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Socio-economic analysis of market participation among small holder apple (*Malus domestica*) farmers in three key agro-ecological zones of Uganda

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Abstract

This study investigates the determinants of market participation among smallholder apple farmers in Uganda, focusing on the role of household income and education. Apple production in Uganda began in the Kigezi highlands and later expanded to Mt. Rwenzori and Mt. Elgon highland regions offering potential for income diversification, food and nutritional security. Previous research focuses on profitability of the enterprise rather than market participation. Moreover, literature reveals that market participation increases household income. However, it remains unclear whether income, in turn, promotes market participation. Similarly, the influence of education on market participation is debated, especially when measured solely by years of schooling. This study was designed to respond to such propositions through a cross-sectional household survey using semi-structured questionnaire, conducted among 270 randomly selected apple farmers in the three key highland agroecological zones of Uganda. Exploratory data analysis (EDA) and an instrumental variable (IV) Probit model were used to analyse the data. Results show that 88.9% of the farmers market their apple fruits in local wet markets. Findings reveal that market participation is positively influenced by gender (favoring males), yield ($P=0.000$), farmer group membership ($P=0.022$), market assurance ($P=0.026$), and extension support ($P=0.000$). Conversely, higher household income and elevated education levels negatively influence participation at 1% and 10% significant levels respectively. The study recommends strengthening of farmer group marketing and partnerships to facilitate market assurance and access. We also advocate for integrated vocational and agribusiness training into higher education to align education with practical market engagements. This study is however limited to use of cross-sectional data and one instrumental variable which renders interpretation of results as association relationships rather than definitive causal effects. Future research should explore use of panel data with inclusion of several instruments to enable definitive causal statistical inferences. The intensity and frequency of farmers' market participation should also be explicitly studied using Heckman or double hurdle models.



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Keywords Apple (*Malus domestica*), Smallholder farmers, Market participation, Instrumental variable probit model, Uganda

1 Introduction

Uganda continues to face persistent poverty challenges, with 16.1% of the population living below the national poverty line by 2024 [29]. Broader estimates by the World Bank indicate that more than 40% of Ugandans live below the international poverty threshold of US\$2.15 per day (approximately 7900 Ugandan shillings) [31]. In response, the government of Uganda rolled out poverty eradication programs such as Operation Wealth Creation (OWC), Emyooga, the Youth Empowerment Program, and the Parish Development Model (PDM), all focused on improving household incomes and welfare. With this movement of improving incomes at household level, apple farming has emerged as a promising income generating enterprise particularly in Kigezi highlands of Uganda with positive returns and net present value (NPV) of over US\$53,525.6 at 28% discount rate annually [22].

Globally, apples are among the most popular fruit crops, second to bananas in household consumption, with an estimated 90 million metric tons produced annually, led by China, the European Union, and the United States [5, 30]. The apple industry is valued at over US\$ 78 billion worldwide [3, 4]. Apples are not only economically significant but also nutritionally important, being rich in vitamins A, B, and C, proteins, carbohydrates, minerals, fiber, and phenolic compounds, which contribute to health benefits such as wound healing and strengthened immunity [18]. These attributes make apple production attractive both from a dietary and market perspective.

In Uganda, apple farming was introduced in 1999 through trials by the National Agricultural Research Organisation (NARO) and the World Agroforestry Centre (ICRAF) in the Kigezi highlands [20]. By 2010, two improved varieties (Anna and Golden Dorset) were officially released, with productivity levels reaching 14 to 18 tons per hectare under optimal conditions [2]. Since 2014, the government and its partners have distributed over three million seedlings, reaching more than 100,000 smallholder households [20]. This seed distribution scaled up production to about 3000 metric tons annually (\approx 25 million fruits), with reported returns of up to 20 times farmers' initial investments [22]. Current research efforts are focused on doubling productivity from 9.5 tons to potential 20 tons per hectare, which could increase annual output to more than 12,000 tons and significantly reduce reliance on apple imports [21].

Despite this growth and government efforts, Uganda still relies heavily on imported apples, spending over US\$6 million between 2018 and 2019 (UBOS, [28]). Imports declined slightly from 6710 tons in 2021 to 4990 tons valued at US\$3.73 million in 2022, while exports remained negligible [14]. Meanwhile, apple production has scaled beyond the Kigezi highlands to Rwenzori, Mt. Elgon, and some mid-altitude areas, with more than 20,000 farmers engaged in apple farming for income generation by 2022 [20]. Beyond income generation, apple farming contributes to nutrition security, soil conservation, and land ownership in highland communities [3, 22]. However, unlike cereals and legumes, socio economic research on fruits trees such as apples remains scanty in Ugandan setting. This gap undermines efforts to position apple production as a viable pathway for commercialization, agro-industrialization, improved household income,

poverty eradication and economic growth. To close this gap, this study examines the factors influencing the market participation of apple farmers in Uganda key for identifying policy and institutional interventions needed to strengthen local apple marketing, enhance farmer incomes, enhance socio-economic transformation aligned with the national development agenda (Vision 2040 & National Development Plan 4- NDP IV) and contribute to international development perspectives such as sustainable development goals (SDGs) such as no poverty (SDG 1) and good health & well being (SDG 3).

2 Materials and methods

2.1 Study area

The study was conducted in Southwestern highlands (Kigezi highlands), Lake Albert crescent (Rwenzori Mountain ranges) and Mount Elgon region (Eastern highlands) which are the three major apple growing agro-ecological zones of Uganda. The zones are characterized by distinct climatic and geographical features that influence agricultural practices including apple production. Kigezi highlands is characterised by terraced landscapes and moderate temperatures (10 °C to 23 °C). The highlands have cool climate and rich volcanic soils, that support the cultivation of crops like tea, coffee, potato, sweet potatoes and various temperate fruits including apples and pears. Rwenzori mountain ranges have a cool climate with temperatures ranging from 10 °C to 15 °C during the day and 2 °C to 6 °C at night which are ideal for apple cultivation. Apple production in the area is often integrated with other high-value crops especially coffee and cocoa. Mount Elgon region features high altitudes and rich volcanic soils, supporting the cultivation of crops like coffee, maize, and various fruits including apples. The zone is also known for its unique biodiversity, cool temperatures (15 °C to 25 °C) and well-drained soils that favour apple production among other high value crops. The three distinct Agro-ecological zones (area of study) are highlighted on the map of Uganda in Fig. 1.

The map in Fig. 1, was generated by the first author using Quantum Geographical Information System (QGIS; version 3.44.1, 'Solothurn' at <https://download.qgis.org>),

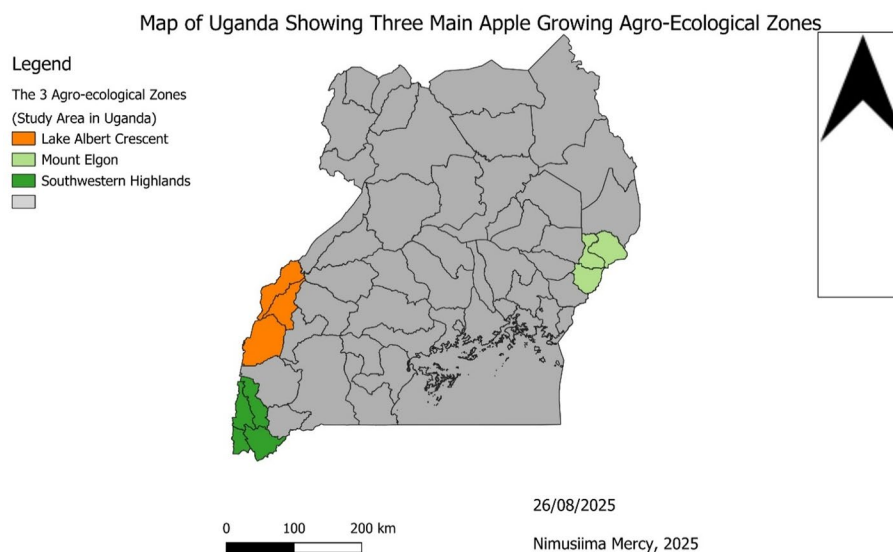


Fig. 1 The map of Uganda Highlighting the Study Area. Source: Author Developed Map in QGIS, 2025

which is a free, open source software that allows users to create, edit, visualize, analyze and publish geospatial information.

2.2 Sampling and data collection

This study was guided by a pragmatic research paradigm, which supports mixed methods by integration of both quantitative and qualitative approaches based on dynamic ontology (reality) and knowledge in this context. A cross-sectional survey design was employed targeting randomized apple growing households in the three major apple producing agro-ecological zones in Uganda. Since the actual population was not well known, the sample size was determined using Cochran's sampling technique specified in Eq. 1.

$$n = \frac{Z^2 pq}{e^2} \quad (1)$$

Where $z = 1.96$, $p = 0.5$, $q = 1 - p$, $e = 0.05$, and inserting the values in Eq. 1 yields a sample size of approximately 385 respondents. Accordingly, a sample of 270 farmers were randomly selected and interviewed using a semi-structured questionnaire. The sample size representing each agro-ecological zone is summarized in Table 1.

2.3 Data analytical procedures

Using STATA version 15, exploratory data analysis (EDA) including descriptive statistics were used to characterize apple growing households and marketing pathways. A Probit model was employed to examine the determinants of market participation decision (binary dependent variable). For unbiasedness, consistency and correct estimation of probabilities and marginal effects, the model was first subjected to heteroskedastic and endogeneity tests. During heteroskedasticity test, a likelihood ratio test ($LR = -2[L_{Restricted} - L_{Unrestricted}]$) was used where the standard Probit model represented a restricted model while a heteroskedastic Probit model represented unrestricted model (the variance of the error term depends on explanatory variables). The non-significant ($P > 0.05$) chi-square distribution test result indicated that there is a constant variance across the error terms hence we fail to reject the null hypothesis of homoscedasticity. For independence of explanatory variables (Table 2) and the error term (endogeneity), annual household income was suspected to be endogenous based on economic theory of simultaneity bias of income and market participation. The Wald test of exogeneity of annual income resulted into $\chi^2(1) = 63.49$ and $P = 0.000$, hence the null hypothesis was strongly rejected and endogeneity was confirmed present. An instrumental variable (IV) Probit regression model (Eqs. 2 and 3) was then adopted since it yields robust estimates when dealing with endogeneity in choice modelling. Production costs were used to instrument annual income. For validity of the instrument, a first stage F-statistic test was performed and the coefficient of production costs on income was $3.78e + 07$ significant at 5% ($P = 0.043$).

Table 1 The Sample Size from the Three Apple Growing Agro-ecological Zones in Uganda

Agro-Ecological Zone	Frequency (n)	Percentage (%)
Kigezi Highlands	108	40.0
Rwenzori Highlands (Lake Albert Crescent)	116	43.0
Elgon Highlands	46	17.0
Total	270	100

Table 2 Variables Hypothesized to Influence Market Participation of Apple Farmers

SN.	Variable description	Theoretical selection of the variables	Ex-pected effect	Source
Y*	Participation in apple marketing, (Yes = 1, No = 2)	Market participation was based on account of selling apple fruits formally or informally	N/A	Olwande et al. [24]
X1	Level of education; 1 = No formal education, 2 = Primary level, 3 = Secondary (O level), 4 = Secondary (A level), 5 = Tertiary level	No/less education may hinder access to market information hence negative effect. On the other hand, no/less education limits other non-farm income sources fostering market participation	-/+	Haile et al., [15] Martey et al. [19]
X2	Yield (Output per acre in Tons)	Increased output increases marketable surplus hence promoting market participation	+	Boughton et al. [11]; Jaleta et al. [17]
X3	Annual income (Ugx)	As market participation increases income, income is expected to simultaneously increase market participation through facilitating transaction costs	+	Oluwole and Babajide [23]
X4	Gender (Male = 1, Female = 0)	Males are fond of engaging in marketing activities and are believed to have strong bargaining power than females. However, to some extent, females may engage in marketing some specific (low- value) crops	+/-	Hlatshwayo et al. [16]
X5	Belonging to farmer group (Yes = 1, No = 0)	Being in farmer group promotes bulk sales, improves bargaining power and enables access to market information thus promotes market participation	+	Sigei et al. [26]
X6	Market assurance (Ready market; Yes = 1, No = 0)	An assured market enhances market participation due to reduced hustles and marketing costs	+	Amgai et al. [8]
X7	Access to extension services (Yes = 1, No = 0)	Extension promotes access to technical knowledge, market information and opportunities which translates into market participation	+	Omiti et al. [25]; Abafta et al. [1]

Y* represents latent independent variable (Market Participation), X1 to X7 are the independent variables

This means production costs are correlated with annual income, satisfying the relevance condition of the instrument. For exogeneity of the instrument, theoretically, production costs exogenously affect household income and do not directly affect market participation decision, except through income. This way, the coefficients are unbiased, the estimates consistent and the statistical inferences about the hypotheses and recommendations are reliable. An instrumental variable Probit model was thence appropriate for the econometric analysis due to endogeneity. Multicollinearity test was also conducted using Variance Inflation Factor (VIF) and the test values ranged from 1.06 to 1.23, with a mean of 1.15. Since the values were all below the threshold of 10, then the independent variables were less correlated hence fit for modelling.

Market participation was proxed to a farmer’s tendency to sell part or all his/her apple fruit output. Consider the binary outcome model structure in Eq. 2 (First-stage estimation),

$$Y^* = X\beta + Z\gamma + \epsilon \tag{2}$$

Y* is the latent (unobserved) variable of participation, Y = 1 if Y*>0 otherwise, Y = 0, X includes the exogenous variables, Z includes the endogenous variables and instruments, and ϵ is the error term which was assumed to be jointly normal (i.e. follow standard normal distribution) as specified structurally in Eq. 3 where in the main probit equation, the dependent variable is binary (Y = 1 and 0 other wise) such that;

$$P(Y_i = 1 \mid X_i, Z_i, \epsilon_i) = e^{\phi(X_i\beta + \epsilon_i)} / 1 + \left(e^{\phi(X_i\beta + \epsilon_i)} \right) \quad (3)$$

Where Y_i is the binary dependent variable (Market participation; Yes = 1, No = 0), X_i is the vector for exogenous independent variables specified in Table 1, Z_i is the endogenous independent variable (annual household income), e is the exponential term, Φ is the cumulative distribution function (CDF) of the standard normal distribution and ϵ_i is the error term. A second stage estimation using OLS would have been performed (the two-step approach) but a full information maximum likelihood (FIML) was preferred for its efficiency. The final instrumental variable (IV) Probit model was thus estimated using the FIML method where both the structural and first stage equations are jointly estimated to account for endogeneity directly. A likelihood ratio test ($LR = -2[\ln L_{null} - \ln L_{full}]$) was used to test for goodness of fit where the significant value ($p < 0.05$) suggested rejection of the null hypothesis and we concluded that the model was fitted well with the explanatory variables (L_{null} represents an empty model and L_{full} represents a model with explanatory variables). Due to the non-linear relationship between predictors and probabilities, marginal effects ($\frac{dy}{dx}$) were used to estimate the change in the probability of the outcome ($P(Y=1)$) for a one-unit change in predictor variables *ceteris paribus*. Table 2 presents predictor (independent) variables which are hypothesized to influence market participation (the dependent) of apple farmers.

2.4 Validity, reliability and trustworthiness

To ensure methodological rigor, the study employed multiple strategies to address validity, reliability, and trustworthiness across its design and analysis. Construct validity was enhanced by operationalizing education through a Likert scale, capturing practical relevance beyond formal years of schooling. Content validity was ensured through expert-informed semi-structured questionnaires tailored to Uganda's apple farming context, while statistical validity was strengthened using an Instrumental Variable (IV) Probit model to address endogeneity between income and market participation. For relevance of production costs as instrumental variable for income, the first-stage regression results indicated that production costs significantly predict household income ($\beta = 3.72e+07$, $p = 0.046$ ie statistically significant at 5%) hence a valid instrument. However, the F-statistic of 5.87 (below conventional threshold of 10), suggested that the instrument is relatively weak [27]. But due to data and instrument limitations, we maintained the production costs as instrumental variable for income and the results are therefore interpreted as suggestive associations and not definitive causal effects." Reliability was supported by standardized data collection across three highland regions for representativeness, with trained enumerators and internal consistency was validated by the acceptable Cronbach's alpha of 0.76 suggesting that the items measured the same construct. Although primarily quantitative, the study incorporated interpretive elements through open-ended responses and contextual analysis. Trustworthiness was addressed by grounding interpretations in empirical data and local dynamics, providing thick descriptions of the study context to support transferability, and linking policy recommendations directly to observed patterns to enhance confirmability. These measures collectively reinforce the credibility and replicability of the findings.

3 Results

3.1 Socio-economic and demographic characteristics

Results in Table 3, indicate that male apple farmers with over 50 years of age dominate the apple farming enterprise. Over 90% of the apple farmers have attained formal education spanning primary, secondary (O' and A`level) and Tertiary levels. Many farmers access extension services and over 88% participate in apple marketing (sell part or all their apple produce). However, a few farmers are assured of the market through various marketing pathways.

Source. Author Field Survey Data of 2021 and the average US dollar (US\$) exchange rate was at 3586.6115 UGX. (<https://www.exchangerates.org.uk>)

3.2 Marketing pathways for locally produced apples

Hawking was the common marketing pathway, followed by farm gate and wet market sales as indicated in Table 4. Some farmers sell the local apple fruits through a combination of channels including farm gate, wet fruit markets, supermarkets, hawking, roadside selling and cooperative.

3.3 Econometric results of market participation

Instrumental variable (IV) probit being used to control for potential endogeneity due to simultaneity bias, the results are summarised in Table 5. The Wald $\chi^2(9) = 115.65$ and $p < 0.001$, suggest that the explanatory variables are jointly significant and the model provides a good fit to the data. Since the VIF values ranged from 1.06 to 1.23, with a mean of 1.15, all below the threshold of 10, then multicollinearity was not a concern in the model hence the estimated coefficients are reliable. Autocorrelation was unlikely since the data was cross-sectional. Although homoskedasticity was initially identified, we estimated robust standard errors to account for any possible heteroskedasticity. These diagnostic checks verify that the model estimated is reliable and robust.

Whereas yield, annual income and extension support were significant at 1%, gender, belonging to farmer group and market assurance were significant at 5% while education

Table 3 The social economic characteristics of apple farmers

Variable		Frequency (n)	Percentage (%)	
<i>Gender</i>	Male	223	82.6	
	Female	47	17.4	
<i>Education Level</i>	No formal education	16	5.9	
	Primary Level	73	27.0	
	Secondary (O`Level)	77	28.5	
	Secondary(A`Level)	45	16.7	
	Tertiary Level	59	21.9	
<i>Market participation</i>	Yes	240	88.9	
	No	30	11.1	
<i>Access to extension</i>	Yes	198	73.3	
	No	72	26.7	
<i>Market assurance</i>	Yes	73	27.0	
	No	197	73.0	
	Mean	Std. Err.	[95%Conf.Interval]	
<i>Age (Years)</i>	52.80	0.89	51.05	54.54
<i>Annual Income (Ugx)</i>	2.76e+07	1.30e+07	1,996,088	5.32e+07
<i>Annual Production Costs (Ugx)</i>	1,480,043	282,935.5	922,993	2,037,092
<i>Yield (Tons per acre)</i>	3.83	0.391	3.06	4.60

Table 4 Marketing Pathways of Small Holder Apple Farmers

Market Pathways	Frequency (n)	Percentage (%)
No sales	30	11.11
Farm gate	62	22.96
Hawking	67	24.81
Wet market	46	17.04
Supermarket	13	4.81
Cooperative	13	4.81
Farm gate and roadside selling	5	1.85
Farm gate and fruit market	9	3.33
Farm gate and supermarket	2	0.74
Roadside selling and fruit market	6	2.22
Roadside selling and supermarket	3	1.11
Fruit market and supermarket	2	0.74
Farm gate, roadside and supermarket	3	1.11
Farm gate, roadside and fruit market	2	0.74
Farm gate, fruit market and supermarket	2	0.74
Farm gate, fruit market and cooperative	3	1.11
Roadside, fruit market and cooperative	2	0.74
Total	270	100.00

Table 5 IV Probit Model Results of Market Participation Determinants

Market participation (n = 270)	dy/dx	Std. Err.	Z	P > z	[95% Conf.Interval]	
Annual income	-4.22E-09	8.60E-10	-4.9	0.000	-5.91E-09	-2.53E-09
Gender	0.667	0.279	2.39	0.017	0.121	1.216
Belong to farmer group	0.508	0.221	2.29	0.022	0.073	0.943
Extension support	0.280	0.009	32.57	0.000	0.263	0.297
Market assurance	1.171	0.525	2.23	0.026	0.143	2.199
Yield (Ton per acre)	0.225	0.061	3.66	0.000	0.104	0.345
Education						
Primary level	-0.461	0.292	-1.58	0.114	-1.033	0.110
Secondary (Ordinally level)	-0.662	0.469	-1.41	0.158	-1.581	0.257
Secondary (Advanced level)	-0.550	0.312	-1.76	0.078	-1.162	0.063
Tertiary	-0.572	0.318	-1.8	0.072	-1.195	0.052

Wald $\chi^2(9) = 115.65$, Prob > $\chi^2 = 0.000$

(secondary “advanced level” and tertiary level) was significant at 10%. Female farmers with advanced and tertiary level of education and, earning more incomes are less likely to participate in the market. Male farmers coupled with higher yields, belonging to farmer groups and assurance of the market are more likely to participate in marketing their apple fruits.

4 Discussion

Many apple farmer respondents were from Albert crescent (particularly, Kasese district in Rwenzori sub region) due to established institutional arrangements through a reputable farmer cooperative (Kasese Apple Grower Organization-KAGO). The cooperative provides institutional support by promoting and supporting apple farming through lobbying the government for quality seedlings, facilitating trainings, and enhancing collaboration with research and development organizations. The cooperative also facilitates apple marketing through bulk sales, advocating for better post-harvest handling practices for quality apple produce and negotiating for premium prices. Apple growing is

a male dominated enterprise which is attributed to the traditional land tenure system behaviour of land being owned and accessed by men. This observation aligns with [13] who revealed that men are much more likely to acquire land through inheritance, distribution by communities or the state and through direct purchase compared to the female counter parts. Apple being a perennial crop is a sign of land ownership yet more land is owned by males explains why male farmers dominated apple farming [22]. Also, the fact that apple farming is a labor-intensive enterprise such that most orchard activities especially pruning, and defoliation are normally executed by males than females explains the dominance of males in apple farming enterprise.

Farmers that marketed their apple fruits, sold them mainly through lucrative imperfect markets characterized by lack of proper market information on available and potential demand, premium prices, consumer tastes and preferences. Average selling price ranged from 3000ugx to 5000ugx per Kilogram (Kg) with 6 to 12 fruits in a Kg dictated by location, size and quality of the fruits and consumers profiles. However, most farmers did not sell in Kgs but rather individual (singular) fruits with the price of each fruit ranging from 200ugx to 1000ugx depending on the size, quality and location. Unlike a few farmers who sold through cooperatives, the common marketing pathways were farm gate, roadside selling, hawking, direct supply to supermarkets and local wet market stalls. This observation concurs with the findings by [22] which reveal that the main marketing channels for locally produced apples in Uganda are supermarkets, open markets, roadside selling, vending and direct sell to neighbours at farm gate. On the contrary, in other developing economies like Nepal, [8] found out that most apple producers market their produce via pre-harvest contract system while others sell directly to wholesalers/collectors. Generally, the marketing system of locally produced apples is not well developed in Uganda such that some farmers don't sell any of their apple fruits, a condition known as Autarky in economics [12].

Considering factors that affect market participation among small holder apple farmers, annual household income had a strong negative significant effect on market participation. Whereas, market participation positively influences household income according to Oluwole & Babajide, 2019, household income does not translate into market participation in this study. This study reveals that increasing income minimizes the probability of market participation, which contradicts the hypothesis that increase in income increases market participation by facilitating transaction costs. This observation is attributed to the fact that most well off farmers do not grow apples as the primary source of income but rather for alternative benefits such as home consumption (nutritional security), soil conservation and to some extent as a sign of land ownership as highlighted by Ntakyo et al. [22]. Such households have alternative income sources like remittances and off farm employment hence rendering income from apples less attractive and thus minimum market participation. Increased income also increases affordability of better storage facilities (cold storage), delaying sales and even shifting to local processing which reduces chances of direct fresh fruit sales. Whereas income increases, structural barriers like poor road networks, variable transaction costs and low bargaining power in markets may discourage market participation. Haile et al., [15] argue that poor road networks and high transaction costs discourage small holder farmers from actively participating in established markets. The traditional subsistence behaviour of small holder farmers may also explain the negative relationship between income and market participation.

Extension support significantly and positively influences farmers' market participation as prior hypothesized. Although Haile et al., [15] found that extension had a negative influence on market participation, this study's positive finding is consistent with Omiti et al. [25] and Alene et al. [6] which demonstrate that access to extension services increases market participation due to enhanced farmers' technical knowledge, improved productivity, reduces risks, less uncertainty and dynamic marketing barriers. Similarly, Abafita et al. [1] found that extension support increases farmers' access to production technologies, market information and market opportunities which foster commercialization through market participation.

Increase in apple yield increases probability of market participation as increased output is associated with more marketable surplus (output beyond household consumption needs). This finding is anchored on the theory of surplus value as put forward by Karl Marx in his critique of political economy in 1863 exposing norms, axioms, social relations and institutions. The observation is also consistent with Chikhawo et al., [12] who argue that higher output levels increase smallholder farmer market participation. Increase in apple yield comes with increased production, and relatedly, apple production in Uganda has scaled up to over 3,000 metric tons annually [20], with reported returns of up to 20 times farmers' initial investments [22]. Such scaled production and returns on investment facilitate market participation [9].

Market assurance positively influence market participation probability because market assurance is associated with readily available market information in terms of pricing mechanism, quality requirements (tastes and preferences), available and effective demand. Market assurance reduces risks and uncertainty of lack of market which encourages farmers to engage in marketing. During the study, farmers were willing to enter a contract agreement with promising buyers such as factories like Uganda Breweries Limited (UBL) which would be a sure deal market. The farmers even promised to double their efforts and expand their orchards to boost production if such arrangements come to fruition. The most promising marketing system that enhances market assurance is contractual farming system as observed in Nepal by [8]. This is because market assurance reduces risks of uncertainty by providing effective demand.

Gender positively and significantly influenced market participation decision such that being male increases the probability of market participation compared to female counter parts. This observation was attributed to varying gender roles, cultural or societal norms. It was revealed that males have ability to search for available markets during developmental community tours and engagements. The study findings concur with [26] who argue that males have strong bargaining and negotiating power which increases chances of market participation. Since marketing is a risky activity, [7] highlight that a gender gap in risk taking remains significant such that women participate less than men in such risky ventures like open marketing, stock markets and have lower score on financial literacy. Hlatshwayo et al. [16] explains that women are less engaged in market participation because they are more likely to be engaged in gender roles and intermediary income generating activities. However, findings by Zamasiya et al. [33] contradict the study findings indicating that being male reduced market participation based on type of crop/enterprise.

The effect of education level was more nuanced. While primary and secondary (ordinary) levels of education had no significant effect on market participation, secondary

(advanced) and tertiary levels significantly but negatively influenced market participation. Farmers with higher levels of education (secondary “advanced” and tertiary levels) were less likely to participate in marketing apple fruits. This contradicts the prior hypothesis and the findings by Martey et al. [19] in Ghana and Bellemare and Barrett [10], who found that higher education levels increase market participation due to enhanced farmers’ ability to access and process market information. However, the negative influence observed in this study aligns with [15] who found that increased years of schooling decreases market participation. The negative association is attributed to the higher opportunity cost in farming where educated household heads prioritize off-farm income sources and formal employment such that higher education does not directly translate into commercial farming engagements.

Belonging to farmer group increases the likelihood of market participation by apple farmers as earlier anticipated. This is because being in a group enhances access to market information, extension services, aggregation (bulking efforts) and enhances the bargaining power for premium prices. For example, the apple farmer cooperative in Kasese and in Rukungiri facilitates access to timely buyers at premium prices as opposed to farmers who are not in the cooperatives/farmer groups. This observation concurs with the findings by [26] highlighting that farmer groups are characterized by bulk marketing which increases bargaining power, facilitates knowledge transfer, information flow, helps farmers to pool resources and output and, encourage advantage of economies of scale. Alene et al. [6] argue that institutional innovations such as group marketing increases market participation by minimizing transaction costs involved in marketing.

5 Conclusions and recommendations

Apple production has gained potential in Uganda having spread to three highland agro-ecological zones. However, the ability of small holder farmers to commercialize apple output by selling fresh apple fruits (market participation) is still in infancy stages. Most marketing pathways used by farmers are lucrative and uncoordinated posing a challenge towards market participation and overall commercialization of the apple enterprise in Uganda. This study provides evidence of significant associations between key socio-economic and institutional factors and market participation among smallholder apple farmers. However, the causal interpretation of these relationships is subject to limitations, particularly regarding the use of instrumental variable in addressing endogeneity. To promote market participation for a commercialized apple enterprise, boosting economic growth of a developing country like Uganda, there is need for researchers and technical advisors to promote yield boosting mechanisms such as recommended apple culture and agronomic practices, pests and disease management and soil fertility/nutrient management techniques. Policy makers should advocate for strengthened extension system to enable farmers access technical knowledge, market information and enhanced market participation. The education policy should incorporate general vocational and agribusiness-specific trainings in higher education curriculum to foster agricultural market participation among highly educated households. Farmers are advised to operate in farmer groups/cooperatives to facilitate collective marketing, timely market access and premium price negotiations. Future research should further explore the negative association between income and market participation. Future similar studies could also employ more instruments and use panel data approaches to establish robust

causal inference. Since the study did not examine the level (extent) of market participation, future researchers could also investigate factors that influence level of market participation by simultaneously assessing both the decision to participate and the level of participation through use of Double hurdle or Heckman models.

5.1 Limitations of the study

This study's limitations are that; the use of only one instrumental variable whose validity relies on the exclusion restriction, may be subject to violation which cannot be directly tested. Second, the use of cross-sectional data limits the ability to fully address dynamic relationships and reverse causality. Third, measurement errors in key variables such as income and production costs may affect the estimates. The study focused only on the decision to participate (binary out come) neglecting the intensity or extent of participation which limits the knowledge base on the frequency of participation.

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Author contributions

M.N. Conceptualized the study, collected and analyzed data, wrote the first draft and reviewed the submission copy of the manuscript. R.A. Conceptualized the study, collected the data, reviewed the first draft draft and facilitated funds acquisition. J.K. Facilitated funds acquisition and supervised the overall process. All authors generally reviewed the manuscript.

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Data availability

The data supporting the reported results can be accessed via email of the corresponding author upon request.

Declarations

Ethics approval and consent to participate

This research was based on the ethical declaration of Helsinki [32] following the principles of respect for individuals including the right to self-determination and the right to make informed decisions regarding participation in the research. The privacy of research subjects (personal information) was treated with utmost confidentiality. The research is scientifically sound and was conducted by qualified research team. This study was conducted in authorization with the National Agricultural Research Organization Science Committee (NARO-SC) who waived the need of ethics approval by an Institutional Review Board (IRB) due to the research mandate default of the organization (the National Agricultural Research Organization-NARO). Established as a corporate autonomous body by the National Agricultural Research Act of 2005, NARO comprises a Governing Council with Committees including the science committee (SC) and audit committee (AC), a Secretariat and 16 Public Agricultural Research Institutes (PARIs) spread across the country. The organization is mandated to undertake research in all aspects of agriculture including crops, livestock, fisheries, forestry, agricultural engineering, environmental and natural resources economics. The organization coordinates and oversees all aspects of public-private partnership funded agricultural research in Uganda based on pre-designed work plans and pre-evaluated research designs by research officers in charge guided by the respective directors of research and the overall NARO governing council with committees supporting the system. This justifies why the study did not require further approval by an independent IRB. Informed consent was obtained from all individual participants included in the study. All participants were fully informed of the study and voluntarily agreed to participate in the study.

Consent for publication

The authors consented to the publication of this manuscript. All co-authors reviewed and approved publication of the final version.

Competing interests

The authors declare no competing interests.

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