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Does choosing processed-potato marketing channels affect household income? Evidence from Musanze District, Rwanda

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Article

Keywords: Household income, Musanze, processed-potato marketing channel

Posted Date: November 20th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11584541/v1

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Additional Declarations: No competing interests reported.

Abstract

Enhancing smallholder farmers' access to reliable markets is a key strategy to improving incomes in the developing countries such as Rwanda. However, smallholder farmers face substantial barriers in their attempt to access direct marketing channels. Despite the establishment of potato processing factories to complement the existing facilities through Community processing centers in the high production zone to facilitate market access, participation in this growing marketing channel has reportedly remained low, resulting in continued losses. While previous studies have assessed the factors that influence market participation, limited attention has been given to the income impact of participating in processed-potato marketing channel. This study assessed the impact of participation in processed-potato marketing channels on household income in Musanze District, Rwanda, using survey data from 408 households selected through a multistage sampling procedure employing an Endogenous Switching Regression (ESR) model. Results revealed that overall, participation in the processed-potato marketing channel had a positive impact on household income. Access to credit, wealth status, and total production cost influenced household income across both participants and non-participants. However, household size was only significant for non-participants, while experience and cropping system influenced income exclusively among participants.

1 Introduction

The global population is anticipated to reach 9.8 billion by 2050, and Rwanda expects to reach more than 50 percent of its current population (NISR 2021; UN 2017). The increasing population's impact on the world's rising food demand has drawn much attention. Moreover, to satisfy this worldwide need, it is essential to expand food production (FSIN 2021). However, about 14 percent and 16 percent of food production is lost after harvest at the global and sub-Saharan Africa (SSA) level respectively (FAO 2019b). Food losses in SSA are primarily attributed to managerial and technical limitations, including derisory storage facilities and meagre post-harvest handling practices where over 40 percent of the produce for human use is lost throughout the supply chain (FAO 2020).

Irish potato (*Solanum tuberosum L.)* is a staple food grown in over 125 countries and devoured by well over a billion people. After rice, wheat, and maize, it is the fourth-largest food crop in the world. It has the ability to lift smallholder farmer households out of poverty and provide them with food security (FAO 2019b; Wubet et al. 2022). Globally, potato production has been increasing steadily over the years, with China being the world's largest producer and Rwanda the 50th (FAOSTAT 2023; Muthoni and Shimelis 2023; Wubet et al. 2022). Rwanda is the third largest producer of Irish potato in sub-Saharan Africa (SSA) and second in the Community of East Africa (EAC) after Kenya (FAO 2021a; MINAGRI 2021; RDB 2021). After plantain and cassava, the Irish potato is Rwanda's third most important staple crop. Further, it contributes 6.5 percent to the aggregate value of agricultural production (FAO 2019b, 2023b; FAOSTAT 2023; Mugabo et al. 2018). Per capita Irish potato consumption in Rwanda is estimated at 125 kilograms per year (Kg/year) (FAO 2020, 2021b).

In comparison to her regional counterparts, Rwanda's potato yields are higher at 12 metric tons per hectare (MT/Ha)(MINAGRI 2021). The crop employs 15 percent of the agricultural households and offers substantial opportunities for value addition and job creation in processing (FAO 2019a; NISR 2020). The Northwest region is the main potato producing zone in Rwanda with four districts (Rubavu, Musanze, Nyabihu, and Burera) accounting for substantial proportion of production. Musanze district is the second largest potato producing district in Rwanda and hosts four major potato processing factories (NISR 2020).

The Irish potato sub-sector in Rwanda is characterized by small-scale farmers with limited access to markets, resulting in postharvest losses (Mugabo et al. 2018). The sub sector has demonstrated a high rate of losses which accounts for persisting nearly 30 percent of the total production (FAO 2023a; FAOSTAT 2023) attributed to the high perishability nature of the crop, limited market access and inadequate post-harvest handling (Akter et al. 2022; FAO 2022). Reducing postharvest losses by 50 percent projects an increase of food availability by 20 percent without increasing the area of cultivated land hence a critical pillar to a sustainable food system (Cossam et al. 2023; Kikulwe et al. 2018). However, achieving this requires more than just improved handling and storage, it demands stronger integration of smallholder farmers into efficient and reliable market systems.

Consequently, marketing channels that involve value addition through processing have become essential. As of 2024, potato processing alone contributed 24 percent to the country's overall manufacturing output, highlighting its critical role in the agricultural and industrial sectors (NISR 2024). These channels enhance market competitiveness, thereby contributing significantly to the economic resilience and success of smallholder farmers (MINICOM 2017; NISR 2024).

Rwandan potato market systems present farmers with a range of marketing channels, including farmgate sales, brokers, open markets, collection centers and processed-potato market channel (processors). Farmgate sales, where farmers sell directly from their farms, are common due to low transport costs and immediate cash payments. However, they often result in lower prices and weak bargaining power (Mugabo and James 2024). Brokers serve as intermediaries, linking farmers to distant open markets, but they often capture a significant share of the marketing margin, reducing farmers' returns (Habimana and Haughton 2022). Open markets provide opportunities for farmers to sell independently yet expose them to price volatility (Mugabo and James 2024). Collection centers, promoted under initiatives such as Rwanda's Crop Intensification Program (CIP), aim to improve coordination, post-harvest handling, and market linkages (MINAGRI 2021). The emerging processed-potato marketing channels (processors) consist of companies that process Irish potatoes into different potato derived products including puffs, crisps, frozen fries, flour, vodka and others for domestic and regional markets. These processors often source directly from either organized farmer in cooperatives or individual farmers under supply contracts to ensure quality and delivery consistency. Enhancing smallholder farmers' access to processed-potato market channels holds considerable potential for improving their income levels. Participation in these higher-value channels not only enables farmers to secure better prices but also strengthens their resilience to market fluctuations and price volatility (Furrer et al. 2018; GIZ 2021). However, barriers like high transaction costs, limited awareness, and inadequate understanding of potential benefit persist. Enabling smallholder farmers to access these markets is crucial for reducing poverty (Tumukunde 2018; Van den Broeck and Maertens

2016). Agriculture interventions have the potential to bring real-time benefits, but fluctuating extent of participation diminish the expected effects on both individual farmers and the whole sector of agriculture (West 2020).

To strengthen the existing processed-potato marketing channels and support a more market-oriented agriculture, the Rwandan government in collaboration with development partners, have established Community Processing Centers (CPCs) across agricultural districts, including Musanze. These centers are designed to support the existing processing plants to ensure farmers find a wider marketing channel for their potato, banana, dairy produce (MINICOM 2017). This increases market competitiveness, thereby contributing significantly to the economic resilience and success of smallholder farmers (MINICOM 2017; NISR 2024).

Previous studies have emphasized on different marketing channels such as farm-gate sales, open-air markets, and collection centers, which remain dominant in Rwanda's potato value chain (Kyomugisha et al. 2018; Tumukunde 2018). However, despite their emergence of processed-potato marketing channels as a potentially transformative avenue for smallholder farmers (Akrong et al. 2021; Donkor et al. 2021; Ho et al. 2021; Jitmun and Kuwornu 2019), little is known about their impact of on household income.

2 Past related studies

A growing body of empirical work has sought to understand how smallholder farmers in Sub-Saharan Africa select among available market channels and the implications of these choices for income generation and livelihood improvement. In Musanze District, Rwanda, for example, Dusabe et al. (2023) and Tumukunde (2018) assessed determinants of potato farmers' choice of market channels, comparing open markets, brokers, farm gate, and collection centers. The studies found that decisions were influenced largely by access costs and the perceived reliability of buyers, with brokers and collection centers dominating as preferred market channels. However, processors were not treated as a distinct marketing channel, and the analysis did not extend to measuring the extent of participation or applying methods capable of estimating the causal impact of channel choice on household income. This omission leaves a critical gap in understanding the potential role of processed-potato marketing channels in enhancing farmer household income, particularly in contexts where such channels could offer price stability, reduced transaction costs, and improved market security.

In Tanzania, Sumari et al. (2018) used a binary logit model to analyze smallholder vegetable farmers' participation in high-value markets. Income, proximity to roads, access to market information, and closeness to high-value markets emerged as significant drivers of participation. However, this study did not capture the extent to which farmers participated in these channels. By contrast, the current study complements this by modeling the decision to participate and directly evaluating the income effects of processing channel participation.

Assessing factors influencing market access, marketing efficiency, and evaluating the impact of value addition for potato farmers using Ordinary Least Squares (OLS) in Uganda, Kyomugisha et al. (2018) found that having contracts with buyers, larger farm size, and growing specific potato varieties significantly improved market access, while potato value addition earns more income to farmers. However, the study did not clarify how income effects were identified as it excluded non-participants, raising concerns about potential selection bias and inconsistent estimates. The current study addresses this limitation by employing econometric methods explicitly designed to control both observable and unobservable differences between participants and non-participants and employed counterfactuals for impact accuracy.

In the study of Wakaba et al. (2022) that applied a Tobit model to assess determinants of extent potato commercialization in Nyandarua County, Kenya, their findings indicated that gender, age, education of the household head, household income, attitudes toward potato marketing, and distance to market had negative effects on commercialization, whereas land size and acreage under potato had positive effects. However, the study omitted important determinants such as quantity of potatoes produced, access to credit, and perceived benefits of commercialization that could lead to unbiased results on the extent of commercialization.

Owuor et al. (2022) offers a distinct contribution by shifting the analytical lens beyond production and marketing to assess consumer demand for value-added products. Using a contingent valuation approach to assess willingness to pay for processed orange-fleshed sweet potato (OFSP) products in Kenya, the study found that nutritional knowledge, product awareness, and perceived health benefits strongly influenced purchase decisions. This demand-side perspective underscores the importance of value addition and consumer preferences in translating market participation into welfare gains. Similarly, Akrong et al. (2021) demonstrated that participation in structured marketing channels for staple crops, influenced by access to information and institutional coordination, can amplify household income gains. The current study complements this existing literature by assessing factors influencing smallholder participation in processed-potato marketing channels in Rwanda, and by quantifying the impact on household income.

Mossie et al. (2021) assessing the effect of smallholder's participating in the value chains of apples and mangoes in northwestern Ethiopia applying propensity score matching (PSM) found that the value chain has a strong positive effect on the food security of smallholder farmers. However, PSM only matches observable factors while there must be unobservable factors that may influence the outcome.

More recently, Chikhawo et al. (2024) and Ma-Azu et al. (2024) have advanced the methodological rigor of market participation studies. Chikhawo et al. (2024) analyzed participation in agricultural projects linked to structured, processor-oriented value chains using selection-corrected and quasi-experimental designs. They found that market linkages, access to extension services, and credit significantly increased participation, which in turn generated notable income and resilience gains. Similarly, Ma-Azu et al. (2024) examined smallholder engagement in high-value and organized markets, using econometric approaches beyond simple mean comparisons, including switching and control-function models. Their results showed that participation in structured channels enhances household income and market stability, with determinants such as information access, institutional linkages, and asset endowments playing crucial roles. These studies highlight the importance of robust identification models to capture the true welfare effects of market participation. Therefore, this study sought to evaluate processed-potato market channel impact on household income as an emerging marketing channel in Rwanda.

3 Methodology

3.1 Theoretical framework

This study was anchored on theory of change (Weiss 1998, 1995). The theory explains how an intervention contributes to chain results that produce an intended outcome or impact. Therefore, the theory describes the processes and mechanisms through which the intervention is supposed to work to achieve the intended impact.

To indicate the change mechanism and the desired outcomes, the theory in general uses “if, then” statements to show the mechanisms of the change and the intended results. The “if “statements portray what the intervention seeks to do and the “then” statements depict what results might look like. This study evaluated the impact of participation in processed-potato marketing channels in Rwanda. Participation in the processed-potato channel was expected to sustainably impact the value chain, increasing the incomes of the respective smallholder farmers and improving their livelihoods

3.2 Empirical model

The endogenous switching regression (ESR) model (Maddala 1986) was used to evaluate the impact of processed-potato marketing channel on household income. The study used P-value to test the hypothesis. The null hypothesis of no impact of processed-potato marketing channel on household income was rejected based on the P-value of the transition heterogeneity (TH).

The model addresses the selection bias which is the greatest challenge in impact evaluation studies. observed and unobserved heterogeneities (Ngoma 2018). The ESR is a two-step procedure that estimates counterfactual outcomes using conditional expectations while correcting for observed and unobserved heterogeneity. The first stage evaluates the decision equation, which is the farmer’s decision to participate directly in processed-potato marketing channel or not. In this case, the dependent variable is binary; Probit model was used.

In the second stage, two outcome equations for smallholder processed-potato marketing channel participants and non-participants are modeled for instance as linear regressions.

The Probit model is modelled as follows (Van Oordt 2019):

$$P_i^* = \beta\, Z_i + \epsilon_i \qquad \text{With } P_i = \begin{cases} 1 & if\ P_i^* > 0 \\ 0, & Otherwise \end{cases} \quad \ldots\ldots\ldots\

$$A_0 = e_0\partial_0 + \epsilon_{0\epsilon}\mu_0 + R_0, \qquad for\ P_i = 0 \ldots\ldots\ldots\

In the second stage, stratified sampling technique was used to obtain participants and non-participants from the list of farmers acquired at the district office. This list, comprising households primarily engaged in Irish potato production across the four sectors, served as the sampling frame from which non-participants were subsequently identified. The list of participants was sourced from the processing plants' database, focusing on farmers within the same four sectors who had consistently supplied to the processors for the past one year prior to the survey and subsequently validated against the district office's list to confirm accuracy.

Moving on to the third stage, simple random sampling technique within each stratum was used to determine the total number of households.

A sample size was determined using Yamane (1967) formula since the population size was known. Musanze District has 91000 agricultural households with 31486 producing irish potatoes (NISR 2022).

The formula is specified as follows:

$$\mathrm{n} = \frac{\mathrm{N}}{1 + \mathrm{N}\left(\mathrm{e}^2\right)} \; Therefore, \; \mathrm{n} = \frac{31486}{1 + 31486\left(0.05^2\right)} = 395 \; households \;\; (15)$$

$$1.10 \bullet \; 395 = 434 \, \text{households};$$

where, n is the required sample size, N is the population of potato farmers in Musanze district, and e is the margin of error, set at 0.05 (95% confidence level). The calculated sample size was adjusted by 10 percent to take care of possible missing data or incomplete questionnaires following Mutiso (2017) and Ojwang et al. (2021), and eventually resulted in 408 households considered for analysis.

To examine the determinants and income effects of farmer participation in processed-potato marketing channels, the analysis employed an endogenous switching regression (ESR) model to correct for potential selection bias and unobserved heterogeneity.

Table 1 summarizes the variables employed in the endogenous switching regression model, detailing their definitions and units of measurement. The dependent variables include a binary indicator of market participation and a continuous measure of household income. The set of explanatory variables reflects key household, institutional, and farm-level characteristics commonly cited in the literature on smallholder market participation and income dynamics.

Table 1
Description of variables used in the endogenous switching regression model

Variables	Description	Unity of measurement
Dependent variables		
Participation	whether farmer markets their produce directly to a processing plant or not	Dummy(1 = Yes,0 = Otherwise)
Household income	Total annual household income	Rwandan Francs (Rwf) (1Rwf = 0.00072US dollars)
Independent variables		
Distance	Distance from farm to processors (Plants)	Continuous (Kilometers)
Credit	Amount of credit a potato farmer received in the last 12 months	continuous (Rwf = 0.00072US dollars)
Farm size	The size of the land used by the household for potato farming	Continuous (Hectares)
Household size	Number of household members	Continuous (Number)
Perceived benefits	Perceived benefits of participation in processed-potato marketing channel (Higher price and ready market)	Dummy(1 = Yes,0 = No)
Yield (MT/Ha)	Total quantity of potato produced per hectare	Continuous (Tons)
Education	Years of schooling of household head	Continuous (Years)
Group Membership	If household head belongs in any farmer organization	Dummy (1 = group member,0 = Not a member of a group)
Experience	Years of experience in potato farming	Continuous (Years)
Off-farm income	If a farmer has another source of income	Dummy(1 = Yes,0 = No)
Wealth index	Wealth index of the household	Score/index (generated using PCA)
Cropping system	The cropping system adopted by a farmer	Cropping System (Crop rotation = 1)

3.4 Justification for inclusion of regressors in the model

Participation is defined as whether a farmer sells directly to the processed-potato marketing channel or not. A farmer is considered to be a participant when he/she has sold the produce within the last 12 months to processors. It is a dichotomous variable where it took 1 for participant and 0 for non-participant

and the household income is defined as sum of farm income, off-farm income and other form of incomes that a household has made in the last 12 months. The previous related studies have influenced the choice of independent variables with evidence of significance. The choice of farmer-specific characteristics like years of potato farming experience, household size, and access to credit is grounded in their proven influence on both market participation and income. Experience serves as a proxy for accumulated know how where farmers with longer engagement in potato production better anticipate post-harvest losses and are more inclined to adopt value adding channels perceived as ready markets, thereby boosting household income (Wu 2022).

Likewise, household size reflects labor availability; larger families can allocate labor to both production and marketing, mitigating loss and facilitating engagement in remunerative markets, which translates into higher income (Paul et al. 2021; Xiang et al. 2021). Access to credit, in turn, unlocks the financial means to procure quality inputs and meet stringent requirements of high value buyers, reinforcing participation and income gains across both participants and non-participants (Akrong et al. 2021; Haile et al. 2022).

Akrong et al. (2021) reported that the level of participation in the high value market among the mango smallholder farmers and the decision to sell a certain extent or proportion varies according to different variables, perceived benefits, group membership, distance to the processors, experience, yield, years of education, off-farm income, and farm size. This study hypothesized similar effects on participation in processed-potato marketing channel and on income for the sold potatoes and positively contributing to household income.

Wealth status and cropping system were selected to capture broader structural determinants of market behavior and productivity. Household wealth underpins the capacity to invest in new technologies and absorb risks associated with unconventional marketing channels (Kanyenji et al. 2022; Weatherspoon et al. 2021). Finally, cropping system choice (rotation versus monoculture) embodies agronomic intensity strategies promoted in Rwanda's Crop Intensification Program (MINAGRI 2018). Empirical evidence shows that crop rotation enhances resource utilization and yields translating into tangible income improvements, making it a critical variable for understanding differential income impacts among smallholders (Himmelstein et al. 2017; Lengwati et al. 2020).

4 Results and discussion

4.1 Characterization of the potato marketing system in Rwanda

The pooled data indicates that farm gate emerged as the predominant market channel, followed by processed potato marketing channel, while collection centers is the least preferred option. Farm gate was chosen by 53.93 percent of farmers overall, with the highest engagement observed in Cyuve. While brokers constituted a significant channel, collection centers were the least chosen channel, with only 9.69 percent of farmers using them. Finally, processed potato marketing channel (processors) was chosen by 41.10 percent of farmers, with Gacaca exhibiting the highest participation rate at 54.69 percent. This high participation can be attributed to the presence of a major processing plant in the Gacaca sector, which likely reduces logistical barriers and provides farmers with a reliable market channel.

To understand the diversity of marketing practices among potato farmers in Musanze district, the study examined the various market channels through which farmers sell their produce. These include open markets, farm gate sales, brokers, collection centers, and processors. The distribution of farmer preferences across these channels is presented in Fig. 2.

The figure illustrates the percentage of farmers, both pooled and disaggregated by sector, who reported using each market channel. The data highlights significant variation in market access and preferences across the four surveyed sectors (Kinigi, Nyange, Cyuve and Gacaca) and the pooled sample.

Figure 3 illustrates farmers' market channel preferences in 2018 as found by Tumukunde (2018) and the current study (2025), reflecting changes in Rwanda's potato marketing landscape. In 2018, the most utilized channel was collection centers (48 percent), followed by brokers (38 percent) directly buying from the farmgate and open-air markets (14 percent). Notably, Tumukunde did not report on the processed potato marketing channel, likely due to its limited development at the time despite the establishment of community processing centers in 2015.

In contrast, the current study 2025 findings revealed the emergence of processors as a second dominant channel (41.1 percent), with continued use of farmgate sales (53.93 percent) independent from the brokers which accounted for 31.68 percent. Collection center use declined to 9.69 percent, suggesting that structured processing outlets may have absorbed their market function. Open-air markets (16.75 percent) and brokers (31.68 percent) remain active, though partially supplanted by more formalized processor-linked arrangements.

The processed potato channel, introduced through government-supported community processing centers, aims to reduce post-harvest losses, stabilize prices, and improve market reliability. This evolution underscores a shift from informal to structured value chains, strengthening farmers' market power and economic outcomes.

Rather than contradicting Tumukunde's findings, the current study complements and extends them by empirically validating the role of processors as a viable marketing pathway. This study provides timely evidence to guide policy on value addition, and market system upgrading for perishable crops like potatoes.

4.2 Empirical results

4.2.1 Endogenous Switching Regression (ESR) Model Estimates for participation in processed potato marketing channels and effect on household income

Table 2 presents the results from the Endogenous Switching Regression (ESR) model, estimated using full information maximum likelihood. The analysis is conducted in two stages. In stage 1, a Probit model identifies the factors influencing household participation in processed-potato marketing channels. In

stage 2, separate income equations are estimated for participants and non-participants. The Likelihood Ratio (LR) test statistic (Chi ($\chi 2$) = 88.58), significant at the 1% level, confirms the joint dependence between the selection and outcome equations, supporting the use of the ESR model.

The estimated correlation coefficients (ρP and ρNP) between the error terms of the selection and outcome equations are both negative and statistically significant, indicating that unobserved factors influencing participation are correlated with income. This suggests that participants in processed-potato marketing channels earn more than non-participants, even after accounting for selection bias. The significance of both the correlation terms (ρP and ρNP) and standard errors (σP and σNP) confirm the presence of selection bias, thus justifying the use of the ESR model over simpler estimation models.

To improve model fit and interpretation, a natural logarithmic transformation was applied to the dependent (income) variable and selected continuous explanatory variables, in this case yield, experience and total production cost. The log transformation is commonly used when variables are strictly positive, exhibit skewness, or when proportional (percentage-based) relationships are theoretically expected. According to Gujarati and Porter (2009), logarithmic transformations help stabilize variance, linearize exponential relationships, and reduce the influence of extreme values.

In this log-linear model, the dependent variable is expressed in natural logs to interpret coefficients as semi-elasticities when independent variables remain in levels, or as elasticities when both variables are logged. A mixed functional form (log-log and log-linear) is appropriate and widely accepted in empirical work, provided the transformations are theoretically justified and enhance interpretability (Wooldridge 2012).

Table 2
Endogenous switching regression model results

	Stage 1	**Stage 2**				
	Selection equation		**Outcome equation**			
Variables	**Participation in processed potato marketing channels**		**Participants**		**Non-Participants**	
	Coef.	**Std.Err.**	**Coef.**	**Std.Err.**	Coef.	Std.Err.
LnHH_Income						
LnExperience	0.061	0.087	**0.355*** **	0.126	0.012	0.114
Household size	-0.009	0.035	0.013	0.056	**0.088** **	0.042
Wealth status	1.002	0.659	**1.674***	0.907	**2.467*** **	0.988
Processing Awareness	0**.839*** **	0.112				
Market perception	**0.378*** **	0.110				
Price perception	**-0.344*** **	0.134				
Off farm income (Rwf)	**0.000*** **	0.000				
Distance farm-processor	**0.000*** **	0.000				
Group membership			-0.249	0.168	0.107	0.167
Credit (Rwf)			**0.000***	0.000	**0.000** **	0.000
Cropping System (Crop rotation = 1)			**0.164** **	0.083	-0.201	0.146
LnYield			0.097	0.060	0.094	0.071
LnTotal production cost per Acre			**0.196*** **	0.083	**0.232*** **	0.092
Education			0.028	0.019	-0.001	0.024
Constant	**-1.481*** **	0.376	**11.340*** **	1.133	**8.998*** **	1.090
σNP					**0.376*** **	0.061
σP			**0.320*** **	0.067		
ρNP					**-1.629*** **	0.190
ρP			**-1.246*** **	0.198		
Number of observations		**408**	**382**			
LR test of indep. Eqns: Chi($\chi 2$)		**88.58*** **				

Note: *, **, *** indicate statistical significance at 10% ,5% and 1% respectively; P and NP stand for participation and non-participant of the processed-potato marketing channels. The **ρP** or **NP** is the correlation coefficient for the error terms between selection equation and adoption equation and **σP** or **NP** is the square root of the variance.

The continuous variable was transformed using an inverse hyperbolic sine to reduce positive skewness and mitigate potential heteroskedasticity while avoiding the loss of observations with zero values.

The results presented in Table 2 show that household size, experience, and wealth status are not significant, but awareness of the processing marketing channel, perceived market readiness, and higher prices, distance to the processor, off-farm income influenced participation in processed-potato marketing channels at 1 percent level of significance. However, different from the rest, the perception of higher price offer is negatively influencing participation, which contrast the existing literature that indicates that the higher the perception of the higher price the higher the probability of participating (Abate and Addis 2021; Gebre et al. 2022; Kolady et al. 2021; Misango et al. 2022; Sheko et al. 2022). The negative influence of the price is however associated with the payment uncertainty and delays in the decision making as highlighted in the key informant interviews and open-ended questions answered, hence risk aversion (Mmbando 2014).

According to Misango et al. (2022), perceived benefits of the technology positively influence the intensity of adoption of integrated pest management practices. In this respect, perception of a ready market and higher price was expected to positively influence participation in processed-potato marketing channels, concurring with studies by Ghimire et al. (2015) and Kolady et al. (2021), independently, who reported that adoption of new technology is positively correlated with their expected advantages. The perceived benefits of processed-potato marketing channel were that it is a ready market and provides a higher price. It was a binary response taking 1 if a farmer perceived it positively and 0 otherwise. While price perception had a negative influence on farmers' participation in the processing market channel, farmers who perceived it as a reliable or ready market were 37.8% more likely to participate, coinciding with literature.

The distance from farm to processing facility in kilometers was expected to be negative or positive depending on how it affects participation. The longer the distance, the more farmers will be discouraged from participating and will choose other market channels. However, it has proven to be positively influencing participation which coincides with Jitmun and Kuwornu (2019), different from Sebatta et al. (2014) and Wakaba et al. (2022) findings. This finding is further supported by the geographic distribution of farmers and processors. Several farmers with larger farm sizes and preferred varieties are situated at the foot of the volcano chain, whereas most processing facilities are located in Musanze city sectors.

The income earned from non-potato farming activities can affect participation either positively or negatively. This study, in contrast with Sebatta et al. (2014), Chikhawo et al. (2024) and Woldeyohanes et al. (2017) that indicate that farmers use off-farm earnings for consumption rather than for investment in agricultural production, found that off-farm income positively influenced participation in processed-potato marketing channel. However, it coincides with Adetunji et al. (2023) and Benimana et al. (2023) that off-farm income positively influences adoption of new technologies.

4.2.2 Determinants of potato farmers' household income

Results in Table 2 indicate that experience in potato farming increases the income of participants rather than non-participants. The plausible explanation is that the more years the farmer has spent in potato farming the more aware he is about the existing market channels losses to be incurred hence the choice of processed-potato marketing channel as a result it increases the household income. This agrees with Wu (2022) that found the experience influenced farm income of farmers adopting new technologies in China hence the total household income.

Although participants had a larger average household size (6 members) compared to non-participants (5 members), household size was not a significant determinant of income among participants. In contrast, for non-participants, household size was positively correlated with household income. This suggests that, for non-participants operating in labor-intensive production systems, each additional household member contributes directly to farm labor, thus supporting agricultural productivity and income generation. These findings are consistent with Paul et al. (2021), who observed that household size serves as a proxy for on-farm labor availability, particularly in smallholder systems where mechanization and hired labor are limited. Similarly, Xiang et al. (2021) found that larger households are more capable of balancing production and marketing tasks simultaneously, improving commercialization outcomes and overall household income.

Among participants, however, household size is not similarly associated with income. Their participation in the processed-potato marketing channel connects them to reliable off-takers, offers price guarantees, and provides aggregation and extension services. This reduces reliance on family labor by shifting income drivers toward market access, quality compliance, and coordination. Larger households among participants may also support off-farm employment, further decoupling income from agricultural labor. This shift aligns with Barrett et al. (2017), who show that external support services reduce dependence on internal labor by enhancing productivity and Bezu and Holden (2014) who found that access to structured markets weakens the traditional link between household size and income.

Consistent with Akrong et al. (2021), Benimana et al. (2023), Burke et al. (2015), Haile et al. (2022) and Quach (2017), this study found that access to credit positively influences participation in processed-potato marketing channel. Once farmers have access to credit, they are able to buy inputs necessary to meet the requirements of high value market that offer higher benefits compared to alternatives. Furthermore, this study shows that it influenced farmers to participate in marketing hence the increase of income to both participants and non-participants at 10 percent and 5 percent level of significance respectively.

In contrast with Weatherspoon et al. (2021) and Nzuma and Mzera (2023), which argue that the wealth status influences farmers to participate in marketing and adoption of agricultural practices, the current study results revealed a contrary nuance. While it acknowledges that wealth provides essential resource endowments necessary for the adoption of agricultural practices, the findings reveal that higher wealth status among non-participant farmers is associated with significantly greater income by 13.3 times. This finding contests the prevailing narrative that wealth unequivocally drives market participation, instead underscoring how resource endowments can enable sustained income generation beyond conventional market integration (Kanyenji et al. 2022).

The results of this study show that crop rotation significantly increased household income by 1.2 times for the participants, with statistical significance at the 1 percent level. This effect suggests that crop rotation enhances resource efficiency and soil fertility, contributing to higher yields and greater returns for smallholder farmers.

This finding aligns with Lengwati et al. (2020), who found that crop rotation increased marginal returns for maize farmers by 225 percent compared to those using alternative practices.

These findings reinforce national policy priorities under Rwanda's Crop Intensification Program (MINAGRI 2018), which emphasizes crop rotation as a key strategy for improving smallholder productivity and income.

4.2.3 Impact of participation in processed-potato marketing channels on household income

The impact of participation in processed-potato marketing channels on household income was obtained using a full information maximum likelihood endogenous switching regression model. The actual and counterfactual expected incomes, presented in Table 3, were estimated for 382 households in Musanze District who participated in the marketing channel. This approach enabled the identification of the income effects conditionally on participation in the processed-potato market.

Table 3
Average treatment effects

Outcome Variable			**Decision**		**Treatment effects**		**%Change**
	n	**Sub-sample**	**To Participate**	**Not to participate**			
	157	Participants	15.638	13.041	ATT	2.589 ***	
Income			(.071)	(.071)		(.10)	
(Rwf)	*225*	Non-participants	16.959	14.486	ATU	2.473***	A(TH/ATT) = 4.48%
			(.065)	(.062)		(.089)	
					TH	0.116***	
						(.048)	
					ATE	2.55***	
						(.464)	

Note: *** indicate statistical significance at 1% levels; ATT: Average treatment for the treated, ATU: Average treatment for the untreated. The income is logged (lnincome) hence the reported figures will be exponential with ATT, ATU and ATE equal to 13.3, 11.8 and 12.8 respectively.

The results demonstrate the positive average treatment effect. The positive ATE implies that participation in the processed-potato marketing channel increases household income by 12.8 times on average. Similarly, the Average Treatment Effect on the Treated (ATT) was positive, revealing that the farmers that chose participation in the processed-potato marketing channels have 13.3 times higher income compared to what they could earn had they not participated. The positive Average Treatment Effect on the Untreated (ATU) implies that non-participants would see a comparable gain of 11.8 times higher their income had they participated. This coincides with the results of Kyomugisha et al. (2018) who reported that participation in Uganda potato structured marketing channels including processors either small or big achieved profit and efficiency levels between 128 percent and 159 percent, indicating far greater economic returns than traditional trading channels. Similarly, in Tanzania, maize and legume farmers participating in formal market systems achieved 12 percent higher household income (Manda et al. 2021). This alignment indicates that the processed-potato marketing channel offers a reliable pathway to improved economic outcomes for farmers which is consistent with the findings of Paul et al. (2021) and Donkor et al. (2021) who found that market participation increases farmer's income.

The transitional heterogeneity (TH), reflecting the difference in income effects between participants and non-participants, is minimal at 11.6 percent, yet statistically significant. This suggests that the benefits of participating in processed-potato market channels are consistent. Overall, while participants of processed-potato marketing channels realize over thirteenfold income gains, the 4.48 percentage (ATE/ATT) ratio signals that most farmers capture only a fraction of this benefit, highlighting its critical role in enhancing financial stability and economic resilience but highlights the need to be reinforced.

5 Conclusion

This study findings underscore the importance of promoting access to processed-potato marketing channels as a strategy to unlock higher income potential for smallholder farmers in Rwanda. The results revealed that there is an increase in income when the farmer chooses to sell directly to the processors. As demonstrated, 41 percent of farmers participated in the processed-potato marketing channel. While farmers may sell to multiple market channels concurrently, those who at least sold any quantity to the processors have proven a significant difference in income compared to those who chose otherwise.

Policies and interventions that facilitate market readiness, creating more awareness, and reducing barriers to these processed-potato marketing channels participation could amplify these gains, delivering equitable and sustainable income growth.

6 Recommendations

The findings highlight the importance of promoting access to processed-potato marketing channels as a strategy to enhance income for smallholder farmers in Rwanda. The findings, which demonstrate a significant positive Average Treatment Effect (ATE) and Average Treatment Effect on the Treated (ATT) on farmer incomes, underscore the importance of integrating smallholders into higher-value markets as a pathway to poverty alleviation and sustainable economic growth. To capitalize on these benefits, policies should focus on improving market access by strengthening farmer-processor linkages, investing in infrastructure, creating awareness that is essential to educate farmers about the benefits of processing markets, and ensure fair payment modalities.

Additionally, capacity-building programs should be implemented to train farmers on quality standards and post-harvest handling through cooperatives under Rwanda cooperative agency together with the agriculture office on district level. Cooperatives occupy a particularly central role in Rwanda's agricultural sector, where they have been actively promoted as a core institutional pillar of the government's agricultural transformation agenda. Therefore, enabling them to meet market demands will maximize their income returns.

Policymakers should also develop supportive frameworks, including tax incentives for processors sourcing directly from farmers or through organized cooperatives that maintain transparent aggregation systems and fostering public-private partnerships to create sustainable market linkages.

Declarations

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Justine Umutoni, Prof. Rose Adhiambo Nyikal and Prof. Johnathan Makau Nzuma The first draft of the manuscript was written by Justine Umutoni and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Ethics approval

The study was performed in accordance with the ethical standards of the institutional research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Consent to participate

Informed consent was obtained from all individual participants included in the study. Permission to contact the farmers was granted by the Musanze District office. The objectives of the research were explained to the farmers, and the questionnaire included a consent section that each respondent completed before the interview proceeded.

Funding

This work was supported by the African Economic Research Consortium (AERC).

Author Contribution

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Justine Umutoni, Prof. Rose Adhiambo Nyikal and Prof. Johnathan Makau Nzuma The first draft of the manuscript was written by Justine Umutoni and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Acknowledgement

I am deeply grateful to Almighty God for his guidance and strength throughout the journey of working on this paper. Sincere appreciation to the lecturers at the department of Agricultural Economics at the University of Nairobi for welcoming and guiding me into the intricacies of Agricultural and applied economics. I am also grateful to the Musanze District office and the farmers of Musanze District, whose support and cooperation made this study possible.

Data Availability

The data that support the findings of this study are openly available in Zenodo at https://doi.org/10.5281/zenodo.23315586

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Figures

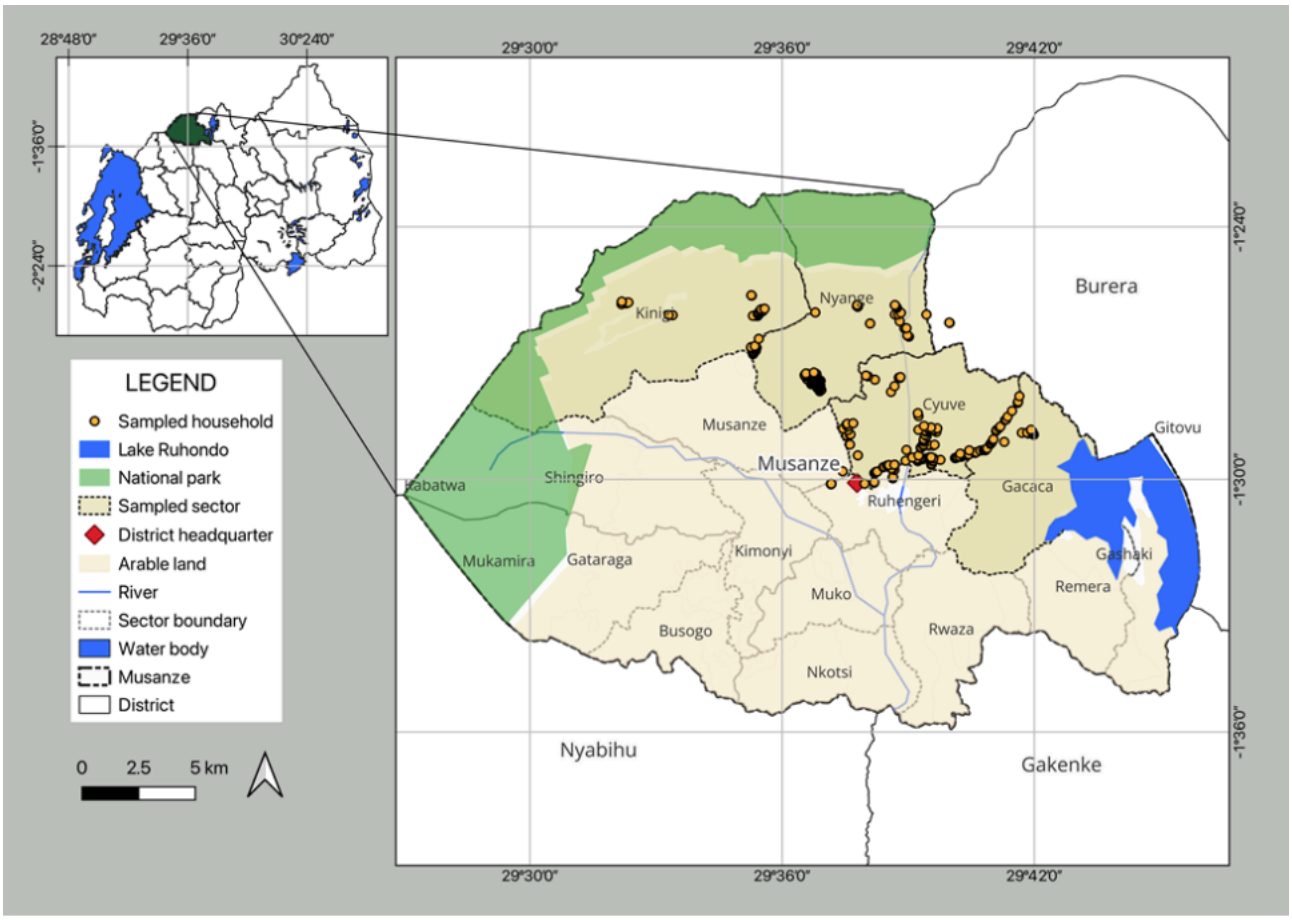


Figure 1

Location of sampled households in Musanze District, Rwanda

Source: Author's elaboration in QGIS using survey data (2024)

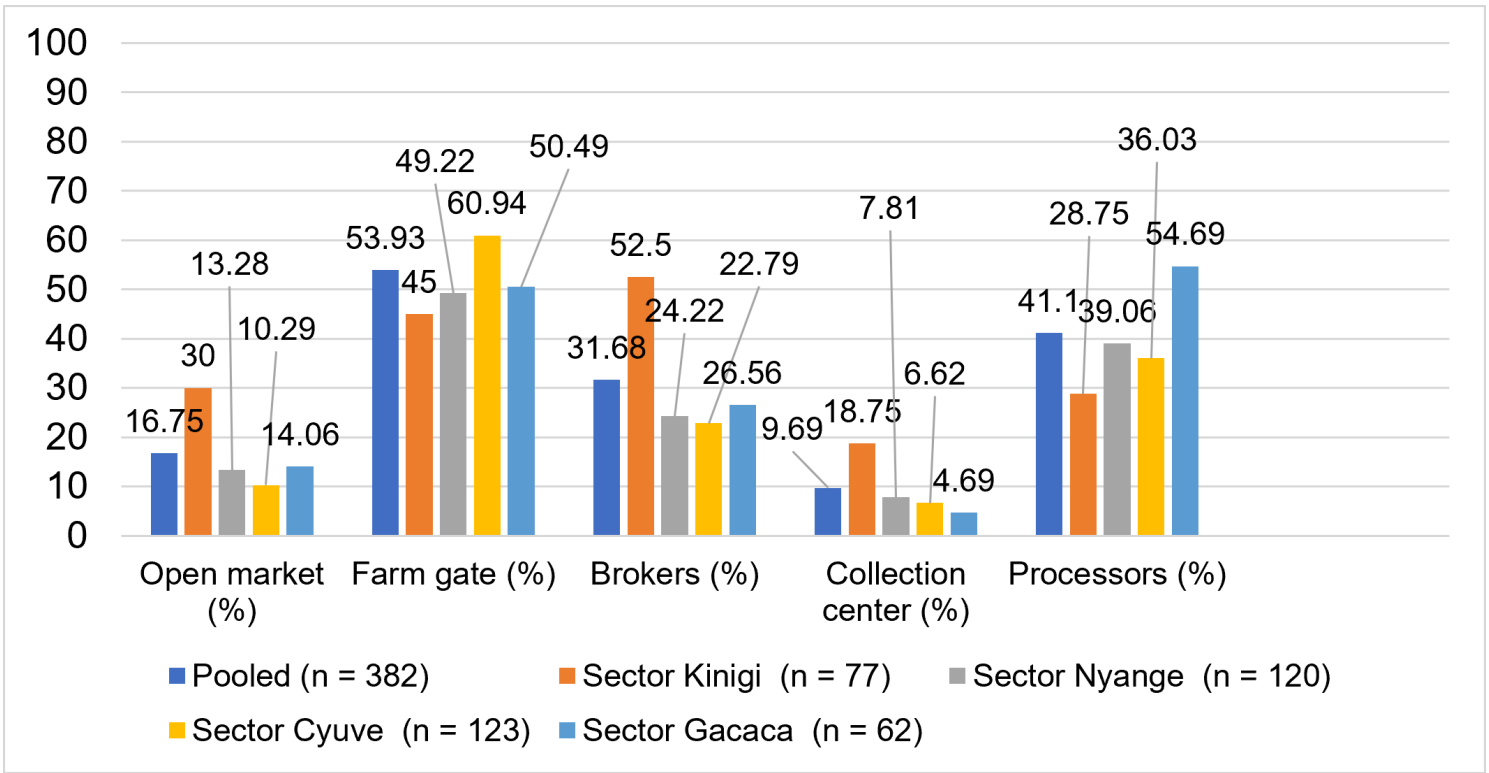


Figure 2

Farmers' choice of potato market channels in Musanze District, Rwanda

Source: Survey data (2024)

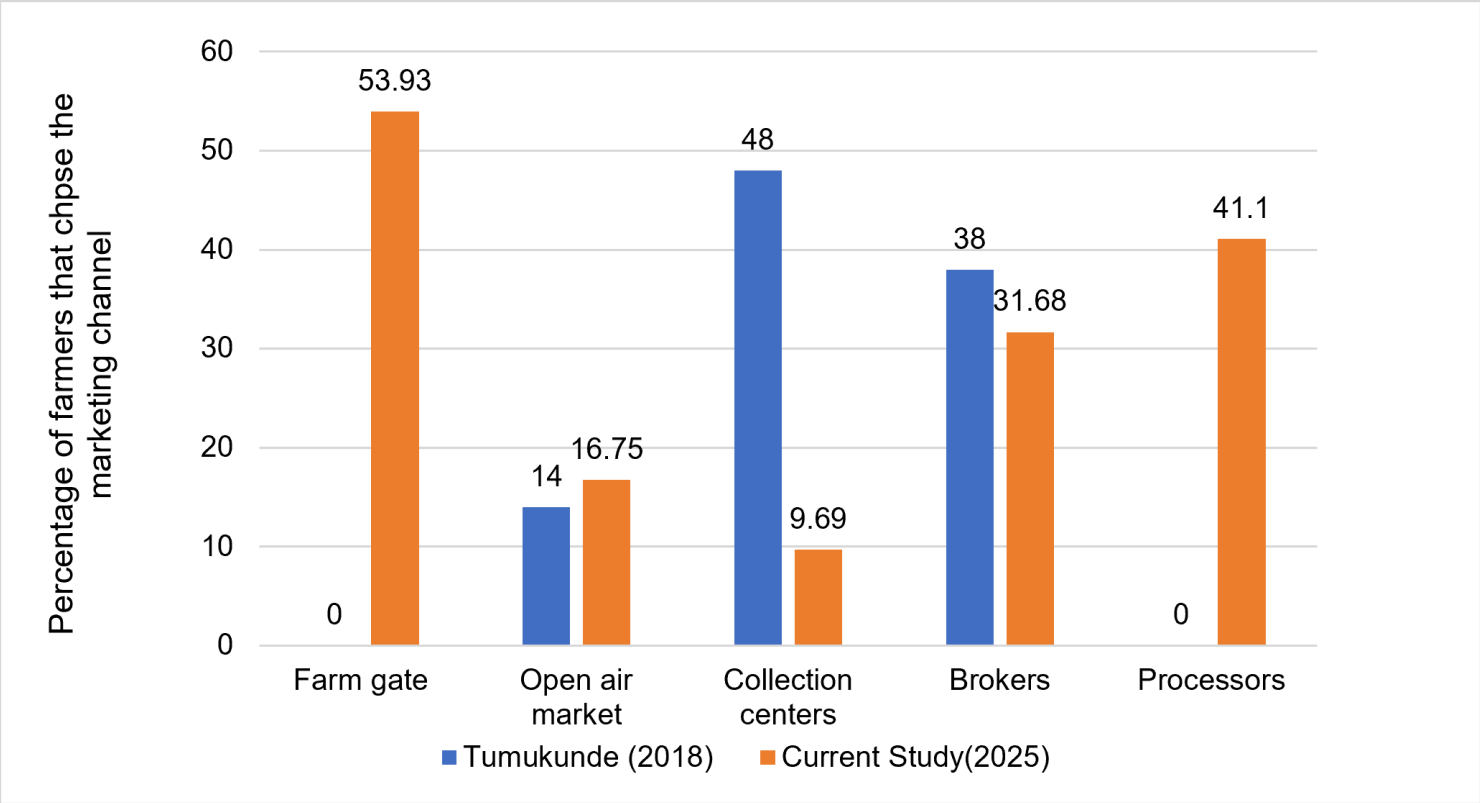


Figure 3

Comparison of farmers' choice of market channels in 2018 and 2025

Source: Tumukunde (2018) and survey data (2024)

Supplementary Files

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