



Quarry-Mining Participation and Household Consumption in Mvomero District, Tanzania: An AIPW-Adjusted Cross-Sectional Comparison

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Abstract: Quarrying can contribute to rural cash income, but participation is self-selected and expenditure comparisons do not measure all livelihood costs. This study examined the association between directly reported quarry participation and household consumption using the June 2026 survey in Kinyenze and Lugono villages, Mvomero District, Tanzania. Of 142 household records, 137 contained direct participation responses; the primary analytic sample comprised 86 participants and 50 nonparticipants with observed food expenditure. Reported expenditure components were aggregated and divided by household size; blank non-food components were coded as zero. Augmented inverse-probability weighting (AIPW) combined participation and outcome models adjusting for age, sex, marital status, education, household size, birthplace and village. The adjusted consumption difference was TZS 11,243 per person per month (95% percentile bootstrap confidence interval: TZS 549–20,764; normal-approximation $p = 0.022$). The food-expenditure estimate was positive, whereas log consumption and the asset/access index were imprecise. Sensitivity point estimates remained positive, but the nonlinear specification's percentile interval included zero. Residual covariate imbalance, a weighted control effective sample size of 30.3, uncertain expenditure reporting and limited bootstrap replications qualify the findings. AIPW does not establish temporal order or eliminate unmeasured confounding. The results are adjusted cross-sectional associations, not causal effects or evidence of comprehensive welfare improvement. Longitudinal research with documented sampling, complete expenditure measurement and direct assessment of occupational and environmental costs is needed.

Keywords: Quarry mining, household consumption, rural livelihoods, augmented inverse-probability weighting, Mvomero District, Tanzania.

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1.0 INTRODUCTION

Extractive activities occupy an ambiguous position in rural livelihoods. They can generate cash income and employment where agriculture is seasonal or paid work is scarce, while exposing workers and communities to occupational hazards, environmental damage and unstable returns. Household consumption expenditure provides one indicator of material living standards, but spending alone does not capture health, ecological losses, income security or long-term resilience.

Evidence from sub-Saharan Africa identifies mining as both an economic opportunity and a response to agricultural constraints. Hilson and Garforth (2012) linked entry into extraction to agricultural poverty, while Fisher et al. (2009) documented poverty-reduction opportunities alongside insecurity in Tanzania. Regional evidence also shows that food-security outcomes vary across mining arrangements and population groups (Wegenast & Beck, 2020). These findings motivate a clearly defined household comparison rather than an assumed livelihood benefit.

Recent Mvomero research documents quarry-related economic opportunities alongside health, safety and environmental challenges (Kitole et al., 2025). The gap addressed here concerns Kinyenze and Lugono: whether direct participation is associated with a specified consumption measure after adjustment for observed household characteristics. Using the June 2026 survey, this study compares participants and nonparticipants with AIPW. Because participation was not randomised and all measures were observed cross-sectionally, the analysis estimates adjusted associations rather than causal or net-welfare effects.

1.1 Empirical Literature Review, Research Gap, and Conceptual Framework

1.1.1 Empirical Evidence from Tanzania

Fisher et al. (2009) examined artisanal gold and diamond mining in Tanzania's Mwanza Region. Mining and related-service workers were less likely to be poor than people in other occupations, and mining income could buffer livelihood shocks. Nevertheless, difficulties accessing or exploiting mineral claims and the marginal position of small-scale mining in planning contributed to insecurity. The study establishes the livelihood relevance of extraction, but its commodity and institutional setting differs from construction-stone quarrying and does not directly establish the participation–consumption relationship in Kinyenze and Lugono.

Kitole et al. (2025) studied quarrying among 300 households in Mzumbe, Mlali and Melela villages in Mvomero District. Economic opportunities coexisted with health and environmental challenges. This is important prior evidence

from the same district, but village coverage and outcomes differ from the present study. The current analysis complements that work through a direct participation comparison, an explicit consumption aggregate and reporting of balance, overlap and missingness.

Together, these Tanzanian studies distinguish livelihood opportunities from secure material well-being (Fisher et al., 2009; Kitole et al., 2025). They motivate studying consumption alongside the occupational, environmental and institutional conditions that spending does not measure.

1.1.2 Empirical Evidence from Sub-Saharan Africa

Asante et al. (2014) used questionnaires and in-depth interviews with 110 respondents in quarrying communities near Kumasi, Ghana. They reported limited socioeconomic improvement and unsatisfactory environmental outcomes despite quarrying's economic prominence. Their community-level findings caution against equating sector employment with shared welfare gains, but are not directly comparable to an adjusted household expenditure contrast.

Hilson and Garforth (2012) linked artisanal-mining expansion in Mali and Ghana to agricultural poverty. Households may enter extraction because of agricultural distress or limited alternatives. Consequently, participants and nonparticipants can differ before entry, and an unadjusted consumption contrast may reflect selection as well as quarry-related income. The present survey does not directly measure those prior livelihood trajectories.

Wegenast and Beck (2020) combined regional survey and mine-control information to examine food security in sub-Saharan Africa. Associations varied by gender and ownership, with adverse food-availability and dietary-diversity outcomes in some settings. Geographical mining exposure differs from direct household participation, and food availability or dietary diversity is not equivalent to food expenditure.

The regional evidence highlights selection into extraction, unequal community gains and outcome heterogeneity (Asante et al., 2014; Hilson & Garforth, 2012; Wegenast & Beck, 2020). These mechanisms motivate explicit exposure and expenditure definitions; they do not establish a common effect across commodities, countries or households.

1.1.3 International Empirical Evidence: Studies Beyond Africa

Hoque and Aktar (2022) examined stone quarrying in Jafong, Bangladesh, through qualitative interviews and observations. They described environmental degradation, land dispossession and disruption of traditional Khasi livelihoods alongside quarry-related employment. Their evidence identifies costs that a consumption aggregate may

miss, rather than an adjusted expenditure effect comparable to the present analysis.

Aragón and Rud (2013) used annual household data from 1997–2006 to examine the Yanacocha gold mine in Peru. Local input demand supported income gains beyond direct mining employment, while prices of nontradable goods also increased. This illustrates possible market spillovers: households that do not participate directly can still experience mining-related employment, trade and price changes. Nonparticipants in the present study are therefore a comparison group for direct participation, not a demonstrably unexposed group.

These selected international comparisons show why consumption should be interpreted alongside livelihood costs and local market conditions (Hoque & Aktar, 2022; Aragón & Rud, 2013). Neither directly establishes the magnitude or direction of the quarry-participation association in the surveyed Tanzanian villages.

1.1.4 Synthesis, Research Gap, and Contribution of the Present Study

The reviewed literature documents economic opportunities, selection pressures and occupational, social and environmental costs. It also uses distinct outcomes: poverty, food security, community transformation and local income. The present contribution lies at the intersection of village coverage, consumption measurement and an adjusted direct-participation comparison, not an absence of mining research.

First, the study adds evidence for construction-stone quarry households in Kinyenze and Lugono. Prior Mwanza and Mvomero research is informative but does not substitute for a comparison within these two villages (Fisher et al., 2009; Kitole et al., 2025). The contribution is local; it does not imply district-wide or national representativeness.

Second, the study specifies reported monthly per-capita household consumption as its primary outcome, distinguishing household expenditure from quarry income and production costs. Food expenditure, log consumption, essential expenditure and an asset/access index provide secondary indicators. Higher expenditure does not by itself establish improved nutrition, freedom from injury or long-term resilience, and the secondary measures require their own measurement and sample qualifications.

Third, AIPW combines a participation model and an outcome model to adjust the participant–nonparticipant comparison for measured demographic and location characteristics. Balance, overlap and sensitivity results make the comparison assessable, but do not eliminate unmeasured selection, establish covariate timing or remove spillovers (Hilson & Garforth, 2012; Aragón & Rud, 2013).

Accordingly, this study provides a locally grounded, consumption-based comparison with transparent reporting of its assumptions and limitations. Baseline and follow-up observations, richer pre-participation covariates and direct measurement of external costs would be needed to identify livelihood transitions or total welfare effects.

1.1.5 Conceptual Framework and Identification Problem

The sustainable-livelihoods perspective treats household well-being as the outcome of assets, capabilities, activities, institutions, and vulnerability contexts rather than income alone (Scoones, 2015). Within this framework, quarry work can add a nonfarm earnings stream, finance food and basic services, and facilitate asset accumulation. It may be especially attractive when crop income is uncertain, market access is weak, or paid employment is scarce. Tanzanian evidence on artisanal mining has long linked extraction to aspirations for upward mobility and poverty reduction (Fisher et al., 2009). Comparable evidence from Africa also links mining expansion to persistent agricultural constraints and livelihood diversification (Hilson & Garforth, 2012).

Livelihood gains need not be universal. Quarry workers may face injuries, dust exposure, fluctuating prices, taxes and fees, transport costs, and limited access to credit. Communities may experience land degradation, open pits, biodiversity loss, or competition between quarrying and farming. Kitole et al. (2025) identify the coexistence of socioeconomic opportunity and environmental, health, and physical safety risks in rural Tanzanian quarrying. Moreover, broader evidence from mining indicates that aggregate extraction activity can coexist with food insecurity or limited welfare spillovers (Wegenast & Beck, 2020). These mechanisms imply heterogeneous returns across employment roles, villages, household assets, and alternative livelihood options.

Quarry participation may influence household spending through income, employment and market linkages, while hazards, production costs and time displaced from farming may constrain livelihoods. Age, education, family responsibilities, place attachment and village opportunities may also relate to both participation and consumption. The empirical strategy adjusts for observed demographic and location characteristics, but their measurement before participation was not established for every covariate. Unmeasured prior wealth, health, skills, networks and livelihood trajectories remain potential explanations for observed differences.

1.2 Study Objective, Research Questions, and Hypotheses

The study aimed to examine the association between directly reported quarry participation and household consumption in Kinyenze and Lugono. AIPW estimates a

participant-standardised adjusted contrast under the assumptions specified below. Because the design is cross-sectional and participation nonrandom, the estimate is not treated as a confirmed causal effect.

Research Question 1: How do the observed characteristics and livelihood outcomes of quarry participants compare with those of nonparticipants?

Research Question 2: What is the adjusted difference in monthly per-capita household consumption between quarry participants and nonparticipants after accounting for measured household characteristics?

Research Question 3: How sensitive are the estimates to alternative exposure definitions, model specifications, samples and livelihood indicators?

The primary two-sided null hypothesis was that the adjusted participation–consumption contrast equalled zero. Secondary analyses concerned food expenditure, essential expenditure, log consumption and an asset/access index. These secondary comparisons are treated as exploratory rather than independent confirmations of a general welfare effect.

2.0 MATERIALS AND METHODS

2.1 Study Design, Setting, and Sampling

The study used a cross-sectional household survey conducted in June 2026 in Kinyenze and Lugono villages, Mvomero District, Morogoro Region, Tanzania. The questionnaire was piloted before the main survey. PMO-RALG granted permission for data collection, and authorisation was presented to relevant local authorities. Questionnaires and responses were translated between English and Kiswahili. Village labels were normalised by removing leading and trailing spaces before analysis. Respondents were described as randomly selected villagers, but the available documentation does not specify village selection, household eligibility, the sampling frame, selection probabilities or the randomisation procedure. It also does not establish whether all respondents were household heads. These omissions limit assessment of representativeness and how household-head characteristics were reported.

2.2 Participants and Consent

All 142 respondents were recorded as consenting to proceed. This does not establish the response rate among all households approached: numbers eligible, contacted, refusing or unavailable were not reported. The available documentation does not specify whether consent was oral or written or describe participant information and confidentiality procedures. PMO-RALG and local-authority permissions are reported, but institutional ethics review, waiver or exemption and its basis are not documented;

administrative permissions should not be equated with ethics approval. Of the 142 records, 137 contained a direct participation response: 87 participants and 50 nonparticipants. Five missing responses were excluded from comparison analyses. Response codes were unique, and no exact duplicate response records were identified.

2.3 Measures

2.3.1 Quarry-Mining Participation

The direct item “Do you participate in quarry mining activities in your area?” defined the exposure: Yes = 1 and No = 0. Five missing responses were not forced into either category. The wording addresses the respondent; the records are analysed at household level, but the documentation does not establish whether participation included every household member. Seven respondents reporting nonparticipation selected a quarry-income source or reported a positive quarry-income amount. These exposure–income inconsistencies were retained under the primary direct-response definition and examined through exclusion and alternative classification. Indirect income, another member’s work, recall-period differences or response error are possible explanations, not verified corrections.

2.3.2 Livelihood Outcomes

The primary outcome was reported household consumption expenditure per person, operationalised as monthly Tanzanian shillings. It summed food, drinks, clothing, water, electricity, cooking energy, transport, health services, school fees, assistance to others and social or ceremonial expenditure, then divided by household size. Farm preparation and quarry operating expenses were excluded as production inputs. Because assistance to others may represent transfers, the aggregate is an operational expenditure measure rather than a comprehensive or independently validated consumption standard. Food expenditure was required to be observed. Blank entries in other components were coded as zero, yielding 136 records: 86 participants and 50 nonparticipants. Available documentation does not distinguish all blanks from nonresponse, describe component-specific recall periods or conversion of irregular expenses, or establish inclusion of own-produced and in-kind consumption. These measurement limitations qualify the monthly aggregate.

Secondary outcomes were the natural logarithm of monthly per-capita consumption, per-capita food expenditure, essential expenditure comprising food, water, electricity, cooking energy and transport, and a reported six-item asset/access index with range 0–6. The primary, log-consumption and food analyses used 136 records; the asset/access index used 137 direct responses. The reported essential-expenditure and broader non-quarry expenditure analyses also used 137 records, despite the food-observation

requirement. Their missingness rules cannot be reconciled from the supplied aggregate results. These estimates are retained as provisional secondary results, explicitly marked in Tables 3 and 4, pending verification of their sample construction. The six index components, weighting and item-level missingness rules were not specified, so the score is interpreted as a reported summary indicator, not a validated multidimensional livelihood measure.

2.3.3 Covariates

The adjustment set comprised household-head age, sex, marital status, years of formal education, household size, birthplace and village. These variables were complete in the survey records. They were selected as plausible correlates of both participation and consumption, but their pre-participation status was not established for every variable. Licences, quarry experience, taxes, current credit and asset-acquisition sources were not used as baseline confounders because their timing was uncertain and they could be consequences of participation. This restriction does not demonstrate that the chosen set removes all confounding.

2.4 Econometric Strategy

The comparison was targeted to participants rather than the full population, corresponding to the conventional average treatment effect on the treated (ATT) estimand under causal identification assumptions. Here, it is interpreted as a participant-standardised adjusted cross-sectional association. AIPW combined a logistic participation-probability model with a linear outcome model fitted among nonparticipants. Both models used age, sex, marital status, education, household size, birthplace and village. AIPW combines outcome predictions with an inverse-probability augmentation; its double-robustness property requires the relevant identification and regularity conditions and correct specification of at least one nuisance model (Glynn & Quinn, 2010). It does not protect against unmeasured confounding, exposure or outcome mismeasurement, or misspecification of both models.

Nonparticipants received odds weights $e(X)/(1 - e(X))$, where $e(X)$ denotes the estimated probability of participation; participants retained weight 1. Balance was assessed using reported standardised mean differences (SMDs), and overlap using propensity-score ranges, extreme-score counts, maximum control weight and weighted effective sample size (Austin, 2011). Detailed code for the ATT-targeted augmentation, weight normalisation and SMD standardisation was not included in the available materials. The reported estimates are therefore retained rather than reconstructed from aggregate tables.

Main and secondary uncertainty estimates used 200 nonparametric bootstrap replicates stratified by village and participation status. Reported intervals are 95% percentile

intervals, whereas p-values use a normal approximation based on bootstrap standard errors. Sensitivity analyses used 100 similarly stratified replicates. A fixed seed was reported, but its value, replicate failures and whether both nuisance models were refitted in every draw were not specified. Percentile intervals and normal-approximation tests need not give identical decisions near zero. The limited replication counts also make interval endpoints and differences across resampling runs uncertain.

2.5 Identification Assumptions

A causal interpretation would require conditional exchangeability, sufficient positivity for participants, treatment consistency, no interference, reliable measurement and a temporally coherent exposure–outcome relationship. Unmeasured prior wealth, health, land quality, skills, networks, risk tolerance and market access may influence both participation and consumption. Nonparticipants may experience quarry-related market, price or environmental spillovers. Cross-sectional data do not establish whether participation preceded consumption or all adjustment characteristics. Accordingly, the analysis is presented as an adjusted association, not a definitive impact estimate.

2.6 Data Quality, Missingness, and Sensitivity Analysis

One participant with a direct response lacked food expenditure and was excluded from the primary analysis. The required food amount was not imputed; observed covariates were complete. The blank-to-zero rule for non-food items remains an untested assumption because component-level missingness counts and alternative-construction analyses were not supplied. Reported sensitivity checks excluded the seven exposure–income inconsistencies, treated them as participants under a composite definition, introduced nonlinear covariate terms, applied a [0.05, 0.95] score restriction, winsorised consumption at pooled 1st/99th percentiles and used a broader expenditure outcome. Exact nonlinear terms, treatment of quantile thresholds during resampling and the broader outcome's full component rules were not documented. Exposure and outcome alternatives can change the estimand; they are not equivalent replications of a single causal contrast.

2.7 Software and Reproducibility

SPSS was named as the analytical software in the survey description. The software and version used specifically for AIPW, weighting, bootstrap resampling and sensitivity estimation were not separately documented. Model syntax, package versions and complete diagnostic output were not supplied with the manuscript. The reported estimates are preserved in this revision, with unresolved sample and inferential inconsistencies disclosed rather than resolved by assumption.

3.0 RESULTS

3.1 Sample Characteristics

Participants and nonparticipants differed before adjustment. In the primary 136-record sample, participant mean age was 39.8 years and mean education 4.9 years, compared with 42.6 and 6.1 among nonparticipants. Female-headed households represented 32.6% of participants in that sample and 50.0% of nonparticipants. Reported per-capita

consumption averaged TZS 41,687 among participants and TZS 31,171 among nonparticipants. In the 137-record direct-response sample, participation was reported by 39 of 67 respondents in Kinyenze and 48 of 70 in Lugono. Table 1 retains the direct-response descriptive statistics, distinguishing the consumption row's smaller sample; the female participant percentage there is 33.3% rather than 32.6% because the participant denominator is 87 rather than 86.

Table 1: Reported Household Characteristics by Direct Quarry-Participation Response

Characteristic	Overall (N = 137)*	Participants (N = 87)*	Nonparticipants (N = 50)
Age of household head, years	40.9	39.8 (11.7)	42.6 (14.2)
Female household head, %	39.4%	33.3%	50.0%
Married household head, %	66.4%	63.2%	72.0%
Formal education, years	5.3	4.9 (4.3)	6.1 (4.8)
Household size	3.45	3.31 (1.59)	3.68 (1.60)
Born in village, %	61.3%	56.3%	70.0%
Monthly per-capita consumption, TZS	37,821 (35,016)	41,687 (41,212)	31,171 (18,987)
Asset/access index (0–6)	2.19	2.26 (0.88)	2.06 (1.08)
Kinyenze, n (%)	67 (48.9%)	39 (44.8%)	28 (56.0%)
Lugono, n (%)	70 (51.1%)	48 (55.2%)	22 (44.0%)

Note. Demographic, village and asset/access statistics refer to the 137 direct-response records (87 participants, 50 nonparticipants); consumption uses 136 records (86, 50). Values are means, with SDs in parentheses where available; SDs not reported in the source are not reconstructed. Village percentages use the relevant direct-response group denominator. The index is a reported six-item summary; its components and coding require verification. * The consumption row has N = 136 overall and N = 86 participants.

3.2 Propensity-Score Overlap and Covariate Balance

In the primary sample, propensity scores ranged from 0.281–0.896 among participants and 0.289–0.883 among nonparticipants. None fell outside [0.05, 0.95]. These ranges indicate substantial overlap but do not demonstrate support for every participant, particularly at the extrema. The maximum control odds weight was 7.51 and the weighted

control effective sample size was 30.3, compared with 50 observed controls. Weighting reduced the largest absolute SMD from 0.357 to 0.256 and improved most covariates. However, marital-status imbalance increased in absolute magnitude from 0.172 to 0.256. Balance was therefore not uniformly improved, and residual observed differences remain relevant to model dependence and inference (Table 2).

Table 2: Covariate Balance Before and After Participant-Targeted Odds Weighting

Covariate	Participants	Nonparticipants, raw	SMD, raw	Nonparticipants, weighted	SMD, weighted
Age (10-year units)	3.981	4.262	-0.215	3.907	0.060
Female head	0.326	0.500	-0.357	0.298	0.060
Married head	0.640	0.720	-0.172	0.756	-0.256
Education (years)	4.907	6.080	-0.256	4.632	0.061
Household size	3.302	3.680	-0.237	3.338	-0.024
Born in village	0.570	0.700	-0.271	0.558	0.024
Lugono indicator	0.547	0.440	0.213	0.592	-0.091

Note. N = 136: 86 participants and 50 nonparticipants. Control weights are $e(X)/(1 - e(X))$; participant weights are 1. SMD = standardised mean difference; signs indicate the reported participant-minus-control direction. The standardising denominator was not specified in the available analysis documentation. Female, married, born-in-village and Lugono are binary indicators; comparison categories are male, not married, not born in the village and Kinyenze, respectively. Age is in 10-year units.

3.3 Main and Secondary Estimates

The reported unadjusted per-capita consumption contrast was TZS 10,517, and the AIPW-adjusted contrast was TZS 11,243 per person per month (bootstrap SE = 4,912; 95% percentile CI: 549–20,764; normal-approximation $p = 0.022$). The positive estimate is an adjusted association within the surveyed sample, not a causal effect. Rounded group means differ by TZS 10,516; the reported contrast of 10,517 is retained because the underlying unrounded output was not supplied.

The food-expenditure association was TZS 8,898 per person per month (95% CI: 2,199–15,147; $p = 0.012$). Log consumption was imprecise (0.126 log points; 95% CI: -0.131–0.364; $p = 0.343$), as was the asset/access index (0.380 points; 95% CI: -0.089–0.888; $p = 0.142$). The reported essential-expenditure estimate was TZS 9,781 (95% CI: 2,210–17,367; $p = 0.018$), but its N = 137 conflicts with the stated food-observation rule and is provisional pending sample verification. Food and essential expenditure overlap with the primary aggregate; these exploratory comparisons are not independent confirmations of broad livelihood improvement.

Table 3: Reported Participant–Nonparticipant Associations in Consumption and Secondary Indicators

Outcome	N	Raw	OR	IPW	AIPW ATT	95% CI	p
Monthly per-capita household consumption (TZS)	136	10,517	11,585	11,919	11,243	[549, 20,764]	0.022
Log monthly per-capita household consumption	136	0.097	0.140	0.132	0.126	[-0.131, 0.364]	0.343
Monthly per-capita food expenditure (TZS)	136	7,691	9,255	8,690	8,898	[2,199, 15,147]	0.012
Monthly per-capita essential expenditure (TZS) †	137 †	8,642	10,148	10,001	9,781	[2,210, 17,367]	0.018
Asset/access index (0–6)	137	0.204	0.355	0.394	0.380	[-0.089, 0.888]	0.142

Note. Raw = unadjusted difference; OR = outcome regression, not odds ratio; IPW = inverse-probability weighting; AIPW = augmented inverse-probability weighting. ATT denotes the conventional average treatment effect on the treated target, interpreted here as an adjusted cross-sectional contrast. The displayed CI and p-value refer only to the AIPW estimate: 200 stratified replicates, percentile CI and normal-approximation p-value. Monetary units are TZS per person per month; log and index rows retain their labelled units. † Essential-expenditure N and missingness rules are unresolved: food was required for the primary sample but this outcome was reported for 137 records. Its results are reproduced provisionally, not corrected or re-estimated.

3.4 Robustness and Sensitivity

All reported sensitivity point estimates were positive (Table 4). Excluding exposure–income inconsistencies gave TZS 11,791; composite exposure classification gave TZS 11,052; nonlinear adjustment gave TZS 10,715; and winsorisation gave TZS 10,348. The nonlinear specification’s percentile interval included zero (−114–20,962), although its normal-approximation p-value was 0.045. The different inferential

methods need not agree, so the checks do not uniformly exclude no association. Score restriction removed no original observations and left the point estimate unchanged at TZS 11,243; differing uncertainty summaries are not evidence of robustness to an actual change in support. The broader expenditure estimate of TZS 15,109 uses an unresolved 137-record construction and is treated as provisional.

Table 4: Sensitivity Analyses for Monthly Per-Capita Expenditure

Specification	N	Adjusted contrast	SE	95% CI	p
Main: direct participation; demographic/village covariates	136	11,243	4,912	[549, 20,764]	0.022
Exclude 7 treatment–income conflicts	129	11,791	5,288	[3,397, 23,373]	0.026
Composite exposure: direct yes or conflict	136	11,052	4,465	[3,749, 18,877]	0.013
Extended nonlinear covariates	136	10,715	5,342	[−114, 20,962]	0.045
Score restriction to [0.05, 0.95]; no original observations excluded	136	11,243	4,644	[2,500, 18,844]	0.015
Consumption winsorised at pooled 1st/99th percentiles	136	10,348	4,573	[2,281, 18,561]	0.024
Alternative broad non-quarry expenditure outcome †	137 †	15,109	6,122	[3,839, 27,623]	0.014

Note. Monetary units are TZS per person per month; estimates are adjusted associations. The main row reproduces the 200-replicate result; sensitivity rows use 100 stratified replicates with percentile CIs and normal-approximation p-values. The restricted-score point estimate uses the same original sample as the main row. Different bootstrap SEs and intervals may reflect resampling variation or implementation differences that cannot be verified from aggregate output. † The broader outcome’s component and missingness rules and N = 137 require verification; the estimate is provisionally retained.

4.0 DISCUSSION

Direct quarry participants reported higher consumption than nonparticipants, and the participant-targeted AIPW contrast remained positive. This finding supplies a local association, not evidence that quarrying caused higher spending. Pre-existing resources may enable participation, participation may support expenditure, or unmeasured characteristics may influence both. Blank-to-zero coding and uncertain recall periods may also affect the observed difference.

The consumption association is compatible with the livelihood opportunities reported by Fisher et al. (2009) and the coexistence of opportunities and risks in Kitole et al. (2025). It does not contradict evidence of insecurity: higher spending can coexist with injury, unstable income or environmental losses. Different commodities, villages and outcomes preclude direct comparison of effect magnitudes.

Higher observed spending among participants may coexist with uneven community outcomes, as suggested by

Ghanaian quarrying evidence (Asante et al., 2014). Agricultural constraints may influence selection into extraction (Hilson & Garforth, 2012). Food-spending associations cannot be equated with food availability, dietary quality or within-household distribution (Wegenast & Beck, 2020), and spending may respond to local prices rather than real consumption gains.

International evidence highlights livelihood losses not fully captured by consumption expenditure (Hoque & Aktar, 2022) and economic spillovers extending beyond mining participants (Aragón & Rud, 2013). Participants and nonparticipants in the present villages may share market, price and environmental exposure. The contrast therefore does not estimate the total welfare effect of the quarry sector.

The diagnostics constrain interpretation. Although most covariates moved closer to balance, marital-status imbalance increased and the weighted control effective sample size was only 30.3. Outcome augmentation may reduce bias

from residual observed differences under a suitable outcome model, but neither adequate adjustment nor stable inference is established by weighting alone. Uncertainty about model implementation and limited bootstrap replications are particularly important when an interval lies close to zero.

Secondary outcomes do not show a uniform livelihood improvement. The food-expenditure estimate was positive, but log consumption and the asset/access index were imprecise; essential expenditure additionally has an unresolved analytic-sample inconsistency. Positive point estimates across overlapping outcomes and alternative definitions do not constitute independent evidence of a general welfare gain. Repeated observations with complete expenditure, price, cost and work-exposure information would provide stronger evidence about livelihood transitions.

The contribution is a consumption-based, adjusted direct-participation comparison in Kinyenze and Lugono, with explicit identification and measurement qualifications. It does not settle causal effects, long-term sustainability or comprehensive household welfare.

5.0 POLICY IMPLICATIONS

The findings do not establish that expanding quarry participation or providing financial support would improve welfare. Nevertheless, the cited livelihood literature supports considering occupational safety, transparent regulation, environmental rehabilitation and viable non-quarry alternatives alongside income opportunities (Fisher et al., 2009; Kitole et al., 2025; Hoque & Aktar, 2022). Market and environmental spillovers make both participants and nonparticipants relevant to community-level planning (Aragón & Rud, 2013). These are policy considerations informed by prior evidence, not interventions evaluated by this survey. Future programmes should document baseline conditions and follow households over time to assess consumption, work hazards, production costs and environmental exposure.

6.0 CONCLUSION

In Kinyenze and Lugono, directly reported quarry participation was associated with higher reported monthly per-capita household consumption after adjustment for measured demographic and location characteristics. The primary AIPW contrast was TZS 11,243 per person per month (95% percentile bootstrap CI: 549–20,764). Residual imbalance, uncertain expenditure reporting, limited comparison information and temporally ambiguous covariates qualify this estimate. Secondary and sensitivity analyses do not establish uniform improvement across livelihood dimensions, and some outcome constructions require verification. The study contributes a local adjusted comparison, not a causal or net-welfare estimate. Larger

longitudinal studies with complete outcome measurement and documented sampling are required to assess livelihood transitions and long-term sustainability.

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

Household-level survey data contain potentially sensitive information and are not included in the manuscript. Access or de-identified release is subject to data-custodian permissions and applicable ethical requirements. The present revision uses the reported manuscript results; household microdata, questionnaire schedules and analysis code were not available for independent verification. Appendix A summarises the sample construction and outstanding reproducibility details without disclosing individual records.

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 as reported in the source manuscript. The present revision used AI assistance for manuscript editing and consistency review; the statistical analyses were not rerun. The author remains responsible for verifying the study documentation, results and final text.

REFERENCES

1. Aragón, F. M., & Rud, J. P. (2013). Natural resources and local communities: Evidence from a Peruvian gold mine. *American Economic Journal: Economic Policy*, 5(2), 1–25. <https://doi.org/10.1257/pol.5.2.1>
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. Austin, P. C. (2011). An introduction to propensity score methods for reducing the effects of confounding in observational studies. *Multivariate Behavioral Research*, 46(3), 399–424. <https://doi.org/10.1080/00273171.2011.568786>
4. 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>
5. Glynn, A. N., & Quinn, K. M. (2010). An introduction to augmented inverse propensity weighted estimators. *Political Analysis*, 18(1), 36–56. <https://doi.org/10.1093/pan/mpp036>
6. 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>
7. 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>
8. 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>
9. Scoones, I. (2015). *Sustainable livelihoods and rural development*. Practical Action Publishing.
10. Wegenast, T., & Beck, J. (2020). Mining, rural livelihoods and food security: A disaggregated analysis of sub-Saharan Africa. *World Development*, 130, Article 104921. <https://doi.org/10.1016/j.worlddev.2020.104921>