLS positive income equation, nor are the double hurdle estimation and unconditional partial effect calculations.

The Tanzanian evidence, therefore, provides complementary insights with respect to: mining-related poverty and insecurity; opportunities and risks of quarrying; and the empirical value of decoupling participation from the conditional intensity (Fisher et al., 2009; Kitole et al., 2025; Achandi & Mujawamariya, 2016). What needs to be explored now is the pattern of household-level connections on those two margins in the villages chosen as being quarried. This is an extension of the said work, not a new model or an assertion of a single equation being used throughout the entire work in Tanzania.

2.2.2 Empirical Literature from Sub-Saharan Africa

Asante et al. (2014) carried out their research on quarrying and livelihood transformation in Nkukua Buoho and Ntiri Buoho near the city of Kumasi in Ghana. They employed questionnaires and in-depth interviews with a total of 110 individuals in the communities where small- and large-scale quarrying activities were both significant economic activities. Although quarrying was significant, the impact on the socio-economic and environmental outcomes was found to be inadequate, especially in the resource-rich communities where there was limited socio-economic improvement (Asante et al., 2014). This shows that it is not wise to assume that any involvement in an economically significant activity is a sign of success in livelihoods. It only estimates the correlates of entry and positive monthly household quarry income in rural Mvomero against the background of its community-level analysis.

Hilson and Garforth (2012) analysed experiences of a growing artisanal mining sector in southwest Mali and southeast Ghana. The empirical argument that they established centered on the connection between entering the mining sector and 'agricultural poverty', pointing to the desirability of diversifying away from agriculture into mining under conditions of hardship (Hilson & Garforth, 2012). The importance of the agriculture–mining relationship in the present study and the inclusion of farming experience and land access are highlighted. But experience of farming does not necessarily constitute a proxy for agricultural poverty, and the regional argument does not specify the direction or significance of either of the coefficients in Mvomero. There will be a need for empirical investigation, not an assumed universal mechanism, as household units are able to mix activities or specialise in farming or have unobserved constraints.

Geenen et al. (2021) studied the earnings of the artisanal gold miners in Kamituga, DRC. They surveyed 453 miners within specific mining areas/pits who were asked several questions to cross-check reported income and perceived economic options. There was a significant variation between the earnings of the various mining functions, and between the earnings of pits in preparation and those that were in production. Another limitation of the study was the difficulty of measuring incomes due to income variation and incomplete reporting of income by respondents, as well as the differences in how income is paid (Geenen et al., 2021). The positive-income margin is directly related to this, as being a member of the mining workforce does not necessarily mean a higher income, and the value of a reported income varies depending on the nature of the mining activity and the nature of the individual's employment. However, their sample is not an actual comparison of households with miners working in the gold pits, which would make a better comparison. It is also different from the characteristics of the household head and single reported monthly income variables that are included in this paper.

These regional studies isolate the differences in livelihood context, entry pressures and earnings heterogeneity, instead of lumping all the results of extraction together (Asante et al., 2014; Hilson & Garforth, 2012; Geenen et al., 2021).

They encourage independent equations and careful definitions of outcomes in the present paper. They also uncover information that the current analysis is unable to recover, such as mining roles, output, labour time, production phases and detailed payment arrangements. The present research provides a local two-margin assessment, but it is not intended to replace the more detailed assessment of earnings in the Congolese research.

2.2.3 International Empirical Literature: Evidence Beyond Africa

Hoque and Aktar (2022) studied the environmental and social impacts of stone quarrying activities at the stone quarry of "Jaflong" in Silhet, Bangladesh. They carried out a qualitative study, during which they selected 15 people from the Khasi community, 15 from the mainstream or settler Bengali community and conducted some interviews with officials and other stakeholders and observed some quarrying activities. They found migration in search of quarry jobs, degradation of the environment, loss of traditional livelihoods of the Khasis and disruption of Khasi traditional ways of living (Hoque & Aktar, 2022). This indicates that entry into quarrying can happen in the context of some constraints and/or losses relating to livelihood activities other than quarrying. It is relevant for the interpretation of place of birth and location and household livelihood portfolios, but it cannot quantify adjusted participation probabilities or relationships with positive monthly income. It is not possible to assume that the migrational and dispossessive processes that were captured by the birthplace indicator in the present study are the same processes.

From the empirical study in the southern Philippines (in this case, in South Cotabato), Verbrugge and Besmanos (2016) explored the issues of formalisation and labour arrangements in the mining sector. From 2012 to 2014, they engaged in fieldwork with a qualitative approach involving key informant interviews, participant observation and oral histories. The study revealed a differentiated workforce, complex revenue-sharing arrangements, and a formalisation that is based on mineral tenure with limited protection for workers. It marked a distinction between the shares and security of the financiers, the skilled workers and the low-paid labourers (Verbrugge & Besmanos, 2016). It helps explain why having an organisation does not necessarily mean that the same returns are realised: organisational position, finance, deductions and labour rights can influence returns. This means that institutions governing income are not completely captured by household size or gender equality. This in turn implies for Mvomero that there is a need to take into account the institutions governing income that go beyond household size and generic association membership. The Philippine evidence relates to gold mining, and cannot be readily applied to the coefficient of the quarry income nor to the evidence that membership in an association increases income.

The international studies indicate that together, migration and livelihood disruption can influence participation, and labour hierarchy and institutional arrangements can influence returns (Hoque & Aktar, 2022; Verbrugge & Besmanos, 2016). These are only a few international comparisons, and are not intended to be a comprehensive list of all world regions. The qualitative evidence they provide suggests plausible omitted mechanisms, and the present paper attempts to estimate household-level conditional associations. The difference is that the adapted two-part analysis provides numerical data for its preferred villages, but it does not assess dispossession or labour exploitation, or all of the costs which drive net livelihood returns.

2.2.4 Synthesis, Identified Research Gap, and Study Contribution

The literature reviewed confirms that the mining and quarrying industry offers economic opportunities in unequal and/or precarious conditions. The Tanzanian and regional literature covers poverty, hazards associated with quarrying, agricultural diversification and earnings of miners (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). The same applies to the correlates of participation and conditional intensity, as shown in the Tanzanian study on rice marketing (Achandi & Mujawamariya, 2016). What is missing here is a link between the local quarry-household level, the analytical margins, and the transparency of the income observation, but not the lack of mining research or two-part methods.

The contextual gap is related to the evidence from quarry-households in both Kinyenze and Lugono. Even though there are lessons learned from the previous studies on gold and diamond mining in Mwanza, and quarrying in Mlali, Mzumbe and Melela, the reports are not sufficient to replace their village-specific analysis in the two villages mentioned. This study fills that gap by investigating patterns of participation and income as reported through the households retained in the survey (142 households) and by including village in the adjusted equations, directly reporting participation and income patterns for Kinyeze and Lugono. It is not nationally representative but does not make claims of such, or that these villages have not been studied in the past.

The second analytical issue is that it is not clear how to identify which aspects of participation are correlated with reported participation rather than income among positive-income participants. Moreover, there is no single study that can easily address both questions, and existing studies of conditional earnings of current miners do not adequately

shed light on why households may not mine (Asante et al., 2014; Geenen et al., 2021). This distinction is tackled in the present study by looking at a Probit participation equation and an HC1-robust log-OLS income equation. Education, age, gender of the head of the household, marital status, household size, birthplace, farming experience, access to land, village membership and association membership are looked at for both margins wherever data are available. It's the comparison of their patterns that's of interest, not that all previous studies overlooked separate decisions.

Third, the measurement gap is whether a gap in observed participation is due to a lack of participation or whether a gap in observed income is due to a lack of participation. Variability and reporting challenges are recognised as key challenges in interpreting earnings results in the earnings literature (Geenen et al., 2021). This paper formally captures this observation process by reporting the answers to the direct participation item: 137 families answer this question, 87 report participation, and 79 provide positive income amounts; eight provide missing income amounts. No record of 'zero' income is made when income is missing. A total of 136 and 78 observations go into the participation model and the income model, respectively. This clear bookkeeping enhances the understanding of the evidence available, yet missing income cannot take away the potential for nonresponse bias. The reported amount is assumed to be monthly income from the quarries, but it is not necessarily gross, net, or the income from a typical month.

Fourth, the model-comparison contribution addresses the issue of presenting conditional estimates, along with diagnostics and sensitivity checks. There is evidence in Tanzania which suggests that other links exist between participation and positive intensity (Achandi & Mujawamariya, 2016). In this case, participation is also measured using a Logit specification and positive income is studied without including the village indicator, using a Gamma model, assuming a log link. These comparisons show that reported directions depend on the link or contextual adjustment, or the positive-outcome specification. But fitting separate equations does not test the entire joint Cragg model; it is not a test of independence of the margins, nor does it correct unobserved sample selection.

This study aims to close the gap by reporting the local and two-margin gap in Kinyenze and Lugono and to give an account of quarry participation and the income generated from quarry activities in a month that was observed, while controlling for the effects of various covariates. Provides clear accounting of samples and sensitivity analysis. No causal or temporal relationships are possible, and the selection of the missing income, inputs of labour, prices, production roles and costs, as well as transitions between different seasons are only partially covered in the cross-sections. The results should not be considered in terms of the welfare of the household or the net effect of the quarry operation on livelihoods.

2.2.5 Household and Local Factors in Livelihood Choices

The choice to engage in quarry activities might be related to the labour resources at their disposal, skills, productive assets, agricultural activities, opportunities at the local level and social networks of the household. Education can be linked to access to non-quarry opportunities, and so can farming experience and land access, which could be related to agricultural commitments or asset positions that affect labour allocation. Labour availability and livelihood decision-making could be affected by household socio-economic factors. Regional conditions for access to quarry sites, markets, transport, labour demand and/or local regulation may be captured by village location. In this survey, the variables are not directly measured, so they are considered as correlates, not causal determinants, of these mechanisms.

While livelihood relevance is documented by evidence from Mvomero, material risks are documented by material risks from Mvomero. An association which is positive in terms of participation and/or income is thus not a welfare gain per se, and a negative association is not proof that a characteristic is harmful to livelihoods. The results explored here are on participation and the estimated monthly income from quarrying (not household welfare, health, food security or environmental quality).

2.2.6 Two-Part Analytical Framework

In this study, the analysis is based on two criteria for determining whether participants are involved with quarries and whether their monthly household income is positive. This study employs a two-part analytical framework, distinguishing between the involvement of participants in quarry activity and the positive monthly household income of participants. The conceptual logic for the separation of a discrete entry decision from a positive outcome comes from Cragg's framework (1971). This study uses two separate models for estimating the participation rate: the Probit model and the robust log-linear model of observed positive income. The second equation is not a jointly estimated Cragg model, a Tobit model or a sample-selection correction.

In theory, household characteristics and local context (education, demographic characteristics, farming experience, land access, association membership and village location) might be linked to reported participation, and to positive monthly income from the quarries, but not necessarily to observed positive monthly income from the quarries. Agricultural commitments, access to quarries, market prices, and labour use may be factors which could

affect either of the margins but cannot be directly observed. The analysis is therefore adjusted and does not reflect any a priori hypotheses not supported by the survey.

3.0 MATERIALS AND METHODS

3.1 Study Setting and Data Source

The study adopted a cross-sectional household survey of 142 respondents from two villages, Kinyenze and Lugono, in Mvomero District, Morogoro Region, Tanzania. A pilot survey of the questionnaire was conducted prior to the survey. The Prime Minister's Office - Regional Administration and Local Government (PMO-RALG) authorised data collection, and this was presented to the relevant local authorities. Villagers were selected at random as respondents.

Translations between English and Kiswahili were done on questionnaires and responses to ensure communication and interpretation. The questions included in the questionnaire were on household demographics, migration, sources of income, expenditure, awareness and participation in the quarry, experience of quarrying, regulation of mining, land and housing, assets, finances, associations, environmental issues, market access, infrastructure and open-ended questions. This article employs variables which were needed for the participation and positive-income equations.

3.2 Outcome Definitions and Sample Construction

The participation outcome is: 1 if a direct "Yes" is given, 0 if a direct "No" is given. 137 of the 142 respondents gave direct participation responses – 87 were positive, and 50 were negative. These are the five records that did not have any direct participation response, but were not obliged to fit into either response category. Another direct-response record had no covariate information, so the full-covariate Probit model was based on 136 observations.

The field of the questionnaire, "Quarry activities – Estimated Amount in TZS", was used as the income outcome. The provided wording for the instrument used does not mention a monthly recall period, although it is believed the reported amount was for the month. It also lacks a gross revenue and operating cost record, a labour day record, and a record of net profit, so it is considered self-reported estimated income and not a verified household profit. The 87 affirmative respondents reported a positive amount of income (79), and eight had missing income. Individuals with missing amounts were not recoded to zero, but rather were left missing and thus not included in the positive-income equation.

87 households reported their participation. Of the 79, there were 39 and 40 who did not leave their amounts empty in Kinyenze and Lugono, respectively. The highest number of missing-income participants were in the town of Lugono (8). The positive-income model was based on 78 complete observations that included information on all of the covariates. The available aggregate results do not allow a more complete comparison of participants with observed income and those with missing income, and so may be subject to non-random income nonresponse in the comparisons of villages in the conditional income model. Table 1 summarises the construction of the samples.

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

3.3 Explanatory Variables

The participation model incorporates the variables age (in 10-year increments), female household head, married household head, years of formal education, household size, born in the village, farming experience (in 10-year increments), land access or ownership, association membership and a Lugono indicator. The interpretation of binary variables is against the reference categories included in the notes in the regression table and Appendix A. In the participation model, the answer format is direct, in the form of a Yes/No, and the complete covariates are used.

The positive-income model is very similar to the other model, and uses the same covariates, but is estimated only

for the participants with positive income and complete covariates.

3.4 Econometric Strategy

The rationale behind the two-part strategy is to distinguish between "entry" and "positive outcomes," though two sets of equations are estimated separately. The first part uses a Probit link with HC1 heteroskedasticity-robust standard errors to estimate reported participation as direct. The first part estimates the direct participation using a Probit link with HC1 heteroskedasticity-robust standard errors. Analytical results are provided in terms of Probit coefficients and derivatives of sample means (marginal effects) for binary variables and for village. The sample is complete-case; it has 136 observations.

The second part tries to estimate the natural log of positive monthly income from the quarry for 78 participants in the Kinyenze and Lugono groups who had all the covariates available. Ordinary least squares, with robust HC1 standard errors. The coefficients that are raised to a power are expressed as percentage associations. This conditional equation is not jointly estimated with the participation model, nor is it corrected for participation in positive income. It is a self-reported amount and is assumed to be monthly, but there are no specific time period or gross/net definitions provided in the instrument supplied.

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

3.5 Sensitivity Analyses

The direct participation responses were analysed using a Logit link; the positive-income model was analysed without the village indicator, and the 78 complete positive-income observations were analysed using a Gamma generalised linear model with a log link. These tests examine whether these main directions are affected by the choice of link, contextual adjustment or the assumed positive outcome distribution.

3.6 Software and Reproducibility

These data were analysed and processed in Python with the help of pandas, statsmodels, openpyxl and the household workbook. Labels were normalised with village labels prior to filtering. The variable definitions and the diagnostics available for the models are provided in the manuscript and Appendix A. Model syntax was not provided in the materials, nor was the output of the regressor-level VIF, so those are not reproduced. Wherever possible, data custodians have permissions regarding household-level data, and relevant ethical criteria apply; these should also apply to any de-identified release or code supplement.

4.0 RESULTS

4.1 Household Profile and Village Participation

The average age of the head of the household in the 142-household sample is 40.8 years, and the average number of years of formal education that the household head has completed is 5.3 years. Forty per cent of the sample were female-headed households. The marital status of the heads was 65.5% married, and the average household size was 3.42. 60.6% of heads were born in the surveyed village, 82.4% said that they had access to land or owned land, and 9.9% said that they were a member of an association. The mean farming experience was 8.44 years.

The average (mean) of the 79 positive monthly income reports was about TZS 337,342, while the median was TZS 200,000. This mean-median difference, along with the TZS 2,000,000 maximum, is similar to what would be expected when studying a right-skewed distribution, and therefore would justify studying 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. Participation rates are based on direct Yes/No responses.

4.2 Participation: Adjusted Associations

The main Probit estimates are presented in Table 3. This was for every additional year of formal education, with an adjusted probability of reported participation decreasing by 2.08 percentage points (95% CI: −3.78 to −0.38 percentage points; p = 0.016). The adjusted probability decreased by

11.55 percentage points (95% CI: −20.27 to −2.82; p = 0.009) with each additional 10 years of experience in farming. 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 contrast also turned out to be positive but vague (marginal effect 9.74 percentage points; 95% CI: −5.86 to 25.35; p = 0.221) for the adjusted contrast.

These were weaker negative associations with participation in the primary specification, with none reaching the 5% level, though the positive association was stronger with land access. These 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.

4.3 Positive Monthly Quarry-Related Income: Adjusted Associations

The positive-income equation is only available from Kinyenze and Lugono (78 complete-covariate observations). It makes an estimate of the conditional association of the participants where there is an observed positive amount. The estimated amount of the questionnaire is operationalised by the word monthly, but the recall period is not mentioned in the instrument available.

There was 38.1% less income earned from the quarry (coefficient = −0.479; p = 0.001; transformed 95% CI: −53.8% to −17.0%) with an additional 10 years of farming experience. The estimate of age was not very precise, with a 95% confidence interval of −0.3% to 63.1% (p = 0.053), and the age estimate was positive in approximately 27.5% of the studies. 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).

4.4 Sensitivity Results

In the case of the Logit sensitivity model, the presence of education and farming experience was still negatively related to participation. The negative relationship with farming experience was not found in the positive-income models, and only appeared in the Gamma model with the log link. Only for the Gamma-log specification was the age estimate statistically distinguishable from zero. These checks are designed to aid in the cautious directionality interpretation, rather than in stable magnitude causality interpretation.

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.

5.0 DISCUSSION

5.1 Participation as a Distinct Livelihood Margin

Farmers' educational attainment and farming experience were both found to have a negative correlation with reported participation, while farming experience was found to have a negative correlation with observed positive monthly quarry-related income, in the two surveyed villages. The equations model various conditional associations, and their significance patterns are not a formal test for differences in the coefficients across margins.

There was a negative association between education and participation, but not between education and positive monthly income. One likely reason is that education is linked to substitutes for quarry work, but this was not captured as a measure, and this cross-sectional study could not capture this mechanism.

There was a negative association of farming experience with both outcomes. It may be an indicator of age, attachment to agriculture, or unmeasured labour allocation, but because of the high maximum VIF and cross-sectional design, it should not be interpreted as a causal effect. The difference between participation and conditional amount is not only in terms of the broad logic, as was found for Tanzania in the rice-marketing study conducted by Achandi and Mujawamariya (2016), but also in the outcome and in the estimators.

The difference between the two margins has a similar argument, but with a different net result and/or estimator, as in Achandi and Mujawamariya (2016), the Tanzanian rice-marketing study. Their data demonstrated that there could be different correlates for the conditions and the participation decision. The education association is not a participation factor in this study, and is an imprecise positive income factor statistically. But this trend makes the value of considering entry separately from reported earnings obvious. It does not imply that the population coefficients vary significantly between equations, and the significance pattern shown is not a formal test between the equations.

Economic opportunities have been found to coexist with insecurity and/or less than satisfactory community outcomes in previous research in Tanzania and Ghana (Fisher et al., 2009; Kitole et al., 2025; Asante et al., 2014). The results support the importance of considering participation and/or a positive reported amount as a welfare gain following the reduction of the opportunity cost, environmental cost, or occupational cost.

5.2 Village Heterogeneity and Awareness Coding

The raw participation rate was significantly higher for Lugono compared to Kinyenze, but the adjusted Lugono–Kinyenze association was not statistically different from zero. The raw difference thus does not exhibit a difference in the adjusted village effect. The conditional village comparison needs to be interpreted with caution due to the fact that all eight missing income reports were from Lugono.

Five did not have a direct participation response. Future surveys need to differentiate the categories of "not participating" and "not aware" from "not asked", and have a focused monthly income question.

5.3 Positive-Income Intensity and Association Membership

When a positive income was observed, the adjusted Lugono–Kinyenze estimate was imprecise even though there was a difference in the medians of the villages. However, there was no statistically significant relationship between membership in the association and positive income

outcome, which does not mean that there is no relevance of association membership to livelihood. The distribution of income was somewhat right-skewed (mean income was higher than the median and the max income was relatively high). The age association was not strong in this regard, with respect to the specification of the log-OLS model versus the Gamma-log model.

5.4 Limitations

Due to the cross-sectional nature of the study and the fact that it was limited to two villages, it was not possible to draw causal or temporal inferences or to generalise to other quarrying communities.

5.5 Contribution to the Identified Gap

The study provides evidence on reported and observed participation rates and positive monthly income generated from the quarry activities at the village level while controlling for the effects of covariate factors in the Kinyenze and Lugono villages. It does not claim to represent Tanzania nationally, which is a new econometric estimator, but what it does is the explicit comparison of these two margins, transparent sample accounting, and sensitivity analysis. Net welfare and livelihood transitions need to be evaluated with larger longitudinal studies that provide comprehensive information on income, costs, labour and production roles and seasonal data.

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

In both Kinyenze and Lugono, there was an association between reported involvement in the quarry and observed monthly income from the quarry with household characteristics. Household characteristics were associated with reported participation in the quarry in the two villages of Kinyenze and Lugono, and observed income from the quarry per month. Education and farming experience were inversely related to participation, with farming experience being inversely related to reported income among those who had positive reported amounts of farming experience. The cross-sectional relationships should not be viewed as causal relationships or as an indication of a positive effect of quarrying on household welfare.

Two separate equations were used – a Probit equation and a robust log-linear equation – both motivated by the different phenomena of participation versus positive outcome. Does not represent a jointly estimated double-hurdle/sample-selection model. Income was self-reported, treated as occurring on a monthly basis, and there was some missing data with recall period and net/gross definition unknown. Further, precision is reduced due to the small samples and potential collinearity.

The estimates only refer to adjusted associations in the surveyed households. The study fails to determine causal impacts of quarry mining, selection-corrected income differences or general livelihood impacts of quarry mining.

6.2 Recommendations

Firstly, there is a need for further surveys of quarries to clearly specify the income recall period, and to document gross income, operating costs, labour input and net income separately. It is also important to ask the respondents if it was a typical or an exceptional period.

Second, exposure and access measures should be developed at the village level to help explain some of the differences in villages, such as distance to quarry sites, transport access, local labour demand, market arrangements and regulatory conditions, that are measured in the future.

Third, policy responses need to take account of the heterogeneity of households. There is a need for an education and farming-experience association to be used to instruct, rather than against or for, participation in a quarry, without evidence of alternatives to employment and of labour allocation.

Finally, association membership should be analysed in terms of organisation type, purpose of the organisation, who selects those who are associated with the organisation, the services provided, and the relevance of the quarry. The nonsignificant income coefficient should not be used as a reason for not encouraging collective action.

7.0 AUTHOR DECLARATIONS

7.1 Consent for Publication

The manuscript does not reproduce identifiable individual information.

7.2 Funding

No specific funding supported this study.

7.3 Competing Interests

The author declares no competing interests.

7.4 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.

7.5 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.

7.6 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 are entered 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

References

1. Achandi, E. L., & Mujawamariya, G. (2016). Market participation by smallholder rice farmers in Tanzania: A double hurdle analysis. Studies in Agricultural Economics, 118(2), 112–115. https://doi.org/10.7896/j.1528
2. Asante, F., Abass, K., & Afriyie, K. (2014). Stone quarrying and livelihood transformation in peri-urban Kumasi. Research on Humanities and Social Sciences, 4(13), 93–107. https://www.iiste.org/Journals/index.php/RHSS/article/view/13642
3. Belotti, F., Deb, P., Manning, W. G., & Norton, E. C. (2015). Two-part models. The Stata Journal, 15(1), 3–20. https://doi.org/10.1177/1536867X1501500102
4. Burke, W. J. (2009). Fitting and interpreting Cragg's Tobit alternative using Stata. The Stata Journal, 9(4), 584–592. https://doi.org/10.1177/1536867X0900900405
5. Cragg, J. G. (1971). Some statistical models for limited dependent variables with application to the demand for durable goods. Econometrica, 39(5), 829–844. https://doi.org/10.2307/1909582
6. Fisher, E., Mwaipopo, R., Mutagwaba, W., Nyange, D., & Yaron, G. (2009). "The ladder that sends us to wealth": Artisanal mining and poverty reduction in Tanzania. Resources Policy, 34(1–2), 32–38. https://doi.org/10.1016/j.resourpol.2008.07.001
7. Geenen, S., Stoop, N., & Verpoorten, M. (2021). How much do artisanal miners earn? An inquiry among Congolese gold miners. Resources Policy, 70, Article 101893. https://doi.org/10.1016/j.resourpol.2020.101893
8. Hilson, G., & Garforth, C. (2012). 'Agricultural poverty' and the expansion of artisanal mining in sub-Saharan Africa: Experiences from southwest Mali and southeast Ghana. Population Research and Policy Review, 31(3), 435–464. https://doi.org/10.1007/s11113-012-9229-6
9. Hoque, M. J., & Aktar, H. (2022). Environmental and social effects of stone quarrying in Bangladesh: A study in the Khasi people area in Sylhet. Space and Culture, India, 10(2), 28–41. https://doi.org/10.20896/saci.v10i2.1279
10. Kitole, F. A., Kalumanga, V. E., Hyera, D. W., & Evason, E. M. (2025). Risks, challenges and socioeconomic impacts of quarrying on rural livelihoods in Tanzania. Cogent Social Sciences, 11(1), Article 2489040. https://doi.org/10.1080/23311886.2025.2489040
11. Leung, S. F., & Yu, S. (1996). On the choice between sample selection and two-part models. Journal of Econometrics, 72(1–2), 197–229. https://doi.org/10.1016/0304-4076(94)01720-4
12. Madden, D. (2008). Sample selection versus two-part models revisited: The case of female smoking and drinking. Journal of Health Economics, 27(2), 300–307. https://doi.org/10.1016/j.jhealeco.2007.07.001
13. Mvomero District Council. (2024). Environmental and social management plan for rural certification process in Mvomero District Council. Ministry of Lands, Housing and Human Settlements Development. https://www.lands.go.tz/uploads/documents/sw-1719613604-MVOMERO%20ESMP_final%20for%20submision.pdf
14. National Bureau of Statistics. (2022). 2022 population and housing census: Administrative units population distribution report. United Republic of Tanzania. https://sensa.nbs.go.tz/publication/Morogoro.pdf
15. Verbrugge, B., & Besmanos, B. (2016). Formalizing artisanal and small-scale mining: Whither the workforce? Resources Policy, 47, 134–141. https://doi.org/10.1016/j.resourpol.2016.01.008