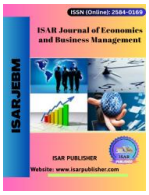
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Quarry-Mining Participation and Household Consumption in Mvomero District, Tanzania: An AIPW-Adjusted Cross-Sectional Comparison

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1.0 Abstract: This study examined the relationship between quarry involvement and household consumption in Kinyenze and Lugono villages, Mvomero District, Tanzania, in the survey of June 2026. There were 142 household records, and 137 of these had direct participation responses, with 86 of the households having observed food expenditure and 50 not observed. Blank non-food components were assigned a value of zero, and expenditure components were aggregated and divided by the size of the household. Augmented inverse-probability weighting (AIPW) was a variant of participation and outcome models that were adjusted 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, and normal approximation p = 0.022). The estimated value of food expenditure was positive, while the estimates of log consumption and the asset/access index were imprecise. The sensitivity point estimates were not only positive, but the percentile interval for the nonlinear specification contained zero. The findings are qualified by residual covariate imbalance, an effective sample size of the controls weighted = 30.3 and uncertainty in reporting expenditures and a limited number of bootstrap replications. Temporal order and the exclusion of unmeasured confounding are not established by AIPW. The conclusion is based on adjusted cross-sectional relationships, rather than causal effects and/or evidence of full welfare improvement. There is a need for long-term studies with documented sampling, comprehensive expenditure calculation and direct evaluation of the costs of the occupation and environment.

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

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2.0 INTRODUCTION

Extractive activities occupy an in-between space of rural livelihoods. They can provide cash income and livelihood opportunities to people in seasonal agriculture or low-paying employment, and also pose risks to the health and safety of labourers and communities, and environmental pollution. Material living standards are measured in many ways, but one of those is household consumption expenditure. Household spending does not account for ecological losses, long-term resilience, income security or health.

From sub-Saharan Africa, evidence shows that in addition to being an economic opportunity, mining is also a solution to agricultural constraints. In Tanzania, Fisher et al. (2009) found links between entry into extraction and poverty reduction opportunities, whereas Hilson and Garforth (2012) found connections between agricultural poverty and entry into extraction. Food security results are also found to be different in various population groups and within different mining arrangements at the regional level (Wegenast & Beck, 2020). These results call for an explicit rather than an implicit comparison of livelihood benefits between households.

Mvomero has recently been documented in several studies that highlight the health, safety and environmental risks and opportunities that can stem from quarry operations (Kitole et al., 2025). The gap that is addressed here is Kinyenze and Lugono: existing research does not yet provide insights on the association between direct participation in the quarry and a specific measure of household consumption when controlling for observed household characteristics in these selected villages. This study compares survey respondents to nonrespondents in June 2026, using that survey and does not attempt to interpret any estimated effects as a causal effect. Since participation in the study was not randomised and all measures were taken at a single point in time, only adjusted associations (not causal or net-welfare effects) can be estimated.

2.1 Study Objective, Research Questions, and Hypotheses

The general objective of the study was to assess the link between direct participation in the quarries and consumption among households in the two villages of Kinyenze and Lugono. The estimates of AIPW are based on a participant-standardised adjusted contrast and the following assumptions. The design is cross-sectional; participation is not random–the estimate is not considered 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 main two-sided null hypothesis was that the adjusted participation–consumption contrast was equal to 0. Food expenditure, essential expenditure, log consumption and an asset/access index were the secondary analyses to be considered. These secondary comparisons are not considered stand-alone, independent tests of the general welfare effect but are rather looked upon as exploratory.

2.2 Empirical Literature Review, Research Gap, and Conceptual Framework

2.2.1 Empirical Evidence from Tanzania

Fisher et al. (2009) studied artisanal gold and diamond mining in the Mwanza Region of Tanzania. However, miners and service workers associated with mining were less likely to be poor than workers in other sectors and mining income may help to mitigate livelihood shocks. Despite this, insecurity was caused by the challenges of access to and exploitation of mineral claims and small-scale mining's poor status when it came to planning. This study does not directly establish the relationship between participation and consumption in Kinyenze and Lugono, as the livelihood relevance of extraction is not the same in both cases since the commodities and the institutional setting is different in the case of stone quarrying in construction and the case of extraction in the study.

Kitole et al. (2025) conducted a study of the activities involved in quarrying in the villages of Mzumbe, Mlali and Melela of Mvomero District with 300 households. Economic opportunities and health/environmental issues were all present. This is prior evidence that is important and comes from the same district, although there is a difference between the outcomes and the coverage of the villages in this prior evidence and the present study. The current analysis builds upon this work by comparing direct participation, reporting the balance and the overlap and missingness of consumption.

These Tanzanian studies work together to differentiate between livelihood opportunities and secure material wellbeing (Fisher et al., 2009; Kitole et al., 2025). They encourage learning about consumption as well as the occupational, environmental and institutional variables that the spending of money does not reflect.

2.2.2 Empirical Evidence from Sub-Saharan Africa

Asante et al. (2014) collected their data through questionnaires and in-depth interviews with 110 people in the quarrying communities in the vicinity of Kumasi, Ghana. Despite the economic significance of quarrying, they claimed that there was not much socioeconomic development and environmental conditions were not satisfactory. Their community-level results suggest that sector jobs do not necessarily create community welfare, but are not directly comparable to a 'tweaked' comparison of household expenditures.

Hilson and Garforth (2012) associated the increased artisanal mining with agricultural poverty in Mali and Ghana. Households can use up extraction due to agricultural difficulties or fewer choices. Thus, the consumption contrast between participants and nonparticipants may be different at the time of the decision to participate, and an unadjusted contrast may be due to selection as well as to income from the quarry. These previous livelihood paths are not directly measured in the present survey.

Wegenast and Beck (2020) analysed food security in sub-Saharan Africa based on data from regional surveys and mine control data. There was a difference in the associations by gender and ownership, and adverse associations in some settings for food-availability and dietary-diversity outcomes. Direct household involvement in mining is not the same as exposure by geographical location, and food availability or food/dietary diversity are not the same as food expenditure.

In the region, the evidence reveals that there is a form of selection into extraction, heterogeneity in outcomes for communities, and the fact that not all communities benefit equally (Asante et al., 2014; Hilson & Garforth, 2012; Wegenast & Beck, 2020). These mechanisms drive the definitions of exposure and expenditure to be explicit, but they do not create a common effect between commodities, countries or households.

2.2.3 International Empirical Evidence: Studies Beyond Africa

In the study, Hoque and Aktar (2022) conducted qualitative interviews and observations to study stone quarrying in Jaflong, Bangladesh. They reported on environmental degradation, loss of land and disruption to traditional Khasi livelihoods, in addition to jobs from the quarries. Their evidence doesn't measure an adjusted expenditure effect like in the present analysis, but rather the costs of the consumption aggregate that it may neglect.

Using data from annual household surveys from 1997 to 2006, Aragón and Rud (2013) have analysed the gold mine of Yanacocha in Peru. In addition to the direct income generated from mining, there were increases in local input demand that led to additional income gains, and prices for nontradable goods also rose. This provides an example of some of the possible market spillovers: households not directly involved in the mining industry can see the employment impact, as well as the changes in prices and trading. Those who did not participate in the present study are, thus, not a directly unexposed comparison group, but rather a group that may not have been very exposed.

The selected international comparisons demonstrate the need to consider consumption in conjunction with livelihood costs and local market conditions (Hoque & Aktar, 2022, Aragón & Rud, 2013). None directly measures the magnitude or direction of the association between the type of quarry and people's participation in the surveyed villages in Tanzania.

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

The literature reviewed includes information on economic opportunities, selection pressures and occupational, social and environmental costs. It also has unique outcomes – poverty, food security, community transformation and local income. This is not the end of the mining investigation, but rather the starting point for the present contribution, which is located at the intersection of the coverage of the villages and the measurement of consumption and an adjusted direct participation comparison.

This work provides evidence of the existence of construction-stone quarry households in Kinyenze and Lugono, first of all. The findings from prior research in the two villages above are informative, but do not replace a comparison between the two villages (Fisher et al., 2009; Kitole et al., 2025). It is a local contribution and is not a representative contribution for the district or the country.

Second, the study focuses on reported per-capita monthly household consumption, rather than on household expenditure, which means that it distinguishes between household expenditure and quarry income and production costs. Secondary indicators include: food expenditure, log consumption, essential expenditure and an asset/access index. Greater spending does not necessarily guarantee better nutrition, protection from injury or long-term fitness, and the secondary measures must each be measured and have their own qualification in terms of samples.

Third, AIPW uses a participation model and an outcome model to correct the participant–nonparticipant comparison by demographic and location characteristics measured. The comparison is evaluable and is unaffected by unmeasured selection, covariate timing and spillovers, but is affected by balance, overlap and sensitivity results (Hilson & Garforth, 2012; Aragón & Rud, 2013).

In light of this, the study has been designed to be locally based and with clear reporting of the assumptions and

limitations in this comparison. Pre-participation information on some of the richer covariates, coupled with the direct measurement of external costs, would be required to detect livelihood transitions and/or total welfare effects.

2.2.5 Conceptual Framework and Identification Problem

The sustainable-livelihoods approach considers well-being a result of assets, capabilities, activities, institutions and vulnerability contexts, not income (Scoones, 2015). In this context, quarry activities may provide an extra earning opportunity, educate families in the financial resources needed to cover their basic needs, and promote savings. It might be particularly appealing in situations of low-paid employment and/or low market access and/or a lack of certainty in crop returns. Tanzania has a long history of evidence that points to aspirations for upward mobility and poverty alleviation as being linked to artisanal mining activities (Fisher et al., 2009). Hilson and Garforth (2012) also find similar evidence from Africa that mining expansion is associated with ongoing agricultural constraints and diversification of livelihoods.

Livelihood improvements do not have to be achieved across all populations. There is a risk of injury to quarry workers, dust, varying prices, taxes and fees, transport costs, and lack of credit at the quarry. Land degradation, open pits, biodiversity loss or competition between quarrying and farming can be a problem in the communities. Kitole et al. (2025) recognise that the multiple dimensions of risk—including socioeconomic opportunity and environmental, health and physical risks—can occur at the same time in the case of quarrying in rural Tanzania. Furthermore, mining literature more generally suggests that mining can have no impact on food security or weak welfare effects. In addition, other evidence from mining suggests that mining can coexist with food insecurity or low welfare spillovers (Wegenast & Beck, 2020). These mechanisms suggest that there are differential returns between various employment outlets, villages, household assets and alternative livelihoods.

Involvement in the quarry can affect the household's spending through income, employment and market linkages, and hazards; production costs and time away from farming can affect livelihoods. Other factors may be related to both participation and consumption, such as age, education, and family responsibilities, as well as place attachment and opportunities in the village. The empirical approach corrects for observed demographic and location variables, but measurement that occurred prior to participation was not defined for all the variables. There are still other factors that could account for the differences observed, such as unmeasured prior wealth, health, skills, networks and livelihood trajectories.

Observed context and covariates	→	**Quarry participation**	→	**Potential mechanisms and costs**	→	**Household consumption**
Age; sex; marital status; education; household size; birthplace; village		T_i = 1 (Yes) T_i = 0 (No)		Income; employment; markets; assets; hazards; production costs; time displaced from farming		Y_i = monthly per-capita reported expenditure

Figure 1. Conceptual pathway linking household context, quarry participation and consumption.

3.0 MATERIALS AND METHODS

3.1 Study Design, Setting, and Sampling

This study employed a cross-sectional household survey conducted in June 2026 in two villages, namely Kinyenze and Lugono, of Mvomero District in Morogoro Region, Tanzania. The sampling unit was the household, and each record was data provided by a household respondent. A questionnaire was pre-tested prior to the main survey. Permission was granted for data collection by PMO-RALG and authorisations were given to relevant local authorities. Interpretation of questionnaires and responses was done from English to Kiswahili and vice versa. Leading and trailing spaces were removed from the village labels for analysis. Accessible village listings were used, and the household respondents were selected at random. The sample size achieved was based on access to the field and logistics.

3.2 Participants and Consent

Everyone consented to the process of all 142 household records sampled. A total of 137 of the 142 household records had a direct participation response (87 participants,

50 nonparticipants). There were five blanks on the responses that were omitted from comparison analyses. There were no exact duplicate household records, and response codes were unique.

3.3 Measures

3.3.1 Quarry-Mining Participation

The direct item "Do you do quarry mining activities in your neighbourhood?" was answered by the household respondent, and the exposure at the household level was defined as Yes = 1 and No = 0. There were five missing responses that did not have to be assigned to either of the categories. The analysis of the records is done at the household level, although the documentation indicates no information on participation being gathered for all members of a household. There were seven respondents who reported that they were not participating, who chose a quarry-income source, or who reported that they had a positive amount of quarry income. The primary direct-response definition was used to retain these exposure–income inconsistencies and to examine the relationships using exclusion and alternative classification of these inconsistencies. This is not necessarily a correction, but may be due to other income, another person's work, recall-period differences or response error.

3.3.2 Livelihood Outcomes

The main outcome was operationalised as reported household consumption expenditure per person (in Tanzanian shillings monthly). It included food and drink, clothing, water, electricity, cooking energy, transportation, health services, school fees, assistance to others and social or ceremonial expenses and then segmented the result based on the size of the household. Production input costs such as farm preparation costs and operating costs of quarries were disregarded. The total is an operational expenditure measure and not a complete or independently verified consumption standard, as providing assistance to others may be seen as transfers. It was necessary to have food expenditure observed. The other components were blank in 136 cases (86 participants and 50 nonparticipants). There are no distinctions made between all blanks and nonresponse; no description of the component-specific recall periods or conversion of irregular expenses; and no definition of own-produced and in-kind consumption. The monthly aggregate is limited by the measurements.

Secondary outcomes included the natural log of monthly per capita consumption, per capita food expenditure, essential expenditure (food, water, electricity, cooking energy and transport), and reported six-item asset/access index (range 0-6). A total of 136 records were used for the primary, log-consumption and food analyses, and 137 direct responses were used in the asset/access index. The food-observation requirement was not the only one that was not followed in the reported expenditure analyses of essential expenditures and other non-quarry expenditures. The missingness rules cannot be matched from the provided "Aggregate results". Estimates are categorised as provisional secondary estimates, are indicated in Tables 3 and 4, and are subject to verification of the construction of the sample. The six index components, the set of rules for missing items and the weighting were not defined; thus, the score is viewed as a summary indicator of livelihoods reported rather than a validated multidimensional measure of livelihoods.

3.3.3 Covariates

The set of adjustments included the age of the household head, sex, marital status, years of formal education, household size, birthplace and village. These variables were filled out on the survey record. They were chosen because they were reasonable indicators of participation and consumption, but not all of the variables were known to have been present before participation. The timing of licences, quarry experience, taxes and the sources of credit and acquisition of assets were unknown at baseline and were therefore not included as baseline confounders, as they might have been outcomes of participation in the study. This does not show that the selected set is purifying.

3.4 Econometric Strategy

The comparison was geared to participants, and thus followed the traditional average treatment effect on the treated (ATT) estimand when using causal identification assumptions. In this context, this is understood as an association that uses the cross-sections of participants as the adjustments. AIPW uses a logistic participation-probability model in conjunction with a linear outcome model for the nonparticipants. In both models, age, sex, marital status, education, household size, birthplace and village have been included. AIPW, which has a double-robustness property, requires at least one nuisance model to be correctly specified and the identification and regularity conditions of AIPW (Glynn & Quinn, 2010). It does not help to protect against unmeasured confounding, exposure or outcome mismeasurement, or misspecification of both models.

The participation model was: $\text{logit}\{e(X_i)\} = \log[e(X_i)/(1 - e(X_i))] = \alpha_0 + \alpha_1 \text{Age10}_i + \alpha_2 \text{Female}_i + \alpha_3 \text{Married}_i + \alpha_4 \text{Education}_i + \alpha_5 \text{HouseholdSize}_i + \alpha_6 \text{BornInVillage}_i + \alpha_7 \text{Lugono}_i$, where $e(X_i) = \Pr(T_i = 1 \mid X_i)$ and $T_i = 1$ for a household reporting quarry participation and 0 otherwise.

For those who do not participate, the expected value of Y_i, given $T_i = 0$ and X_i, is $E(Y_i \mid T_i = 0, X_i) = m_0(X_i) = \beta_0 + \beta_1 \text{Age10}_i + \beta_2 \text{Female}_i + \beta_3 \text{Married}_i + \beta_4 \text{Education}_i + \beta_6 \text{BornInVillage}_i + \beta_7 \text{Lugono}_i + \varepsilon_i$.

For the participant-targeted AIPW contrast, the estimator was: $\hat{\tau}_\text{ATT} = n_1^{-1} \Sigma_i[T_i\{Y_i - \hat{m}_0(X_i)\} - (1 - T_i)\{\hat{e}(X_i)/(1 -$

$\hat{e}(X_i))\}\{Y_i - \hat{m}_0(X_i)\}]$. As such, participants' weights were updated to weight 1, while the non-participants' weights were updated to odds weights $\hat{e}(X_i)/(1 - \hat{e}(X_i))$. The following variables were entered in 10-year intervals: age; years of education; household size (a count); and 1 for females, and 0 for the stated reference categories: not married, and Kinyenze for people born in another village.

Non-participants were given odds weights of $e(X)/(1 - e(X))$, where $e(X)$ is the estimate of participation. The weights of the non-participants were $e(X)/(1 - e(X))$, where $e(X)$ is the estimate of participation. Reported standardised mean differences (SMDs) were used to assess balance and propensity score ranges, extreme counts, maximum control weight and weighted effective sample size (Austin, 2011) to assess overlap. The materials included did not contain detailed code for the augmentation performed on the ATT. Materials were not provided that included detailed code for the ATT-targeted augmentation, weight normalisation and SMD standardisation. This is reported as estimates and not reconstructed from the table of aggregates.

The two types of uncertainty (main and secondary) were calculated using 200 nonparametric bootstrap replicates stratified by village and participation status. Reported intervals are 95% percentile intervals, while p-values are based on bootstrapping of standard errors, with an approximation to the normal distribution. The sensitivity analyses were performed on 100 replicates, which were equally stratified. A fixed seed was reported, but the value of this seed, whether any replicates failed and whether both nuisance models were refit in each draw were not reported. It is possible to have different decisions near zero from percentile intervals and normal-approximation tests. The small number of replications also gives rise to uncertainty regarding interval endpoints and differences between runs of replications.

3.5 Identification Assumptions

There would need to be conditionally exchangeable observations of both exposures and outcomes, positivity of the observations of the participants, consistency of treatment, no interference, reliable measurements, and the exposure–outcome relationship would have to be temporally coherent, in order to make a causal interpretation. Participation and consumption may be affected by unmeasured prior wealth, health, land quality, skills, networks, and risk tolerance and market access. Nonparticipants can suffer spillover effects on the market or on prices due to the quarry activity, or on the environment. The cross-section data cannot provide information on participation preceding consumption, or all adjustment characteristics. Therefore, this analysis is reported as an adjusted association, rather than a measure of impact.

3.6 Data Quality, Missingness, and Sensitivity Analysis

One of the participants who responded directly was excluded from the main analysis because they did not report on their food expenditure. The needed quantity of food was not imputed, and the observed covariates were complete. The blank-to-zero assumption for non-food items has not been tested, as counts of missing values for the component items were not provided, nor were alternative construction analyses. The seven exposure–income inconsistencies were reported as sensitivity checks and included as participants under a composite definition; nonlinear covariate terms were added, the consumption outcome was winsorised at the pooled 1st/99th percentile, and a wider income outcome was used. There were no details provided regarding exact nonlinear terms, treatment of quantile thresholds during re-sampling and the complete component rules of the entire outcome. Exposure and outcome alternatives change the estimand (not one and the same causal contrast); exposure to one alternative is unlikely to be an exact copy of exposure to another.

4.0 RESULTS

4.1 Sample Characteristics

There were preadjustment differences between participants and nonparticipants. The mean age of the 136 participants was 39.8 years, and their mean education was 4.9 years, in comparison to 42.6 and 6.1 years, respectively, among the nonparticipants. Of those who participated, 32.6% were female-led, while 50.0% of nonparticipants were female-headed. Consumption per capita reported by participants was, on average, TZS 41,687, while that of the nonparticipants was TZS 31,171. Of the 67 who participated in Kinyenze, 39 reported participating in the direct-response, and 48 of 70 who participated reported participating in the direct-response in Lugono. The direct-response descriptive statistics remain the same for Table 1, as the sample size from the consumption row is smaller, with the female participant percentage being 33.3% and 32.6% for that row, respectively; this is because the denominator for the female participants in the consumption row is 87, not 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 are based on the 137 direct-response records (87 participants, 50 nonparticipants); consumption is based on 136 records (86, 50). Values are means with SDs in parentheses (when available), but SDs are not reconstructed if they are not reported in the source. Village percentages are based on the denominator from the direct-response group to which the village belongs. The index is a summary of six items that are reported and components and coding have to be verified. In the consumption row, N = 136, and N = 86 in this row.

4.2 Propensity-Score Overlap and Covariate Balance

The propensity score of the participants in the primary sample ranged from 0.281-0.896, while that of the non-participants ranged from 0.289-0.883. None fell outside [0.05, 0.95]. While there is a significant overlap, emphasis is not placed on the support of all participants in particular, at the extremes. The max control odds weight was 7.51, while the weighted control effective sample size was 30.3, with 50 observed controls. When weighting was used, the absolute SMD was decreased the most by this (from 0.357 to 0.256), and most of the covariates were improved. The absolute number of people whose marital status is not the same as that of their spouse, however, grew from 0.172 to 0.256. This, however, was not a consistent improvement in balance, and the differences in balance observed were still important for the study of 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. The control weights are $e(X)/(1 - e(X))$, and the participant weights are 1. SMD = standardised mean difference; arrows represent the direction of the reported difference (participant – control). There was no available analysis documentation that mentioned what the denominator was standardised on. The female and married variables are binary indicators, and the comparison groups are male and not married. The born in village and Lugono variables are binary indicators, comparing with not born in the village and Kinyenze, respectively. The ages are measured in 10-year increments.

4.3 Main and Secondary Estimates

The unadjusted per-capita consumption contrast was TZS 10,517, and the AIPW adjusted per-capita consumption contrast was TZS 11,243 per person per month (bootstrap SE = 4,912; 95% percentile CI: 549 – 20,764; normal-approximation p = 0.022). A positive estimate does not imply a causal effect; it is an association within the sample that has been adjusted. The reported difference is 10,517, which is the difference between the rounded values for group (A) and (B); the unrounded difference is not provided and is therefore not shown.

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); however, sample verification is still pending, because the number of samples N = 137 does not meet the food-observation rule. Exploratory comparisons between food and essential expenditure are not independent broad livelihood-improvements, but rather overlap with the primary aggregate.

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. The conventional average treatment effect on the treated target (ATT) is an adjusted cross-sectional contrast here referred to as ATT. CI and p-value displayed are for the AIPW estimate only – 200 stratified replicates, percentile CI and normal-approximation p-value. Monetary units per person per month; log and index rows remain labelled: food was required for the primary sample and was reported for 137 records, but no log or index was generated for this. The results of this are presented in a provisional (uncorrected/re-estimated) form.

4.4 Robustness and Sensitivity

However, all of the sensitivity point estimates were positive (Table 4). The exclusion of exposure–income inconsistencies yielded TZS 11,791, while the composite (grouped) exposure classification yielded TZS 11,052, the nonlinear adjustment yielded TZS 10,715 and winsorisation yielded TZS 10,348. The percentile interval of the nonlinear specification contained zero (−114–20,962), but the normal approximation p-value was 0.045. The checks do not consistently rule out no association, as the different inferential methods do not necessarily agree. The point estimate TZS 11,243 was not changed from the original estimate, and there were no original observations eliminated because of the score restriction, and so the change in support, if it does actually occur, does not appear to be robust; hence, the uncertainty summaries are not different. The overall estimate of expenditure for TZS 15,109 is for construction of an undetermined number of 137 and is 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

Specification	N	Adjusted contrast	SE	95% CI	p
Score restricted 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 measures are in the form of TZS per person per month; estimates are adjusted associations. The result of the 200 replications is shown on the main row, and on the sensitivity rows, 100 stratified replications are shown with percentile CIs and normal-approximation p-values. The restricted-score point estimate is based on the same original sample as the main row. The wider outcome's component and missingness rules and N = 137 call for verification, and the estimate has been provisionally retained.

5.0 DISCUSSION

The AIPW contrast between the participants and nonparticipants was positive and was reported as being higher among the participants. This discovery provides no evidence that quarrying resulted in increased expenditures; it was merely a supply. Participation can enable expenditure, participation can support participation, or characteristics that have not been measured can influence participation and/or expenditure. The difference may also be due to blank-to-zero coding or to the fact that the recall period is not certain.

The consumption association fits in with the livelihood opportunities as reported by Fisher et al. (2009) and the coexistence of opportunities and risks as described by Kitole et al. (2025). It does not interfere with evidence of insecurity: Injury and instability of income or losses to the environment can coincide with higher spending. The amounts of impacts cannot be directly compared between different commodities, villages and outcomes.

While it may be true that more spending is observed in participants, it is also possible that community outcomes are not equal, as evidenced by the Ghanaian quarries (Asante et al., 2014). Constraints affecting agriculture could affect the decision to enter into extraction (Hilson & Garforth, 2012). Association with food spending does not necessarily correspond to food availability, food quality and intra-household distribution (Wegenast & Beck, 2020), and spending may be driven by local food price changes, not by actual improvements in consumption.

Livelihood losses beyond consumption expenditure (Hoque & Aktar, 2022) and spillovers in the economy that are not just confined to the mining participants (Aragón & Rud, 2013) are evident in the data from other countries. There can be market, price and environmental exposure that is shared between participants and nonparticipants in the present villages. The contrast thus does not measure the overall welfare impact of the quarry industry.

The diagnostics limit interpretation. Most of the covariates were balanced, but marital status imbalance grew, and the weighted control effective sample size was 30.3. Even if the model for the outcome is appropriate, the bias from unobserved differences is not reduced by weighting alone, and outcome augmentation is necessary to achieve this. Intervals close to zero are of special interest if few bootstraps are used and when there is uncertainty regarding the implementation of the model.

There is no consistent improvement in livelihoods with secondary outcomes. The log consumption and the asset/access index were not precisely estimated, and essential expenditure was also subject to an unresolved analytic-sample inconsistency in the food-expenditure estimate. It is not evidence of a general welfare gain if point estimates of outcomes are positive and if the outcomes are overlapping and the definitions are alternative. Evidence on livelihood transitions would be more robust if it were possible to observe multiple times and have full expenditure, price and work-exposure data.

The contribution is an adjusted consumption-based direct participation comparison in the areas of Kinyenze and Lugono, and is qualified and measured explicitly. It leaves unaddressed causal effects, sustainability and full household welfare.

6.0 POLICY IMPLICATIONS

The results are not conclusive with regard to the effect of increased participation at quays and/or financial support on welfare. However, the literature on livelihood cited above includes the consideration of OS, transparent regulation and environmental rehabilitation and viable alternative industries to the quarry business, in addition to income opportunities (Fisher et al., 2009; Kitole et al., 2025; Hoque & Aktar, 2022). Community-level planning engages both participants and nonparticipants because of the market and environmental spillovers (Aragón & Rud, 2013). These are policy issues based on previous evidence rather than interventions reviewed by this survey. New programmes should record baseline data and track households over time to enable a measurement of changes in health and hygiene,

consumption, production costs and hazardous conditions at work and environmental exposures.

7.0 CONCLUSION

Higher reported monthly per-capita household consumption was reported in Kinyenze and Lugono, where the share of quarry participation was reported directly. The major difference between the two contrasts was for the primary AIPW contrast, which was TZS 11,243 per person per month (95% percentile bootstrap CI: 549–20,764). This estimate is qualified by residual imbalance, the uncertainty regarding expenditure reporting, and a lack of comparison information and temporally ambiguous covariates. Secondary and sensitivity analyses do not provide a consistent improvement with regard to the dimensions of livelihoods, and some constructions of outcomes need to be confirmed. The study does not provide a causal or net-welfare estimate; it only provides a locally adjusted comparison. There is a need for larger longitudinal studies with full outcome measurement and with documented sampling to evaluate livelihood transition and sustainability.

8.0 AUTHOR DECLARATIONS

8.1 Consent for Publication

No individual information is reproduced in the manuscript.

8.2 Funding

There was no funding allocated for this study.

8.3 Competing Interests

The authors have no competing interests to disclose.

8.4 Data Availability

Data from the household surveys are not included in the manuscript because they may include potentially sensitive information. Access/release is at the discretion of the data custodian and in compliance with ethical guidelines. Information on the construction of the samples and the excellent reproducibility is summarised in Appendix A but is not reported by the individual samples.

8.5 Author Contributions

Conceptualisation, resources, supervision, writing, review and editing – Nehemia Dauson Kaaya. He sets the aim and content of the study, clarifies the research design and presents the results of the research, and is in charge of the critical review and approval of the version presented for the study.

8.6 Use of AI-Assisted Tools

Data auditing, Statistical programming and language editing were aided by Generative AI tools.

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