The Effect of Participation in High-Value Markets on Assets Ownership among Smallholder Vegetable Farmers in Arumeru District, Tanzania

Happiness Anton Huka[1*], Fredy Timothy Kilima[2], Alban Dismas Mchopa[1]

[1] Department of Procurement and Supply Chain Management, Moshi Co-operative University (MoCU), Email: hpendo046@gmail.com; albanmchopa@gmail.com
[2] Department of Economics and Statistics, Moshi Co-operative University (MoCU), Email: ftmkilima@gmail.com
[*] Correspondence: hpendo046@gmail.com

Abstract: *High-value market chains offer a promising opportunity for smallholder farmers and have the potential to improve their livelihoods. However, the effect of these markets on livelihood outcomes is not well established. A study was conducted to investigate the effect of participation in high-value markets (HVM) on asset ownership among smallholder vegetable farmers in the Arumeru District. Using the Sustainable Livelihood Approach as a framework, the study applied a cross-sectional research design. Data were collected through household surveys, focus group discussions and key informant interviews. The study aimed to assess the effect of participation in HVM on farmers' ownership of livelihood assets while addressing potential selection bias. The analysis was conducted using Propensity Score Matching techniques. The findings indicated that farmers who participated in HVM experienced significantly greater improvements in physical, natural, and human assets compared to non-participants ($p < 0.01$). The study concluded that participation in HVMs positively influences asset ownership among smallholder farmers. To further enhance these effects, ongoing collaboration between state and non-state actors is needed to provide essential business support services to smallholder farmers, increase their productivity, and improve the quality of agricultural commodities. Supporting smallholder farmers in these areas could facilitate their entry into HVMs and ultimately enhance their livelihoods.*

Keywords: High-Value Markets, Participation, Assets, Smallholder Farmers, Vegetables, Sustainable Livelihood Approach

1. Introduction

The horticultural industry plays a crucial role worldwide in providing livelihoods, ensuring food quality, generating income, and offering employment opportunities (Misra & Baskaran, 2020). With rapid population growth and emerging demand for high-quality and specialized products, this sector is expected to support food and nutritional security worldwide (Adebayo *et al*., 2020). The trade of horticultural crops, including flowers and vegetables, is vital for job creation. In countries like India, vegetables account for nearly 18% of agricultural output (Gogoi, & Borah, 2013). In Kenya, horticulture is a crucial source of income, employing over six

million people. Notably, women constitute a significant portion of the workforce, accounting for 75% of those engaged in the industry (Bhatti *et al*., 2022).

In Tanzania, the horticulture industry is characterized by a dominance of small-scale farmers. These farmers comprise over 70% of producers and typically cultivate plots under two hectares, relying heavily on manual labour (Dey & Singh, 2023). The sub-sector boasts a remarkable 10% annual growth rate, exceeding the overall agricultural sector growth of 4% (Jaworski *et al*., 2023). This impressive performance is fuelled by the cultivation of a wide range of horticultural crops, including fruits, vegetables, spices, and medicinal plants. The industry plays a crucial role in ensuring food security, fostering economic growth, and creating employment opportunities (Hlatswayo *et al*., 2023).

Smallholder farmers can benefit from diversifying their economic activities through vegetable cultivation (Bhandari & Paudel, 2021). Access to profitable markets, such as high-value markets (HVMs), can significantly affect their income, well-being, and rural development (Debie & Anteneh, 2022; de Brauw & Swinnen, 2023). High-value markets are more lucrative outlets for agricultural produce compared to traditional markets. In the Tanzanian vegetable value chain, these markets reward farmers for adhering to specific practices that enhance product value, such as sorting, arranging, cleaning, slicing, blending, packaging, and labelling (Makule *et al.,* 2024). HVM includes supermarkets, tourist hotels, fast food chains, and restaurants. Unlike traditional markets, where product quality and value vary, HVM emphasizes strict quality specifications. Marketing of agricultural produce usually involves formal contracts or structured agreements that specify important details such as quantity, quality, pricing, production location, production, and postharvest practices. This often leads to more competitive pricing.

By meeting the required standards, smallholder vegetable farmers can gain access to these markets and improve their farming practices and business orientation (de Brauw & Swinnen, 2023). Shifting to HVM is essential for smallholder vegetable farmers to achieve sustainable livelihoods and inclusive growth, as HVM focuses on product quality and standards (Manda *et al*., 2021; Huka *et al*., 2024). Participation in HVM helps address challenges like limited finance, adoption risks, and spoilage through strong relationships with buyers who provide production support (de Brauw & Swinnen, 2023). However, only 4% of smallholder vegetable production reaches HVMs, with the remaining 96% being sold locally or through middlemen, negatively affecting farmers' livelihoods (Agholor *et al*., 2023). Many smallholder farmers participate in local (farm-level) markets, which are easier to access, less competitive, and have fewer stringent volume and quality requirements than the HVM.

Farmers selling in the traditional vegetable markets face several livelihood challenges. First, they are vulnerable to market risks, such as price fluctuations, due to the inability to bargain effectively. Second, the potential for increasing earnings is restricted, as farmers primarily supply low-value vegetables. Third, farmers can potentially sell limited quantities of

vegetables due to buyers' limited capacity for storage and distribution, further hindering growth in vegetable production and market development (Kilima and Kurwijila, 2020). The long-term effect of these challenges is linked to farmers' inability to invest in improved production methods which negatively impacts their earnings and chances of improving their livelihood outcomes (Widadie *et al*., 2024; Ma *et al*., 2024).

Limited access to market information and communication services has been identified as a hindrance to the participation of smallholder farmers in the HVM and upholding good agricultural practices (Waris & Kumar, 2022; de Brauw & Swinnen, 2023). However, the government of Tanzania, in collaboration with development organizations, has implemented various value-chain programs to support smallholder farmers in the vegetable sector. One of the notable interventions is the Tomato Value Chain Information System (ToVCIS) introduced to improve communication; farmers' access to market information, and their ability to negotiate (Nyamba *et al*., 2020). Another intervention is the introduction of smart drip irrigation kits, which have significantly enhanced crop productivity, farmers' resilience to production shocks, and enhanced earnings (Bhatti *et al*., 2022).

Challenges linked to the inadequate provision of vital business support services have also been reported (Waris & Kumar, 2022; de Brauw & Swinnen, 2023). Many smallholder vegetable farmers in Tanzania face financial constraints that hinder their ability to invest in yield-enhancing inputs and access post-harvest services. Recent efforts by the government of Tanzania to tackle these challenges include instituting policies to boost vegetable production, improving farmers' access to essential inputs and diverse business support services, and enhancing storage and processing facilities to reduce post-harvest losses (Ruta, 2024). These initiatives aim to improve productivity, market access, and overall livelihoods.

Studies have shown that smallholder farmers can benefit from engaging in profitable markets (Yanuartati, 2023; Mpogole *et al*., 2023), but the livelihood impact of these benefits is expected to vary across commodities, locations, and domains of the livelihood outcomes (DFID, 2001). Farmers' involvement in the HVM is expected to have better livelihood outcomes than their counterpart farmers who are not involved in these markets. Their asset portfolio is also likely to improve with an overall improvement in well-being and resilience to economic and environmental shocks. Market participation can enhance farmers' access to better-quality land and improve productivity (Abebe *et al*., 2021). However, this advantage often diminishes in regions facing severe land degradation, leading to low agricultural yields and food security (Pozza & Field, 2020). Similarly, market participation allows farmers to increase and diversify income sources and access financial services, which helps them buffer shocks and reinvest in farming. However, farmers experiencing price fluctuations are likely to be more vulnerable to financial instability (Huka *et al*., 2024). Market participation provides farmers with exposure to innovative farming techniques and market intelligence, strengthening their decision-making abilities and boosting both productivity and earnings (Mmbando *et al*., 2017; Li *et al*., 2023). The resulting increase in income can also lead to improvements in health, contributing to a more available and productive labour force and optimized land utilization (Mkuna & Wale, 2022).

Moreover, market participation is expected to foster robust social networks as farmers interact with various market actors, enhancing their access to information, bargaining power, and social cohesion (Mdoda, 2023). Collective action through co-operatives further strengthens their collaboration by enabling them to aggregate products, negotiate favourable prices, and reduce costs, thereby boosting their market power (Kilima, 2021). However, social exclusion can hinder these benefits for marginalized groups like women, who may face barriers to market entry, limiting their prospects of gaining from market opportunities (Singh-Peterson & Iranacolaivalu, 2018).

Market participation can incentivize farmers to invest in essential infrastructure such as storage, irrigation, and transportation, thereby enhancing productivity and reducing post-harvest losses. It also encourages investment in modern farming equipment for more efficient production and distribution (Melaku, 2019). However, farmers in remote areas often face challenges due to inadequate physical capital, hindering their ability to fully capitalize on market opportunities (Haile *et al*., 2022). In rural areas, inadequate public services and infrastructure hinder the attraction and retention of businesses, thereby exacerbating the challenges faced by farmers. The lack of essential infrastructure, such as reliable transportation and communication networks, limits economic opportunities and impedes the development of local markets. This situation not only stifles economic potential but also diminishes the quality of life in rural communities. Similarly, limited access to financial services in remote areas can restrict farmers' ability to invest in essential infrastructure and equipment.

Our research addressed the complex and context-specific effects of market participation on farmers' livelihoods, focusing on the effects across different asset categories disaggregated by farmer's participation status. While existing literature acknowledges the broad benefits of market engagement, a nuanced understanding of these effects remains limited. This study aims to fill this gap by examining the effect of HVM participation on asset ownership among smallholder vegetable farmers. By disaggregating the analysis and focusing on distinct asset categories, this research will contribute to the literature on market participation and livelihood assets, revealing potential variations in the effect of HVM engagement. This detailed examination will provide valuable insights for policymakers and practitioners seeking to optimize the benefits of market participation for smallholder farmers, particularly in the context of high-value agricultural commodities.

2. Theoretical Framework

The conceptual framework for the study underscores that smallholder farmers' market participation aligns closely with the Sustainable Livelihood Approach (SLA), as it plays a critical role in enhancing multiple forms of human, social, physical, natural, and financial assets (DFID, 2001). The framework focuses on understanding how these forms of assets contribute to the well-being and resilience of smallholder farmers. It explores how market participation can

enhance farmers' livelihood assets leading to long-term improvements in income, resilience, empowerment, and well-being (Mchopa & Jecknoniah, 2018).

The potential for smallholder vegetable farmers to achieve surplus production for market sales, in either traditional or HVM; is contingent on a complex interplay of cultural, socioeconomic, and institutional factors that shape their capacity to produce and market their crops (Abafita *et al*., 2016; Ademe *et al*., 2017). Experience shows that the farmers' market outlet choices yield inconsistent outcomes (Cousins, 2012). Smallholder farmers, who are relatively poor and potentially less commercialized, have limited capacity to meet the demands of the buyers in HVM. Therefore, they generally sell in traditional markets, accepting lower prices and less quality control (Kilima & Kurwijila, 2020). Conversely, smallholder farmers who can meet the demands of HVM have the potential to achieve substantial gains beyond price, securing access to stable value chains and bolstering their livelihood assets (Donovan & Poole, 2014). Our study used the SLA and propensity score methods to analyse how smallholder vegetable farmers build their assets over time and how their choice of market outlets i.e., HVM vis-à-vis traditional, relates to variations in their natural, human, social, physical, and financial assets. This knowledge is essential for shaping policies that focus on strengthening farmers' asset base, including prioritizing the provision of key business development services and reinforcing social networks to enhance market engagement and resilience.

Literature acknowledges several limitations of the SLA such as its complexity linked to the difficulties in measuring intangible assets like social assets, and the challenge of integrating various livelihood dimensions across different contexts. Additionally, the framework often overlooks power dynamics and external factors such as policies or environmental changes that influence farmers' livelihoods (Morse & McNamara, 2013; Natarajan *et al*., 2022). To overcome these limitations, we adopted a flexible and context-specific approach incorporating mixed-methods research to capture both qualitative and quantitative data. The survey also adopted stringent on-site oversight to ensure the information collected was accurate, and representative of the study population, the process entailed wider consultation with key informants and deployed relevant measures to validate the gathered data and information.

3. Empirical Framework

The empirical model adopted in our study was implemented in four sequential steps starting with the propensity score estimation (Guo *et al*., 2020; Hui & Hübner, 2023). In the context of our study, the propensity score was the probability of a farmer participating in HVM given his/her socio-economic characteristics (X). This estimation was done using a linear probability equation defined in Equation (1).

$$Pr(D_i = 1|X_i) = F(\beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_k X_{ik}) \quad (1)$$

In Equation (1) D_i =1 if the farmer participates in HVM, and D_i=0 if the farmer participates in traditional markets meaning he/she belongs to the control group; Xi represents the socio-

economic variables of the farmer. The coefficients $\beta_0, \beta_1, \ldots, \beta_k$; represent parameters to be estimated, and $F(.)$ stands for the cumulative distribution function of the logistic function in a logit model or normal cumulative function in a probit model. The second step entailed matching farmers in the treatment group (HVM participants) with farmers in the control group (participants in the traditional markets) who have similar propensity scores to create a comparable control group. The process is typically done using different matching techniques, especially nearest neighbour, kernel, radius, and stratification. The third step involved comparing the ownership of each of the livelihood assets (Y_i) between the treatment and control groups. The outcome of interest Y_i was estimated as in Equation (2).

$$Y_i = \alpha + \varphi D_i + \phi X_i + \varepsilon_i \quad (2)$$

where; D_i is the treatment indicator, α is the intercept, φ is a measure of the average treatment effect on the treated (ATT), which reflects the difference in asset ownership between the two groups after controlling for differences in their socio-economic characteristics, ϕ is a vector of coefficients on the socio-economic variables, and ε_i .is the error term. The final step involved estimating the average treatment effect, which was calculated after the matching process using Equation (3).

$$ATT = \frac{1}{N_T} \sum_{i \in T} [Y_i(T) - Y_i(C)] \quad (3)$$

where; N_T is the number of farmers in the treatment group, while $Y_i(T)$ and $Y_i(C)$ are the outcomes for farmers in the treatment and control groups; respectively. The sum computes the difference in outcomes for each matched pair of treated and control farmers. The Propensity Score Matching (PSM) helps to isolate the causal effect of HVM participation on asset acquisition, adjusting for socio-economic factors. The calculated Average Treatment for the Treated (ATT) shows how HVM participation differentiates farmers based on their livelihood assets (i.e., between participants in HVM and traditional markets).

4. Study Approach and Methodology

4.1 Study Design and Sampling Procedure

Our study adopted a cross-sectional research design, allowing for efficient data collection from a large number of individuals at once (Zuleika, 2022). This design permitted the researcher to simultaneously assess multiple variables, providing a robust framework for evaluating the reliability and validity of key findings (Wang & Cheng, 2020). The research was conducted in the Arumeru in Arusha Regions; with the sample size determined using Daniel's (2009) sampling formula. This formula ensured the inclusion of individuals with (p) and without ($1 - p$) specific characteristics. Counterfactual techniques were employed to analyse livelihood asset ownership among both participants and non-participants in the cohort of smallholder farmers studied. The formula used to calculate the sample size is presented in Equation (4).

$$n = \frac{z^2(p)(1-p)}{d^2} \quad (4)$$

where; n is the sample size; d is the 95% level of confidence (1.96); p is the proportion of the population believed to possess specific attributes (0.5); and, d is the margin of error to be tolerated (0.05).

Therefore, the required sample size was 384 as calculated in Equation (5).

$$n = \frac{1.96^2(0.5)(1-0.5)}{0.05^2} = 384 \quad (5)$$

This study included a sample of 384 respondents, maintaining a 1:1 ratio of HVM participants to non-participants, which is a commonly recommended approach for case-control studies (Tenny *et al*., 2017; Mohanty & Doke, 2020). This balanced ratio enhances the comparability between the two groups and increases the study's statistical power (Andrade, 2022; Tenny *et al*., 2017).

Three wards (Akheri, Kikwe, and Usa River) were randomly selected, and then two villages were randomly selected from each ward. A comprehensive list of farm households was created from the village registers, including their distribution, village locations, and the types of vegetables cultivated. Finally, a random sample of 384 smallholder vegetable farmers growing onions, tomatoes, and cabbage was chosen from the list, consisting of HVM participants and non-participants. Quantitative data were collected from sampled farmers using a structured questionnaire administered at the household level. Qualitative data were gathered through key informant interviews (KIIs) and focus group discussions (FGDs). The key informants included two community leaders, two village executive officers, and two village agriculture extension officers. In total, six FGDs were conducted, with each group consisting of 6 to 8 participants. This group size is optimal because larger groups can be difficult to manage, while smaller groups may limit interaction and lead to biased or limited information (Othman *et al*., 2020).

4.2 Livelihood Assets and Index

The unit value approach (Moser & Felton, 2007) was adopted to create an asset ownership index by assigning a value of 1 to each owned asset, represented as a binary variable. These values were summed to produce a simple count of owned assets, the livelihood asset ownership index (*LAI*) for each category. This method is commonly employed in socioeconomic research to analyse wealth distribution and poverty levels due to its straightforward quantification of asset ownership. Empirically, the *LAI* for each category of asset (*j*) was calculated as in Equation 6.

$$LAI_j = \sum_{j=1}^{n} x_{ij} \quad (6)$$

where; LAI_j represents the livelihood asset index for assets in category j, n is the total number of assets considered in each category, and x_{ij} is a binary variable representing the ownership of each asset in the jth category by individual i (1 if owned, 0 if not).

The SLA (DFID, 2001) categorizes the resources individuals and households rely on into five key areas: human assets, encompassing skills and health; social assets, reflecting support networks and community ties; natural assets, including access to natural resources; physical assets, which covers infrastructure and tools; and financial assets, representing available financial resources like savings and credit. These categories provide a comprehensive view of the assets contributing to persons' or households' abilities to sustain their livelihood. These assets collectively determine the capacity of individuals and communities to pursue and achieve desired livelihood outcomes (DFID, 2001). Table 1 offers a comprehensive summary of livelihood assets considered in the analysis.

Table 1: Description of livelihood assets

	Asset	Category		Asset	Category
1	Radio	Physical	18	Goats	Physical
2	Bicycle	Physical	19	Solar power	Physical
3	Smartphone	Physical	20	Animal vehicle	Physical
4	TV	Physical	21	Access to financial service	Financial
5	Watering can	Physical	22	Savings	Financial
6	Bed	Physical	23	Access to education	Human
7	Sofa set	Physical	24	Adequate number of meals	Human
8	Motor Vehicle	Physical	25	Access to food	Human
9	Ox plough	Physical	26	Access to health services	Human
10	Chemical sprayer	Physical	27	Food adequate throughout the year	Human
11	Motorized water pump	Physical	28	Access to water	Human
12	Manual water pump	Physical	29	Access to support services	Social
13	Power machine	Physical	30	Access to extension services	Social
14	Cupboard	Physical	31	Access to information	Social
15	Biogas	Physical	32	Access to land	Natural
16	Land	Physical	33	Access to alternative sources of energy	Natural
17	Cows	Physical	34	Access to water	Natural

2.3 Data Analysis

We used two primary techniques to analyse the qualitative data collected from focus groups and key informant discussions. Firstly, we systematically organised participants' opinions based on the specific questions or checklists used to gather their responses. This method ensured that each opinion was linked to the relevant discussion topic. Secondly, we coded and categorised the most significant opinions into key ideas and themes. This thematic coding allowed us to identify recurring patterns and critical insights more effectively, facilitating the synthesis and discussion of the findings. These methods ensured that the analysis was structured, comprehensive, and accessible for further interpretation and decision-making.

The analysis of quantitative data used both descriptive and inferential techniques. Descriptive analysis summarized categorical data through frequencies and percentages, while continuous data were summarized using means and standard deviations. We used a chi-square test to assess the association between participation statuses in HVM and selected categorical independent variables. Meanwhile, a *t*-test was employed to evaluate the mean differences in computed indices of livelihood assets (notably; human, natural, social, physical, and financial assets) based on participation status. A more comprehensive inferential analysis was performed using PSM. This method was preferred over others because it is particularly useful for single-point-in-time studies that involve both control and treated groups (Guo *et al*., 2020; Hui *et al*., 2023). PSM was chosen to address potential bias arising from uneven baseline characteristics. In

this analysis, participants were designated as the treated group, while non-participants served as the control group. The inclusion of control participants allowed for more informed comparisons, as PSM assumes that the scores between treated and control units are comparable.

The PSM method effectively addresses high dimensionality by balancing observable characteristics across groups. This facilitates a controlled analysis of the effects of specific covariates on predetermined outcomes based on their propensity scores. Key assumptions of PSM, such as the absence of unmeasured confounders, the balancing property within the common support area, and the lack of unobserved confounders, were evaluated to ensure the analysis's validity. Rajkhowa & Qaim (2021) emphasize that the absence of unobserved confounders is essential for obtaining unbiased estimates of the average treatment effect (ATE), strengthening the robustness of causal inferences drawn from observational data. This condition holds when the treatment assignment (*Wi*) and the outcome are independent given a set of covariates (*Xi*) (Keele *et al*., 2020).

Propensity score analysis is an effective method for controlling selection biases, both overt and hidden (Rajkhowa & Qaim, 2021). Overt bias is evident in the data, such as the lower pre-treatment income of individuals who received treatment compared to those in the control group. In contrast, hidden bias refers to present but unobserved similarities, which may arise from missing data. To ensure the accuracy of the sample's characteristic distributions, we performed sensitivity tests. These tests included evaluating the balance of characteristics and the areas of common support. The balancing property was assessed using the Ps R test, which examines the distribution of propensity scores between treated and control groups after matching. When the propensity scores are well-matched, it suggests that the treated and control groups are comparable, meaning that any differences in outcomes can be attributed to the treatment rather than to variations in covariates. Inferences regarding the balance of propensity scores are evaluated using the likelihood ratio chi-squared statistic (LR chi^2), which assesses whether the coefficients of the covariates are collectively different from zero. A significant LR chi^2 (with a *p*-value below acceptable confidence levels) indicates that at least one covariate in the model is significantly associated with treatment assignment. This reinforces the effectiveness of the propensity score model for matching.

4.2.1 Area of common support and balance characteristics across HVM participation status

4.2.1.1 Propensity score on the region of common support for livelihood assets

To ensure comparable outcomes between the treatment and control groups, PSM was conducted. Propensity scores were calculated, representing the probability of treatment given observed covariates. A rule of thumb stipulates that these scores should fall between 0 and 1. To be able to compare the treatment and control groups based on propensity scores, the ATT was estimated for households with a propensity score of less than 1. This approach aimed to balance the covariates between the two groups, a crucial step for drawing valid causal inferences. A balanced comparison ensures that the treatment and control groups are similar in terms of observable characteristics, allowing for more reliable comparisons of outcomes. This is achieved

when the probability of being in the treatment group is equal to the probability of being in the control group, conditional on the observed covariates.

4.2.1.2 Testing of balancing property and common support assumption

A parametric test was conducted to estimate the treatment effect using PSM and to evaluate the balance of covariates (Supplementary Table 1). The results indicate that, after matching, the distribution of covariates (or characteristics) was similar between the treated and control groups ($p < 0.01$). Overall, the findings were consistent across all asset categories, suggesting that the balancing property was achieved and the matching process effectively formed balanced subgroups. The overlap between participant and non-participant groups demonstrates a strong alignment between treated and control units, supporting a robust and equitable comparison (Rosenbaum *et al.*, 2021). To estimate propensity scores, three sets of covariates were considered: general characteristics, treatment-related variables, and potential confounders. The treatment of interest was participation in HVM, and the outcomes were ownership of livelihood assets. The study aimed to analyse the effect of HVM participation on livelihood assets, calculating both the Average Treatment Effect (ATE) and ATT by considering two potential outcomes if they participated in HVM or not. The treatment effect was defined as the difference between these two potential outcomes. The ATE measures the average effect of HVM participation across the entire population, while the ATT focuses on the average effect for those who participated in HVM. Given the study's specific focus, both ATE and ATT were crucial for understanding the effects of HVM participation on livelihood assets (Negi and Wooldridge, 2021).

5. Results and Discussion

5.1 Socio-economic Characteristics of Respondents

Table 2 summarizes the demographic characteristics of respondents based on their involvement in HVM. Male participants (80.54%) were more prevalent than female participants (19.46%). It was also observed that male farmers were overrepresented among the non-participants. The test statistic revealed a significant association between HVM participation and crop diversification ($p < 0.05$), indicating that participants were more likely to diversify crops than non-participants. Crop diversification emerges as a crucial strategy for smallholder farmers, offering a dual benefit of risk reduction and income enhancement. By mitigating market fluctuations, diverse cropping systems allow farmers to stabilize their earnings, preventing reliance on single commodities (Mihrete & Mihretu, 2025). However, Horton *et al.* (2020) note that crop diversification may have trade-offs in terms of crop productivity and efficiency gains. Results reveal a significant association between HVM participation and better access to market information and extension services, with participants having significantly greater access compared to non-participants ($p < 0.01$). This advantage enabled the vegetable farmers to stay informed about market trends, pricing, and negotiation strategies, leading to improved sales. Previous research also suggests that access to market information, especially through ICT, is crucial for achieving higher sales and better prices (Kilima & Chikuni, 2021;

Huka *et al*., 2023). Additionally, Drewryb *et al*. (2022) underscores the role of extension services in boosting yields, incomes, and the adoption of new technologies.

Table 3 offers a comparison of quantitative variables between HVM participants and non-participants. It shows that HVM participants were generally older and had slightly more farming experience than non-participants ($p < 0.05$). A significant difference was noted in market access, with participants living closer to markets having better access than those detached from the markets ($p < 0.05$). Participants also had larger households than non-participants ($p < 0.05$). Regarding the livelihood assets indices, participants consistently outperformed non-participants across all categories of natural, social, physical, human, and financial assets (Supplementary Table 2).

These differences were statistically significant ($p < 0.05$). These results underscore the positive effect of HVM participation on asset accumulation, which fosters financial stability and wealth growth (Kansiime *et al*., 2021). Incomes from HVM activities boost savings and investment, further driving asset expansion (Shrestha *et al*., 2024). The observation that non-participants are primarily farmers in distant and remote areas aligns with Kim *et al*. (2025) suggestion that geographic barriers can exacerbate inequalities in market access. This supports Maqsood *et al*. (2024) perspective that addressing these barriers could enhance economic outcomes for individuals disconnected from agricultural markets.

The connection between HVM participation, asset accumulation, and access to essential services has also been documented in other studies. Engagement in HVM promotes wealth generation and improves livelihoods, especially in rural areas. Households involved in commercial farming often exhibit a positive relationship between market participation and the value of durable assets, underscoring how wealth accumulation is linked to commercial activities (Nwangwu *et al*., 2024). A study in Zimbabwe revealed that smallholder farmers' involvement in agricultural commercialization can be a powerful tool for poverty alleviation (Mahofa *et al*., 2022). Commercialization enables farmers to sell more crops, increases household income; improves food security, and enables better access to essential services and asset accumulation. While HVM participation offers numerous advantages, it is vital to acknowledge the need for tailored interventions to enhance crop productivity and quality and mitigate potential risks associated with market fluctuations (Marion *et al*., 2024). The findings from previous studies align with the feedback provided by participants in the focus group discussions during the survey. It was reported that farmers supplying vegetables to HVM often faced quality-related rejections but earned higher incomes compared to non-participants, as they received better prices. These financial gains improved their housing and overall quality of life.

Table 2: Qualitative variables of respondents categorized by participation status in HVM

Variable	**Participants**		**Non-participants**		**Chi-square Statistic (*p*)**
Sex	Male (%)	Female (%)	Male (%)	Female (%)	1.4305 (0.232)
	80.54	19.46	75.46	24.54	
Whether used hired labour	Yes (%)	No (%)	Yes (%)	No (%)	0.6791(0.410)
	48.42	51.58	44.17	55.83	
Whether used both family and hired Labour	Yes (%)	No (%)	Yes (%)	No (%)	0.8352(0.361)
	27.60	72.40	31.90	68.10	
Whether diversified crops	Yes (%)	No (%)	Yes (%)	No (%)	4.6181(0.032)
	40.72	59.28	30.06	69.94	
Whether the household had access to market information	Yes (%)	No (%)	Yes (%)	No (%)	384.0000(0.000)
	90.95	9.05	7.98	92.02	
Whether the household had access to extension services	Yes (%)	No (%)	Yes (%)	No (%)	29.1933(0.000)
	74.21	25.79	47.24	52.76	

Table 3: Quantitative variables of respondents categorized by participation status in HVM

Variable	Type of respondent	n	Mean	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference		*t*-test for mean difference (*p*)
						Lower	Upper	
Age of household head	HVM Participant	221	44.09	10.742	0.723	0.802	5.026	2.713 (0.007)
	Non-participant	163	41.17	9.925	0.777			
Experience in farming	HVM Participant	221	15.74	10.702	0.720	-0.314	4.076	1.685 (0.0930)
	Non-participant	163	13.86	10.958	0.858			
Size of land	HVM Participant	221	2.1450	1.39023	0.09352	-0.43627	0.23858	-0.576 (0.5650)
	Non-participant	163	2.2439	1.97234	0.15449			
Distance to market (km)	HVM Participant	220	4.2939	10.51810	0.70913	-9.47688	-3.74852	-4.539 (0.0000)
	Non-participant	163	10.9066	17.82440	1.39611			
Household size	HVM Participant	221	5.71	2.272	0.153	0.550	1.402	4.504 (0.0000)
	Non-participant	163	4.73	1.836	0.144			
Natural asset index	HVM Participant	221	2.1402	0.63479	0.04270	-.50076	-.76137	-9.5224(0.0000)
	Non-participant	163	1.5092	0.65138	0.05102			
Social asset index	HVM Participant	221	1.48	0.57648	0.03877	-.05954	-.27718	-3.0420(0.0025)
	Non-participant	163	1.31	0.47572	0.03726			
Physical asset index	HVM Participant	221	2.69	0.69235	0.04657	-.87650	-1.1861	-13.0969(0.0000)
	Non-participant	163	1.66	0.84896	0.06649			
Human asset index	HVM Participant	221	2.4841	0.62229	0.04185	-.28634	-.54700	-6.2861(0.0000)
	Non-participant	163	2.0674	0.66785	0.05231			
Financial asset index	HVM Participant	216	2.1851	0.8143	0.05541	-.37278	-.69495	-6.5173(0.0000)
	Non-participant	152	1.6513	0.7118	0.05774			

5.2 Effect of HVM Participation on Livelihood Assets

The study employed various PSM estimators to evaluate the effect of HVM participation on livelihood assets (Table 5). The ATT was consistently positive and statistically significant for all PSM estimators. The effect of HVM participation on physical assets was relatively consistent, with ATT values ranging from 44.17 to 45.45 ($p < 0.01$). A similar pattern was observed for natural assets, ranging from 36.03 to 37.49 ($p < 0.01$). However, the effect on human assets was less consistent, with only the nearest neighbour and radius estimators showing statistically significant effects ($p < 0.05$). The impact of social ($p < 0.05$) and financial ($p < 0.01$) assets was the least consistent, as only the radius estimator exhibited a statistically significant effect.

Table 5: Effect of HVM participation on livelihood assets

Asset category	Matching estimator	Treatment	Control	ATT	Bootstrapped *S.E.*	*t*-Statistic
Physical	Nearest neighbour	114	33	45.45	2.63	17.38***
	Radius	114	74	44.42	2.55	17.44***
	Kernel	114	74	44.57	2.66	16.77***
	Stratification	114	74	44.17	2.75	16.08***
Natural	Nearest neighbour	220	160	36.03	3.67	9.81***
	Radius	220	160	36.03	3.27	11.02***
	Kernel	220	160	36.97	3.41	10.85***
	Stratification	219	161	37.49	3.29	11.36***
Human	Nearest neighbour	117	77	8.33	260	3.21***
	Radius	117	77	8.33	2.46	3.39***
	Kernel	117	77	4.38	2.55	1.71
	Stratification	117	77	3.27	2.86	1.14
Social	Nearest neighbour	220	83	1.41	4.34	0.32
	Radius	220	160	5.56	2.78	2.00**
	Kernel	220	160	1.03	2.99	0.34
	Stratification	220	160	-1.06	4.11	-0.26
Financial	Nearest neighbour	220	79	8.76	4.71	1.86
	Radius	220	160	17.29	2.44	7.10***
	Stratification	220	160	8.79	5.53	1.59

*** Significant at 1%, and **Significant at 5%

The study's findings consistently demonstrate a positive effect of HVM participation on livelihood assets. Most PSM estimators were statistically significant, with *t*-values consistently above 2, indicating significant effects ($p < 0.01$). Participation was found to positively influence financial, human, natural, and to a lesser extent social assets. These results highlight the importance of HVM in improving the well-being of smallholder farmers (Li *et al*., 2020; Chidembo *et al*., 2022; Huka *et al*., 2024).

5.3 Effect of HVM Participation on Livelihood Assets Comparing ATE and ATET

The study also examined the effect of HVM participation on livelihood assets by comparing ATE and average treatment effects on the treated (ATET) results. Table 6 shows that HVM participation had a significantly greater positive effect on livelihood assets than for non-participants, with ATE and ATET being statistically significant. For example, in the case of physical assets, the ATE and ATET had positive coefficients of 32.59 and 35.33, respectively; both highly significant ($p < 0.01$). A similar effect was found for natural, human, and financial assets that were statistically significant ($p < 0.01$). These findings are consistent with previous research by Huka *et al.* (2023), which emphasized the transformative potential of HVM participation in improving smallholder farmers' access to various assets. The participation typically involves premium agricultural products, allowing farmers to invest in key physical assets like land, housing, tractors, irrigation systems, and storage facilities. These investments promote farmers' livelihoods (Manda *et al*., 2020). The findings align well with the observations from key informants who acknowledged that:

> "*Farmers supplying vegetables to HVM reported receiving higher prices compared to those selling in conventional markets. This increase in income allowed them to improve their living conditions. Many farmers transitioned from homes made of mud bricks with grass roofs to houses built with burnt bricks and iron sheets. Moreover, families could construct larger homes with more rooms, improving privacy and raising overall household living standards.*"

The effect of HVM participation was also evident in land ownership, where access to HVMs allowed smallholder farmers to expand their land size. This was highlighted during the FGD, where participants agreed that HVM involvement helped them to acquire additional land for cultivation, boosting their potential for higher yields and enhancing income. This finding aligns well with Sumari *et al*. (2018), who found that HVM participation enabled smallholder farmers to earn more income and acquire more land for cultivation.

Farmers' participation in HVM also strengthened human assets, as they received training in production, quality control, and marketing, which enhanced their technical skills and productivity. Additionally, this training can potentially equip them with valuable skills in supply chain management and financial literacy (Li *et al.*, 2023). Targeted training programs, such as the market information and linkage system, equip farmers with timely market data, enhancing their bargaining power and income potential (Mukhebi *et al*., 2008). Furthermore,

studies indicate that farmers with higher education levels achieve better economic outcomes, with those possessing secondary education or higher earning more than their less-educated counterparts. Participation in HVMs also provides farmers with essential skills, such as contract negotiation, which are crucial for profitable marketing (Li *et al.*, 2023).

Table 6: Effect of HVM participation on livelihood assets comparing ATE and ATET

Asset category	ATE				ATET			
	Coefficient	Robust *S.E.*	*Z*-statistic	*p*-Value	Coefficient	Robust *S.E.*	*Z*-statistic	*p*-Value
Physical	32.59	2.90	11.22	<0.001	35.33	3.67	9.62	<0.001
Natural	32.96	3.89	8.45	<0.001	34.54	4.56	7.58	<0.001
Human	7.28	2.49	2.93	<0.01	9.04	2.53	3.57	<0.001
Social	3.29	3.33	0.99	0.32	3.91	4.69	0.83	0.41
Financial	17.89	2.67	1.08	<0.01	23.68.1	2.17	10.93	<0.001

By participating in HVM, farmers can enhance their natural assets through the financial resources necessary to invest in land, improve soil quality, and obtain higher-quality seeds and inputs (Loki & Mdoda, 2023). This increased income facilitates the adoption of sustainable practices like crop rotation and water conservation, helping to maintain soil fertility and biodiversity (Abebe *et al*., 2021). Additionally, farmers can invest in irrigation systems, advancing modern farming techniques. Profits from market participation also support better livestock management, ensuring the long-term sustainability of their natural resources (Olofsson *et al*., 2021).

Moreover, the value of financial assets for HVM participants surpassed that of non-participants, resulting in increased income and diversified investments ($p < 0.01$). Studies confirm that HVM participants secure better product prices, leading to improved household food security, access to health services, and education (Kogachi & Shaw 2023). For instance, Legesse *et al*. (2023) found that farmers in Ethiopia's HVM channels for indigenous chicken and avocado experienced greater dietary diversity and food security. The additional income also allowed farmers to reinvest in livestock and machinery, further expanding their agricultural activities (Peddi & Kumar, 2021). Participants in FGD conducted during this study reported diversifying their income sources by investing in motorcycles for transportation businesses, commonly known as "*bodaboda*," highlighting the connection between market access and financial growth (Cuffaro *et al*., 2022).

Participation in HVMs can also strengthen social networks, facilitate knowledge exchange, and improve market access. By entering into formal agreements with buyers, farmers can establish connections essential for meeting HVM demands. These agreements promote resource sharing and enable farmers to negotiate better terms with buyers (Loki & Mdoda, 2023). In areas where contract farming is viable, it can offer essential information as well as

production and post-harvest technologies, thereby supporting farmers to intensify production and uphold good practices (Albizua *et al*., 2021). These social networks also encourage the adoption of sustainable practices through shared knowledge (Kreft *et al*., 2023).

Overall, participation in HVM provided smallholder farmers with higher incomes, increased market access, and opportunities for skill development, which contribute to asset accumulation across physical, natural, human, financial, and social assets. This participation allows farmers to move beyond subsistence farming, enhancing their resilience, productivity, and overall well-being. Post-estimation tests confirmed the robustness of the PSM results. Balancing tests demonstrated a significant reduction in bias after matching (Supplementary Table 1). Additionally, an analysis of outcome variable density functions (Supplementary Figure 1) revealed a perfect match between the treated and untreated samples. These findings provide strong evidence for the validity of the PSM approach used in the study.

5.4 Study Limitations

The findings of this study should be interpreted with certain limitations in mind. First, it is based solely on the study area: its results may not be generalized due to variations in market dynamics. Although similar vegetables are grown in other areas, a broader representation would be necessary for generalization. Second, the study's cross-sectional design limits the ability to draw causal inferences, which are better assessed through longitudinal studies.

6. Conclusion and Recommendations

Our study revealed significant improvements in asset ownership among HVM participants. These included the construction of better houses, saving, increased land ownership, and using advanced agricultural tools and equipment. These findings suggest that HVM participation positively influences changes in livelihood outcomes. In contrast, non-participants exhibited lower levels of asset ownership. To further amplify the effects of HVM participation, ongoing collaboration between state and non-state actors is essential in providing crucial business development support services to smallholder farmers, enabling them to increase productivity and improve the quality of their agricultural commodities. These interventions would enable farmers to supply larger volumes of higher-quality produce allowing them to compete more effectively in commodity markets, rather than continuing to supply small quantities of agricultural goods to traditional markets that hardly recognize or reward quality. Another strategic approach to boost farmers' participation in HVM is through collective efforts, such as establishing farmers' groups. These groups can enable farmers to access microfinance institutions and small-scale loans, allowing them to invest in improved agricultural equipment and better utilize available support services. This strategy would increase productivity, resulting in higher household incomes and improved livelihood.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Abafita, J., Atkinson, J., & Kim, C.S. (2016). Smallholder Commercialization in Ethiopia: Market Orientation and Participation. *International Food Research Journal*, 23(4): 1797-1807. http://www.ifrj.upm.edu.my/23%20(04)%202016/(60).pdf.

Abebe, T., Chalchisa, T., & Eneyew, A. (2021). The Impact of Rural Livelihood Diversification on Household Poverty: Evidence from Jimma Zone, Oromia National Regional State, South Ethiopia. *The Scientific World Journal*, 3: 1-11. https://doi.org/10.1155/2021/3894610.

Adebayo, I.A., Pam, V.K., Arsad, H., & Samian, M.R. (2020). The Global Floriculture Industry: Status and Prospects. *The Global Floriculture Industry: Shifting Directions, New Trends, and Prospects.* New York: Apple Academic Press. 1-14 pp. https://www.taylorfrancis.com/chapters/edit/10.1201/9781003000723-1/global-floriculture-industry-status-future-prospects-ismail-abiola-adebayo-victoria-kaneng-pam-hasni-arsad-mohammad-razip-samian.

Ademe, A., Legesse, B., Haji, J., & Goshu, D. (2017). Smallholder Farmers Crop Commercialization in the Highlands of Eastern Ethiopia. *Review of Agricultural and Applied Economics (RAAE)*, 20(2): 30-37. DOI: 10.15414/raae.2017.20.02.30-37.

Agholor, A.I., Ogujiuba, K.K., & Shongwe, N.I. (2023). Determinants of Small Farmers Access to Agricultural Markets in South Africa. *Agricultural Science and Technology*, 15(1): 80-87. https://agriscitech.eu/wp-content/uploads/2023/03/10-AST_1_March_2023.pdf.

Albizua, A., Bennett, E.M., Larocque, G., Krause, R.W., & Pascual, U. (2021). Social Networks Influence Farming Practices and Agrarian Sustainability. *PloS One*, 16(1): e0244619. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0244619.

Andrade, C. (2022). Research Design: Case-Control Studies. *Indian Journal of Psychological Medicine*, 44(3): 307-309. https://doi.org/10.1177/02537176221090104.

Bhandari, K., & Paudel, B. (2021). Impact of Vegetable Farming on Farmers Livelihood Patterns in Dhankuta, Nepal. *The Geographical Journal of Nepal*, 14: 131-150. https://doi.org/10.3126/gjn.v14i0.35556.

Bhatti, M.A., Godfrey, S.S., Divon, S.A., Aamodt, J.T., Øystese, S., Wynn, P.C., Eik, L.O., & Fjeld-Solberg, Ø. (2022). Micro-investment by Tanzanian Smallholders in Drip Irrigation Kits for Vegetable Production to Improve Livelihoods: Lessons Learned and a Way Forward. *Agriculture*, 12(10): 1732. https://doi.org/10.3390/agriculture12101732.

Chidembo, R., Kilonzo, B., Zuwarimwe, J., & Kativhu, S. (2022).Contribution of Heifer International Programme to Smallholder Households' Livelihoods in Mberengwa District, Zimbabwe. *African Journal of Development Studies*, 12(1): 25-47. https://doi.org/10.31920/2634-3649/2022/v12n1a2.

Cousins, B. (2012). Smallholder Irrigation Schemes, Agrarian Reform and 'Accumulation From Above and From Below' in South Africa. *Journal of Agrarian Change*, 13(1): 116-139. https://doi.org/10.1111/joac.12000.

Cuffaro, N., Prota, L., & Bertini, R. (2022). Are Large-Scale Land Acquisitions in Africa Pro-development? A Network Analysis of FDI in Land and Agro-industry. Springer Books, In: Wamboye, E.F., & Fayissa, B. (eds), *The Palgrave Handbook of Africa's Economic Sectors*. Springer, 87-116 pp. DOI: 10.1007/978-3-030-75556-0_4.

Daniel, W. (2009). *Biostatistics: A Foundation for Analysis in the Health Sciences*. John Wiley & Sons Inc, New Jersey. 783pp. http://www.wiley.com/go/permissions

de Brauw, A., & Swinnen, J. (2023). Building Inclusive Value Chains for Smallholders: The Role of Finance. Chapters, In: Hartarska, V. & Cull, R.J. (eds), *Handbook of Microfinance, Financial Inclusion and Development*. Chapter 11, Edward Elgar Publishing. 181-193 pp. DOI: 10.4337/9781789903874.00018.

Debie, E., Yayeh, T., & Anteneh, M. (2022). The Role of Sustainable Soil Management Practices in Improving Smallholder Farmers' Livelihoods in the Gosho Watershed, Northwest Ethiopia. *Cogent Food & Agriculture*, 8(1): 2097608. https://doi.org/10.1080/23311932.2022.2097608.

Dey, S., & Singh, P.K. (2023). Role of Market Participation on Smallholder Vegetable Farmers' Wellbeing: Evidence from Matching Approach in Eastern India. *Agribusiness*, John Wiley & Sons, 39(4): 1217-1237. DOI: 10.1002/agr.21813.

DFID (2001). Sustainable Livelihoods Guidance Sheets. The Department for International Development. UK. https://www.livelihoodscentre.org/documents/114097690/114438878/Sustainable+livelihoods+guidance+sheets.pdf/594e5ea6-99a9-2a4e-f288-cbb4ae4bea8b?t=1569512091877.

Donovan, J., & Poole, N. (2014). Changing Asset Endowments and Smallholder Participation in Higher Value Markets: Evidence from Certified Coffee Producers in Nicaragua. *Food Policy*, 44: 1-13. https://doi.org/10.1016/j.foodpol.2013.09.010.

Drewry, J.L., Shutske, J.M., Trechter, D., & Luck, B.D. (2022). Assessment of Digital Technology Adoption and Access Barriers among Agricultural Service Providers and Agricultural Extension Professionals. *Journal of the ASABE*, DOI:10.13031/ja.15018. (https://api.semanticscholar.org/CorpusID:252482989.).

Gogoi, M., & Borah, D. (2013). Baseline Data on Area, Production and Productivity of Horticulture Crops in North-East and Himalayan States - A study in Assam. Agro-Economic Research Centre for North-East India Assam Agricultural University, Jorhat–785013, Assam, 166: 182-8. https://aercnei.aau.ac.in/uploads/reports/Baseline%20Data%20on%20Area,%20Production%20and%20Yield%20of%20Horticulture%20Crops%20in%20North%20East%20and%20Himalayan%20States-%20A%20Study%20in%20Assam.pdf.

Guo, S., Fraser, M., & Chen, Q. (2020). Propensity Score Analysis: Recent Debate and Discussion. *Journal of the Society for Social Work and Research*, 11(3): 463–482. https://doi.org/10.1086/711393.

Haile, K., Gebre, E., & Workye, A. (2022). Determinants of Market Participation among Smallholder Farmers in Southwest Ethiopia: Double-hurdle Model Approach. *Agriculture & Food Security*, 11(18): 1-13. https://doi.org/10.1186/s40066-022-00358-5.

Hlatshwayo, S.I., Slotow, R., & Ngidi, M.S.C. (2023). The Role of Smallholder Farming on Rural Household Dietary Diversity. *Agriculture*, 13(3): 595. https://doi.org/10.3390/agriculture13030595.

Horton, D., Devaux, A., Thiele, G., Hareau, G., Ordinola, M., López, G., Mayanja, S., & Bernet, T. (2020). Collective Action for Inclusive Value-chain Innovation: Implementation and Results of the Participatory Market Chain Approach. Social Sciences Working Paper No. 2020-1. Lima, Peru: International Potato Center. http://doi.org/10.4160/02568748CIPWP20201.

Hui, B., Ma, W., & Hübner, N. (2023). Alternatives to Traditional Outcome Modelling Approaches in Applied Linguistics: A Primer on Propensity Score Matching. *Research Methods in Applied Linguistics*, 2(3): 100066. https://doi.org/10.1016/j.rmal.2023.100066.

Huka, H.A., Kilima, F.T., & Mchopa, A.D. (2023). Socio-Economic Factors Influencing the Participation of Smallholder Vegetable Farmers in High-value Markets (A Case Study of Arumeru District, Tanzania). *International Journal of Agricultural Science, Research & Technology (IJASRT)*, 13(3): 179-194. https://sanad.iau.ir/en/Article/1033820?FullText=FullText.

Huka, H.A., Kilima, F.T., & Mchopa, A.D. (2024). Impact of High-Value Market Participation on Income, Saving and Assets among Smallholder Vegetable Farmers in Arumeru District, Tanzania. *Cogent Food & Agriculture*, 10(1): 2398767. https://doi.org/10.1080/23311932.2024.2398767.

Jaworski, C. C., Thomine, E., Rusch, A., Lavoir, A. V., Wang, S., & Desneux, N. (2023). Crop Diversification to Promote Arthropod Pest Management: A Review. *Agriculture Communications*, 1: 100004. https://doi.org/10.1016/j.agrcom.2023.100004.

Kansiime, M.K., Bundi, M., Nicodemus, J., Ochieng, J., Marandu, D., Njau, S.S., Kessy, R.F., Karanja, D., Tambo, J.A., & Romney, D. (2021). Assessing Sustainability Factors of Farmer Seed Production: A Case of the Good Seed Initiative Project in Tanzania. *Agriculture & Food Security*, 10(1), 15. https://doi.org/10.1186/s40066-021-00289-7https://doi.org/10.1186/s40066-021-00289-7.

Keele, L., Stevenson, R. T., & Elwert, F. (2020). The Causal Interpretation of Estimated Associations in Regression Models. *Political Science Research and Methods*, 8(1), 1-13. https://doi.org/10.1017/psrm.2019.31.

Kilima, F.T.M**.** (2021). Integrating Smallholder Dairy Farmers into Formal Milk Markets in Tanzania: Key Lessons and Policy Implications. *Tanzania Journal of Agricultural Science*, 20 (1): 72-81. https://www.ajol.info/index.php/tjags/article/view/217206/204852.

Kilima, F. M., & Chikuni, A. C. (2021). The Role of Information and Communication Technologies (ICTs) in Enhancing Access to Markets and Marketing Efficiency for Small-scale Farmers in Tanzania. *Journal of Agricultural Science and Food Technology*, 7(6), 205-217. http://ijasrt.iau-shoushtar.ac.ir

Kilima F.T.M., & Kurwijila L.R. (2020). Integrating Smallholder Farmers to Commodity Value Chains in Sub-Saharan Africa: Challenges, Prospects and Policy Issues. In: Singh B., Safalaoh A., Amuri N., Eik L., Sitaula B., Lal R. (eds). *Climate Impacts on Agricultural and Natural Resource Sustainability in Africa*. Springer, Cham. 119-140 pp. DOI: 10.1007/978-3-030-37537-9_24.

Kim, Y., Armstrong, T.S., Gilbert M.R., & Celiku, O. (2025). Disparities in the Availability of and Access to Neuro-oncology Trial-supporting Infrastructure in the United States. *Journal of National Cancer Institute*, 1; 117(3): 511-516. https://doi.org/10.1093/jnci/djae240.

Kogachi, A., & Shaw, R. (2023). Application of Sustainable Livelihood Approach (SLA) to Address Climate-Induced Risks through the Lens of Africa Borderland. *Climate*, 11(3): 65. https://doi.org/10.3390/cli11030065.

Kreft, C., Angst, M., Huber, R., & Finger, R. (2023). Farmers' Social Networks and Regional Spillover Effects in Agricultural Climate Change Mitigation. *Climatic Change*, *176*(2): 8. https://doi.org/10.1007/s10584-023-03484-6

Legesse, T., Ashebir, A., & Kebede, K. (2023). Farmers' Participation Decision in High Value Market and Its Effect on Food Security of Smallholder Avocado Producers in Sidama Region, Ethiopia. *Research Square*, 1-29. https://doi.org/10.21203/rs.3.rs-3124184/v1.

Li, J., Ma, W., & Gong, B. (2023). Market Participation and Subjective Well-being of Maize Farmers. *Economic Analysis and Policy*, 80: 941-960. https://doi.org/10.1016/j.eap.2023.09.037.

Li, W., Shuai, C., Shuai, Y., Cheng, X., Liu, Y., & Huang, F. (2020). How Livelihood Assets Contribute to Sustainable Development of Smallholder Farmers. *Journal of International Development*, 32(3): 408-429. https://doi.org/10.1002/jid.3461.

Loki, O., & Mdoda, l. (2023). Assessing the Contribution and Impact of Access to Extension Services Toward Sustainable Livelihoods and Self-reliance in Eastern Cape Province, South Africa. *African Journal of Food, Agriculture, Nutrition & Development*, 23(4): 23000–23025. https://doi.org/10.18697/ajfand.119.22990.

Ma, W., Sonobe, T., & Gong, B. (2024). Linking Farmers to Markets: Barriers, Solutions, and Policy Options. *Economic Analysis and Policy*, 82: 1102-1112. https://doi.org/10.1016/j.eap.2024.05.005.

Mahofa, G., Mutyasira, V., & Sukume, C. (2022). Impact of Commercialisation Pathways on Income and Asset Accumulation: Evidence from Smallholder Farming in Zimbabwe. APRA Working Paper 89. Brighton: Future Agricultures Consortium. https://doi.org/10.19088/APRA.2022.024.

Makule, E., Dimoso, N., & Tassou, S. A. (2024). Production, Postharvest Practice, Marketing and Challenges of Smallholder Vegetable Producers in Tanzania. DOI: 10.22004/ag.econ.347784.

Manda, J., Alene, A.D., Tufa, A.H., Feleke, S., Abdoulaye, T., Omoigui, L.O., & Manyong, V. (2020). Market Participation, Household Food Security, and Income: The Case of Cowpea Producers in Northern Nigeria. *Food and Energy Security*, 9(3): e211. https://doi.org/10.1002/fes3.211.

Manda, J., Azzarri, C., Feleke, S., Kotu, B., Claessens, L., & Bekunda, M. (2021). Welfare Impacts of Smallholder Farmers' Participation in Multiple Output Markets: Empirical Evidence from Tanzania. *PloS One*, 16(5): e0250848. https://doi.org/10.1371/journal.pone.0250848.

Maqsood, H., Kwok, C.S., Gillani, S.A., Suri, F.K., Shah, Q.A., Siddiq, F., Gomez, C.R., & Qureshi, A.I. (2024). Regional Disparities in Mechanical Thrombectomy Utilization for Treatment of Acute Ischemic Stroke in the United States. *Stroke*, 55(Suppl_1): A139-A139. DOI: 10.1161/str.55.suppl_1.139.

Marion, P., Lwamba, E., Floridi, A., Pande, S., Bhattacharyya, M., Young, S., Villar, P.F., & Shisler, S. (2024). The Effects of Agricultural Output Market Access Interventions on Agricultural, Socio-economic, Food Security, and Nutrition Outcomes in Low-and Middle-income Countries: A Systematic Review. *Campbell Systematic Reviews*, 20(2): e1411. DOI: 10.1002/cl2.1411.

Mihrete, T. B., & Mihretu, F. B. (2025). Crop Diversification for Ensuring Sustainable Agriculture, Risk Management and Food Security. Global Challenges, 2400267. https://doi.org/10.1002/gch2.202400267.

Mchopa, A.D., & Jeckoniah, J.N. (2018). Impact of Sunflower Cultivation on Livelihood Outcomes among Smallholder Farmers in Iramba District, Tanzania. *Advances in Social Sciences Research Journal*, 5(10). https://doi.org/10.14738/assrj.510.5325.

Melaku, J., & Tadesse, T. (2019). Impact of Rural Infrastructures on Smallholder Farmers' Credit Market Participation in Ethiopia: The Case of Smallholder Farmers in Jimma Zone, Oromia Region. *Horn of Africa Journal of Business and Economics (HAJBE)*, 2(2): 71-90. https://journals.ju.edu.et/index.php/jbeco/article/download/612/67/.

Misra, R.L., & Baskaran, V. (2020). Global Floriculture Scenario. In: *Advances in Pest Management in Commercial Flowers*. pp. 57-62. Apple Academic Press. DOI: 10.4324/9780429284120-4 (https://www.taylorfrancis.com/chapters/edit/10.1201/9780429284120-4/global-floriculture-scenario-misra-baskaran).

Mkuna, E., & Wale, E. (2022). Explaining Farmers' Income via Market Orientation and Participation: Evidence from KwaZulu-Natal (South Africa). *Sustainability*, 14(21): 14197. https://doi.org/10.3390/su142114197.

Mmbando, F.E., Wale, E.Z., & Baiyegunhi, L.J. (2017). The Welfare Impacts of Market Channel Choice by Smallholder Farmers in Tanzania. *Development in Practice*, **27**(7): 981-993. DOI: 10.1080/09614524.2017.1353066.

Mohanty, T., & Doke, P.P. (2020). A Critical Appraisal of a Case-control Study on Healthcare Workers. *Indian Journal of Medical Research*, 152(1-2): 146-147. DOI: 10.4103/ijmr.IJMR_3025_20 (https://pubmed.ncbi.nlm.nih.gov/32801226/).

Morse, S., & McNamara, N. (2013). *Sustainable Livelihood Approach: A Critique of Theory and Practice*. Springer Science & Business Media. https://link.springer.com/book/10.1007/978-94-007-6268-8.

Moser, C., & Felton, A. (2007). The Construction of an Asset Index Measuring Asset Accumulation in Ecuador. Chronic Poverty Research Centre Working Paper No. 87. Available online at SSRN: https://ssrn.com/abstract=1646417 (http://dx.doi.org/10.2139/ssrn.1646417).

Mpogole, H., Kauki, B., Namwata, B., Ngilangwa, E., Mandara, C., & Hauli, E. (2023). Can Subsistence Farmers Commercialize? Evidence from the Southern Highlands of Tanzania. *Farming System*, 1(2): 100022. https://doi.org/10.1016/j.farsys.2023.100022.

Mukhebi, A. W., Kundu, J., Okolla, A., Wambua, M., Ochieng, W., & Fwamba, G. (2008). Linking Farmers to Markets through Modern Information and Communication Technologies in Kenya. DOI: 10.22004/ag.econ.51988.

Natarajan, N., Newsham, A., Rigg, J., & Suhardiman, D. (2022). A Sustainable Livelihoods Framework for the 21st Century. *World Development*, 155: 105898. https://doi.org/10.1016/j.worlddev.2022.105898.

Negi, A., & Wooldridge, J.M. (2021). Revisiting Regression Adjustment in Experiments with Heterogeneous Treatment Effects. *Econometric Reviews*, 40(5): 504-534. https://doi.org/10.1080/07474938.2020.1824732.

Nwangwu, K.N., Onyenekwe, C.S., Opata, P.I., Ume, C.O., & Ume, N.N.C. (2024). Can Digital Technology Promote Market Participation among Smallholder Farmers. *International Food and Agribusiness Management Review*, 27(4): 706-728. https://brill.com/view/journals/ifam/27/4/article-p706_6.xml.

Nyamba, S.Y., Kalungwizi, V.J., Mlozi, M.R.S., Busindeli, I.M., Kilima, F.T.M., Msuya-Bengesi, C.P., Chija, B.B., Mvena, Z.S.K., Gabagambi, D.M., Gjotterud, S.M., & Kiranga, E. (2020). Tomato Value Chain Information System in Tanzania: Lessons from Kilolo District and Dodoma Municipality, Tanzania. *International Journal of Agricultural Science, Research and Technology in Extension and Education Systems*, *10*(1): 9–15. http://ijasrt.iau-shoushtar.ac.ir/article_674032.html.

Olofsson, M., Ros-Tonen, M., Gupta, J., de Steenhuijsen Piters, B., & Van Leynseele, Y. (2021). Rethinking the Divide: Exploring the Interdependence between Global and Nested Local Markets: *Journal of Rural Studies*, 83: 60-70. https://doi.org/10.1016/j.jrurstud.2021.02.018.

Othman, M.S., Oughton, E., & Garrod, G. (2020). Significance of Farming Groups for Resource Access and Livelihood Improvement of Rural Smallholder Women Farmers: *Development in Practice*, 30(5): 586-598. https://doi.org/10.1080/09614524.2020.1764502.

Peddi, D., & Kumar K.S.K. (2021). Adoption of Soil Conservation Measures: Evidence from Rain-fed Watershed Areas of Telangana. *Ecology, Economy and Society-the INSEE Journal*, 4(2): 95-117. https://doi.org/10.37773/ees.v4i2.273.

Pozza, L.E., & Field, D.J. (2020). The Science of Soil Security and Food Security. *Soil Security*, 1: 100002. https://doi.org/10.1016/j.soisec.2020.100002.

Rajkhowa, P., & Qaim, M. (2021). Personalized Digital Extension Services and Agricultural Performance: Evidence from Smallholder Farmers in India: *PloS One*, 16(10): e0259319. https://doi.org/10.1371/journal.pone.0259319.

Rosenbaum, M. S., Russell-Bennett, R., & Contreras-Ramírez, G. (2021). Business Education in Profound Disruption. *Journal of Services Marketing*, *35*(5): 553-558. https://doi.org/10.1108/JSM-08-2021-528

Rutta, E.W. (2024). Postharvest Food Loss Reduction and Agriculture Policy Framework in Tanzania: Status and Way Forward. *Agriculture & Food Security*, 13(1): 36. https://doi.org/10.1186/s40066-024-00489-x.

Singh, B.R., Safalaoh, A., Amuri, N.A., Eik, L.O., Sitaula, B.K., & Lal, R. (eds.). *Climate Impacts on Agricultural and Natural Resource Sustainability in Africa*. Springer International Publishing. pp 407–428. DOI:10.1007/978-3-030-37537-9

Singh-Peterson, L., & Iranacolaivalu, M. (2018). Barriers to Market for Subsistence Farmers in Fiji – A Gendered Perspective. *Journal of rural studies*, 60: 11-20. https://doi.org/10.1016/j.jrurstud.2018.03.001.

Shrestha, S.K., Karki, T.B., Mahat, D., & Neupane, D. (2024). Analysing the Impact of Social Interaction on Stock Market Participation: A Qualitative Study Using NVivo. *Nepal Journal of Multidisciplinary Research*, 7(2): 57-69. https://doi.org/10.3126/njmr.v7i2.68245.

Sumari, G.S., Mishili, F., & Macharia, J. (2018). Participation of Smallholder Vegetable Growers in High-Value Market Chains in Arusha, Tanzania. *International Journal of Scientific and Research Publications*, 8(4): 371-380. http://dx.doi.org/10.29322/IJSRP.8.4.2018.p7653.

Tenny, S., Kerndt, C.C., & Hoffman, M.R. (2017). Case Control Studies. National Library of Medicine, National Centre for Biotechnology Information. https://www.ncbi.nlm.nih.gov/books/NBK448143/.

Wang, X., & Cheng, Z. (2020). Cross-sectional Studies: Strengths, Weaknesses, and Recommendations. *Chest*, *158*(1): S65-S71. DOI: 10.1016/j.chest.2020.03.012

Waris, A. & Kumar, S.A. (2022). Local Food Systems and Farmers' Markets-an Exploratory Study. *Asian Journal of Agricultural Extension, Economics & Sociology*, 40(12): 60-67. https://doi.org/10.9734/ajaees/2022/v40i121765.

Widadie, F., Wulandari, E., & Lestari, R.D. (2024). Business Models for Engaging Smallholder Farmers in High-Value Markets: Empirical Evidence from Vegetable Value Chains. *Agricultural and Resource Economics: International Scientific E-Journal*, 10(4): 179-202. https://doi.org/10.51599/are.2024.10.04.08

Yanuartati, B.Y.E. (2023). Understanding the Framework of Sustainable Rural Livelihoods in the Implementation of Market-led Rural Development. *Jurnal Penelitian Pendidikan IPA*, 9(5): 3800–3807. https://doi.org/10.29303/jppipa.v9i5.3572.

Zuleika, P. (2022). Cross-Sectional Study as Research Design in Medicine. *Archives of The Medicine and Case Reports*, 3(2): 256-259. https://doi.org/10.37275/amcr.v3i2.193.

SUPPLEMENTARY INFORMATION

Supplementary Table 1: Test for balancing after matching

Asset category	Sample	Ps R^2	LR chi^2	*p*>chi2	Mean Bias	Med Bias	B	R	% Concern	% Bad
Physical	Unmatched	0.125	65.08	0.000	25.0	18.7	87.9*	1.08	33	11
	Matched	0.014	2.90	0.968	6.7	4.5	27.8*	0.66	11	0
Natural	Unmatched	0.125	65.08	0.000	25.0	18.7	87.9*	1.08	33	11
	Matched	0.014	2.90	0.968	6.7	4.5	27.8*	0.66	11	0
Human capital	Unmatched	0.15	38.76	0.000	28.9	32.2	96.3*	1.50	56	11
	Matched	0.15	6.83	0.555	17.13	17.1	85.5*	5.91*	22	33
Social	Unmatched	0.12	65.08	0.000	25.0	18.7	87.9*	1.08	33	11
	Matched	0.01	2.90	0.968	6.70	4.5	27.8*	0.66	11	0
Financial	Unmatched	0.13	64.71	0.000	26.5	22.4	89.9*	1.04	33	11
	Matched	0.063	12.67	0.178	12.5	11.6	65.5	0.97	11	22

* If B>25%, R is outside the range of 0.5 to 2

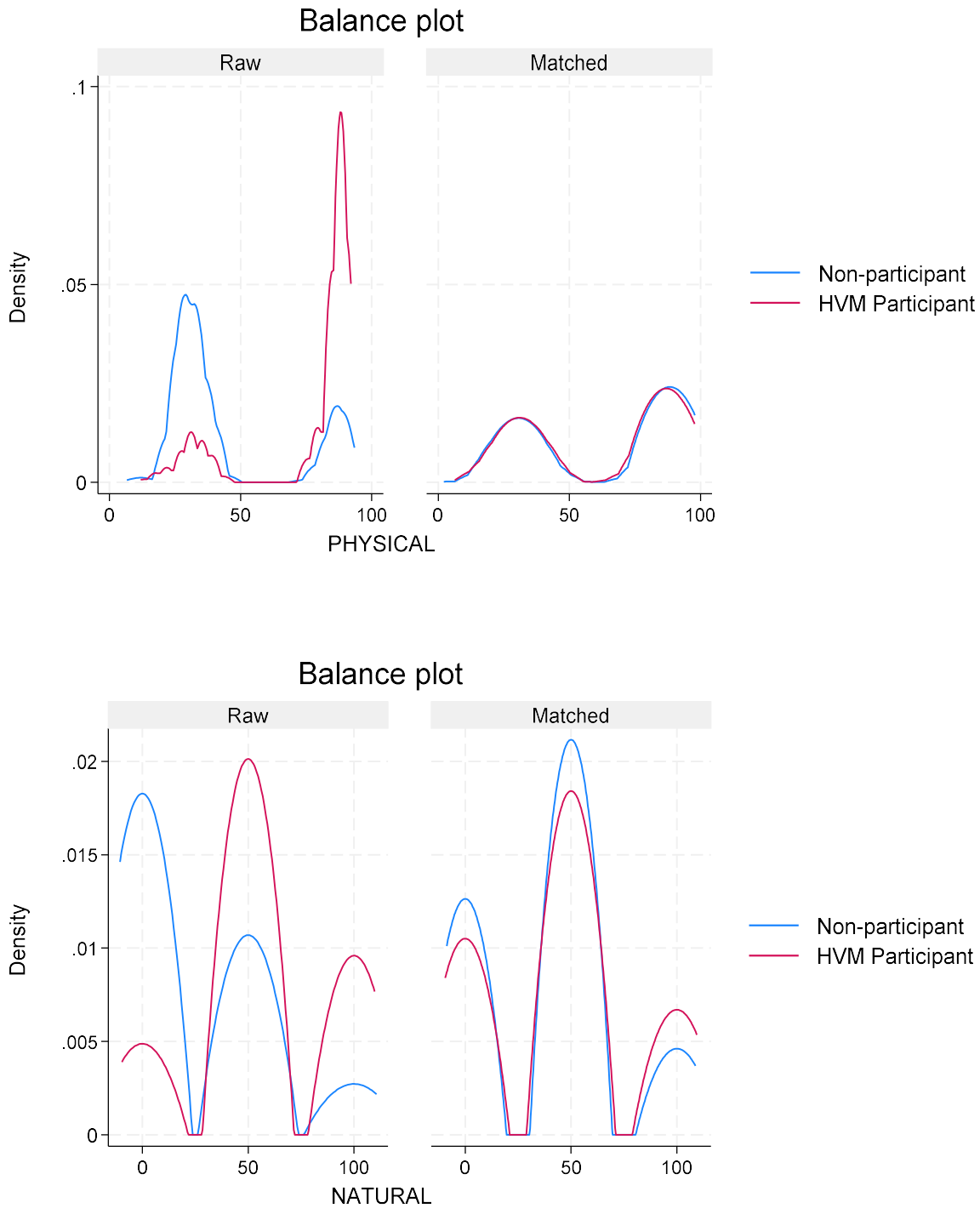
Supplementary Table 2: Assets owned by respondents by participation status in HVM

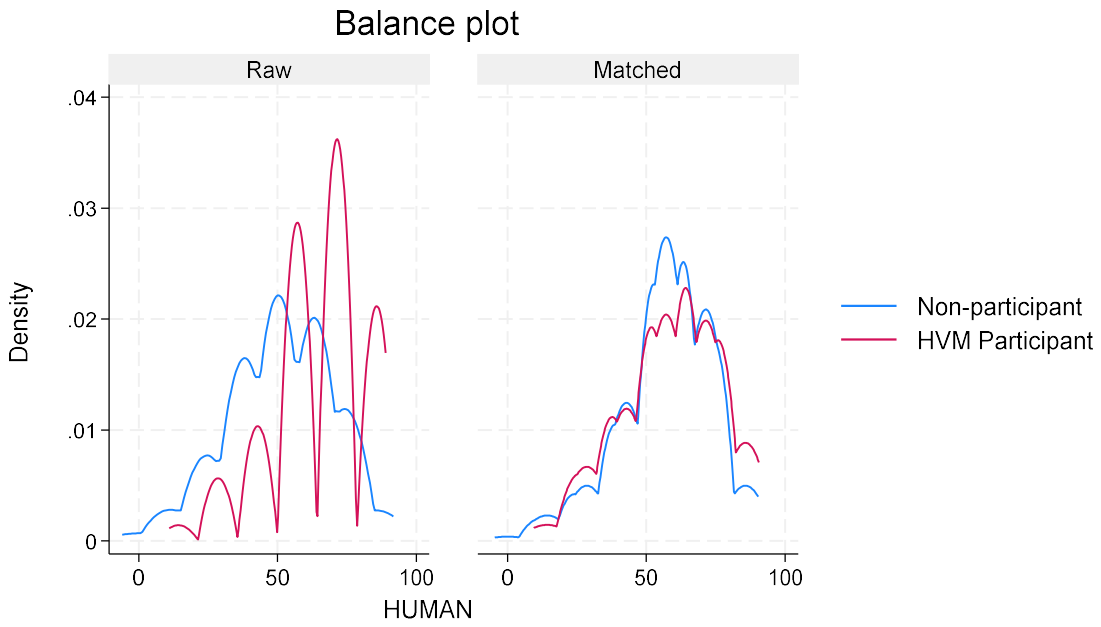
Asset	Participants		Non-participants		Chi-square Statistic (*p*)
Radio	Yes (%)	No (%)	Yes (%)	No (%)	
	81.04	28.90	18.96	71.10	105.7882 (0.000)
Bicycle	Yes (%)	No (%)	Yes (%)	No (%)	
	81.99	27.75	18.01	72.25	1114.4978(0.000)
Smartphone	Yes (%)	No (%)	Yes (%)	No (%)	
	58.33	33.33	41.67	66.67	2.9741(0.085)
TV	Yes (%)	No (%)	Yes (%)	No (%)	
	66.30	35.19	33.70	64.81	30.7709(0.000)
Watering can	Yes (%)	No (%)	Yes (%)	No (%)	
	81.50	31.52	18.50	68.48	97.9854(0.000)
Bed	Yes (%)	No (%)	Yes (%)	No (%)	
	81.4	28.90	18.96	71.10	105.7882(0.000)
Sofa set	Yes (%)	No (%)	Yes (%)	No (%)	
	71.88	28.91	28.12	71.09	64.4921(0.000)
Motor Vehicle	Yes (%)	No (%)	Yes (%)	No (%)	
	59.34	25.00	40.66	75.00	9.1517(0.002)
Ox plough	Yes (%)	No (%)	Yes (%)	No (%)	
	82.30	28.00	17.70	72.00	114.9428(0.000)
Chemical sprayer	Yes (%)	No (%)	Yes (%)	No (%)	
	82.57	24.70	17.43	75.30	129.1883(0.000)
Motorized water pump	Yes (%)	No (%)	Yes (%)	No (%)	
	81.22	28.07	18.78	71.93	109.6835(0.000)
Manual water pump	Yes (%)	No (%)	Yes (%)	No (%)	58.2644(0.000)

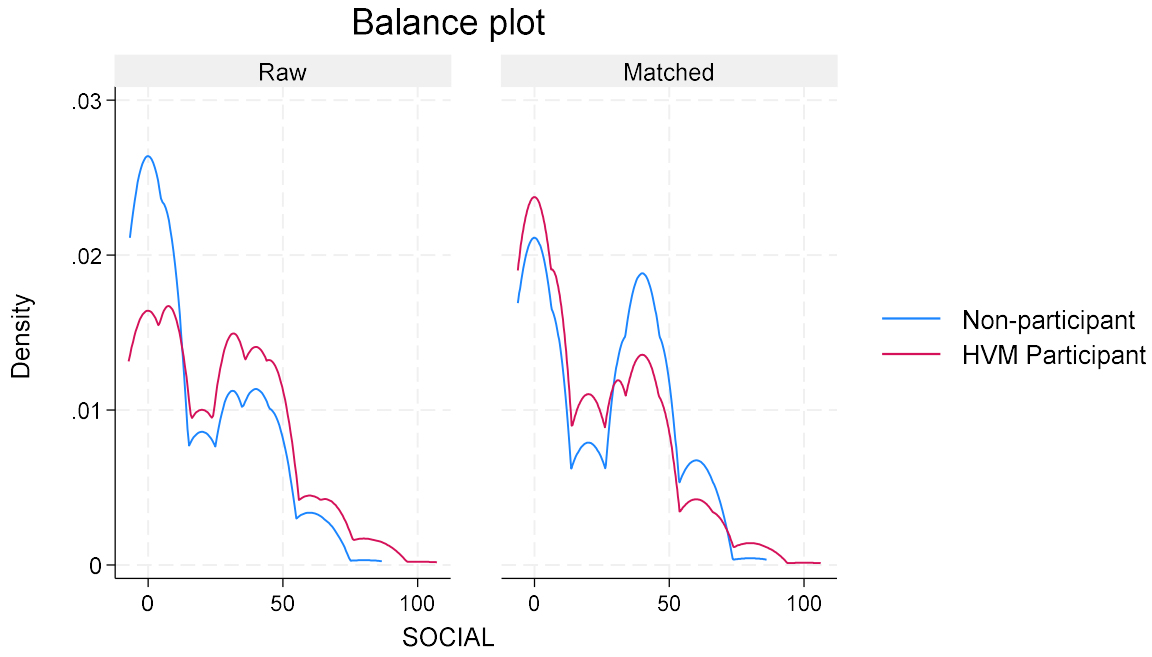
Asset	Participants		Non-participants		Chi-square Statistic (*p*)
	69.29	25.96	30.71	74.04	
Power machine	Yes (%)	No (%)	Yes (%)	No (%)	126.3450(0.000)
	24.54	81.90	75.46	18.10	
Cupboard	Yes (%)	No (%)	Yes (%)	No (%)	115.4132(0.000)
	82.61	28.25	17.37	71.75	
Biogas	Yes (%)	No (%)	Yes (%)	No (%)	126.3450(0.000)
	24.54	81.90	75.46	18.10	
Land	Yes (%)	No (%)	Yes (%)	No (%)	117.8954(0.000)
	83.01	28.09	16.99	71.91	
Cows	Yes (%)	No (%)	Yes (%)	No (%)	4.9952(0.025)
	58.65	28.57	41.35	71.43	
Goats	Yes (%)	No (%)	Yes (%)	No (%)	116.5151(0.000)
	82.08	27.33	17.92	72.67	
Solar power	Yes (%)	No (%)	Yes (%)	No (%)	124.1631(0.000)
	81.82	25.00	18.18	75.00	
Animal vehicle	Yes (%)	No (%)	Yes (%)	No (%)	124.4940(0.000)
	82.11	25.30	17.89	74.70	
Alternative source of energy	Yes (%)	No (%)	Yes (%)	No (%)	49.6839(0.000)
	68.46	28.57	31.54	71.43	
Adequate number of meals	Yes (%)	No (%)	Yes (%)	No (%)	4.9648(0.026)
	59.70	42.86	40.30	57.14	
Access to financial services	Yes (%)	No (%)	Yes (%)	No (%)	7.7721(0.005)
	62.26	47.06	37.74	52.94	
Access to education	Yes (%)	No (%)	Yes (%)	No (%)	5.9511(0.015)
	62.78	50.31	37.22	49.69	

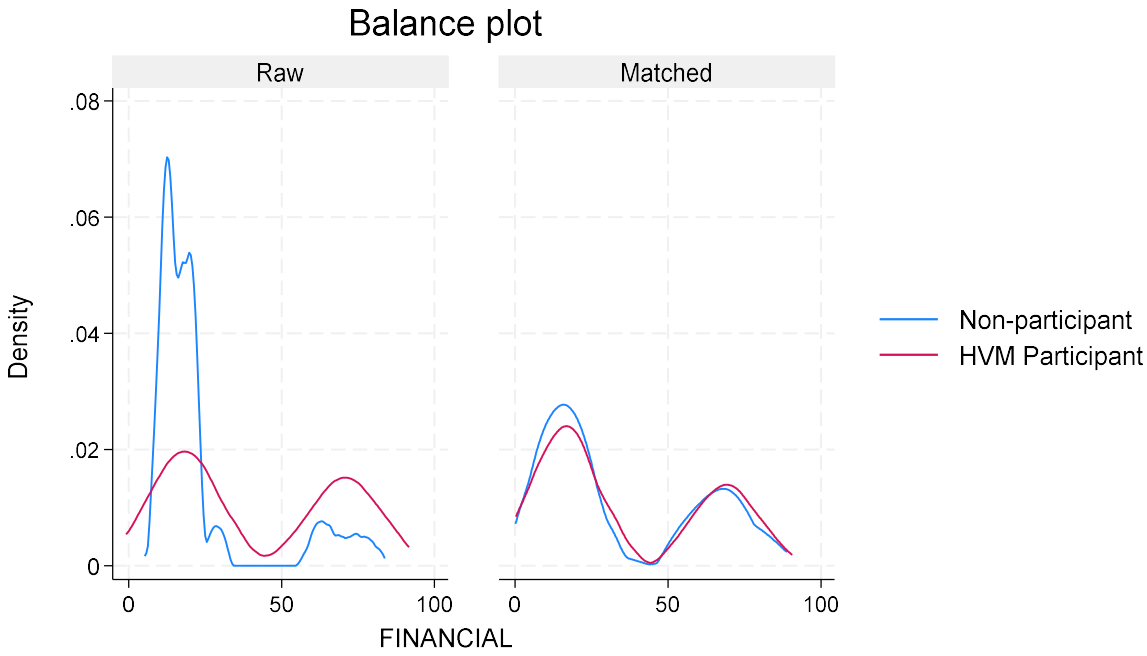
Asset	**Participants**		**Non-participants**		**Chi-square Statistic (*p*)**
Access to food	Yes (%)	No (%)	Yes (%)	No (%)	2.1154(0.146)
	60.62	53.16	39.38	46.84	
Access to health services	Yes (%)	No (%)	Yes (%)	No (%)	23.6395(0.000)
	66.27	40.31	33.73	59.69	
Food adequate throughout the year	Yes (%)	No (%)	Yes (%)	46.84	2.8816(0.090)
	60.46	51.24	39.54	48.76	

Supplementary Figure 1: Density functions of asset ownership indices before and after match




Balance plot
Raw
Matched
Density
.04
.03
.02
.01
0
0
50
100
HUMAN
Non-participant
HVM Participant


Balance plot
Raw
Matched
Density
.03
.02
.01
0
0
50
100
SOCIAL
Non-participant
HVM Participant


Balance plot
Raw
Matched
Density
.08
.06
.04
.02
0
0
50
100
FINANCIAL
Non-participant
HVM Participant